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MASTER'S THESIS

Evaluating Ecosystems and Ecosystem Services in Protected Areas

An Integrative Analysis of the Wilderness Area Sulzbachtäler in the Nationalpark Hohe Tauern, Austria

by

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Abstract

Due to the steady modification of natural environments resulting from anthropogenic land use change, the need for protected areas is increasing. Not only people living in mountain areas, but also the population of surrounding lowlands benefit from the ecosystems provided by mountainous regions. Water runoff is one of the most essential services available, but people also profit from other provided natural resources or these area's potential for recreational purposes. Furthermore, unmodified environments preserve important regulating services, such as biodiversity conservation and natural hazard reduction. Scientists have already studied the ecosystem services' framework from various standpoints, including mountain regions. However, little focus was put on the services available in protected mountain areas. Therefore, this master's thesis aimed to comprehensively evaluate the ecosystems and ecosystem services in the wilderness area Sulzbachtäler in Austria. An integrative methodological approach based on a remote sensing data analysis and a self-administrated questionnaire was performed to identify the most essential ecosystems and services in the area, as well as to investigate the visitor's perception of these ecosystem services. Twelve ecosystems and nine ecosystem services were identified. The results revealed that more diverse ecosystems, with a predominate vegetation cover provide a greater range of services compared to other ecosystems. Furthermore, the diversity of ecosystems decreases above 2,500 meters a.s.l. The output of the questionnaire's statistical analysis showed that not all available services are consciously perceived by the visitors. Mainly those services were named that could be visually recognized (e.g., water provision) or personally experienced (e.g., cultural services: recreation and sports). In contrast, the respondents were not actively aware of the regulating services provided by the case study area.

Keywords

Mountain ecosystems, Ecosystem services, Ecosystem services' perception, Wilderness, Nationalpark Hohe Tauern

Zusammenfassung

Evaluierung von Ökosystemen und Ökosystemdienstleistungen in Schutzgebieten: Eine integrative Analyse des Wildnisgebietes Sulzbachtäler im Nationalpark Hohe Tauern

Die steigende Landnutzungsänderung zu Gunsten der Bevölkerung, erhöht gleichzeitig den Bedarf an Schutzgebieten. Neben den Bewohner:innen von Gebirgsregionen, profitieren auch jene des umliegenden Flachlands von den materiellen und immateriellen Ressourcen, die die Berge bereitstellen. Der Wasserabfluss gehört dabei zu den wichtigsten verfügbaren Dienstleistungen. Jedoch profitiert die Bevölkerung auch von anderen natürlichen Rohstoffen oder der Möglichkeit die Berge zur Erholung zu nutzen. Darüber hinaus wird in Gebirgslandschaften die lokale Artenvielfalt bewahrt und das Risiko von Naturgefahren verringert. Das Konzept der Ökosystemdienstleistungen, auch für alpine Regionen, wurde schon von verschiedenen Fachrichtungen wissenschaftlich untersucht. Jedoch wurden bisher Schutzgebiete in Gebirgsregionen kaum berücksichtigt. In dieser Masterarbeit dient das Wildnisgebiet Sulzbachtäler als Fallbeispiel, um die Ökosysteme und Dienstleistungen zu untersuchen. Ein integrativer Ansatz beruht auf einer Fernerkundungsanalyse und einem standardisierten Fragebogen. Zwölf Ökosysteme und neun Ökosystemdienstleistungen stellten sich als relevant heraus. Die Ergebnisse zeigten, dass in vielfältigeren Ökosystemen, mit einer überwiegenden Vegetationsbedeckung, eine größere Vielzahl an Dienstleistungen verfügbar ist. Außerdem nimmt die Diversität der Ökosysteme oberhalb von 2.500 Metern über dem Meeresspiegel ab. Die Befragung hatte das Ziel, mehr über die Wahrnehmung von Besucher: innen des Gebiets hinsichtlich der lokalen Ökosystemdienstleistungen herauszufinden. Die statistische Auswertung des Fragebogens ergab, dass nicht alle in den Sulzbachtälern verfügbaren Dienstleistungen von den Besuchern bewusst wahrgenommen werden. Dienstleistungen, welche visuell wahrnehmbar sind (z.B. Wasserversorgung) oder die man selbst erleben kann (z.B. Erholung und Sport), wurden überwiegend genannt. Die regulierenden Leistungen des Untersuchungsgebiets wurden von den Befragten kaum wahrgenommen.

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a.s.l.	meters above sea level
CH_4	methane
CO_2	carbon dioxide
°C	degree Celsius
GHG	greenhouse gas
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
NCP	Nature's Contributions to People
SD	Standard Deviation
SDGs	Sustainable Development Goals
US	United States (of America)
WWF	World Wide Fund for Nature

1 Introduction

Until 2050, almost one quarter of the global population is predicted to depend on water provided by mountain runoff (Viviroli et al., 2020). This number does not only include alpine regions' inhabitants, but also counts in the profiting population living in the surrounding lowlands, who also rely on resources provided by mountains (Grêt-Regamey et al., 2012; Millennium Ecosystem Assessment, 2005; Viviroli et al., 2020). Already today, a great number of people benefit from the natural resources provided by mountain areas (Grêt-Regamey et al., 2012; Schirpke et al., 2021a). To what extent human well-being and survival is connected to the sparsely populated, natural environments of mountain regions is often underestimated (Grêt-Regamey & Weibel, 2020). Besides the fact that mountains are known as the Earth's "water towers" (Egan & Price, 2017, p. 7), they offer habitats for a great range of species due to their high elevation gradient (Egan & Price, 2017; Glushkova et al., 2020; Grêt-Regamey & Weibel, 2020; Quintero & Jetz, 2018). Moreover, these areas with unmodified land cover protect humans against natural hazards (Grêt-Regamey & Weibel, 2020). Furthermore, these regions are highly frequented for recreational activities (Glushkova et al., 2020; Grêt-Regamey & Weibel, 2020), while they also play an important role regarding global and regional climate regulation (Glushkova et al., 2020; Grêt-Regamey & Weibel, 2020; Klein et al., 2019). These services and values, made available by the local ecosystems are often referred to as ecosystem services according to the ecosystem services framework (Millennium Ecosystem Assessment, 2005). These services that can either be material or non-material, contribute indirectly or directly to human well-being (Braat & Groot, 2012; IPBES, 2019). An ecosystem itself is a natural complex that does not only include the plant-based components of the environment, but also implicates wildlife, micro-organisms, as well as humans in its definition (United Nations, 1992).

The rise in anthropogenic pressures, such as human-induced climate change, the modification of mountain ecosystems and the provision of the underlying ecosystem services, increases steadily (Egarter Vigl et al., 2021). The reasons for changes in ecosystems depend on different natural drivers and pressures. However, also management and legal policies, as well as decision making of various actors play a crucial role to what extent ecosystems are allowed to be adopted. Land use change is therefore one of the main drivers of human induced climate change. Beside the impacts of fossil fuels and land cover change it can be seen as a severe threat to the terrestrial biosphere, because natural vegetation covers support the maintenance of a balanced climate (IPBES, 2019; Ramankutty & Coomes, 2016). Transformation into agricultural areas is the most frequent reason for land use change. Natural ecosystems are often replaced by croplands, plantations and pasture lands, because these provide a more stable and reliable food source (IPBES, 2019). Even though, this does not sound like a threat, the monocultural characteristics of these croplands are vulnerable to numerous stress factors. Furthermore, land use change is rising biodiversity loss, due to destruction and reorganization of ecosystems (Millennium Ecosystem Assessment, 2005). Additionally, the introduction of alien species threatens the existence of vegetation and wildlife as well as weakens the resilience of ecosystems (IPBES, 2019). Moreover, agricultural activity, and industry entail greenhouse gas (GHG) emissions as a byproduct (e.g., methane (CH_4) and carbon dioxide (CO_2)). These are well-known drivers for global warming, as they contribute largely to the GHG effect (Ramesh et al., 2017; Salinger, 2007).

Since the 1980s, the population's awareness for protected areas has risen and turned into a relevant subject until today. People realized that the consequences of climate change do not only affect the local environment, wildlife and plants, but also human's quality of life (Dudley, 2013).

1.1 Knowledge Gap and Problem Definition

A great number of research institutes, NGOs and scientists have addressed and studied the topics related to ecosystems and the provided ecosystem services, since they form the base for human well-being (e.g., IPBES (2019) and Millennium Ecosystem Assessment (2005)). Furthermore, publications concerning ecosystem services assessment have steadily been increasing over the past 20 years (Harrison et al., 2018). In addition, the number of assessments applied in "real-world situations" (Harrison et al., 2018, p. 482) is also rising, with the aim to develop more sustainable management strategies, often with the result that the local population is included in decision making processes (Harrison et al., 2018). For example, the internationally performed project AlpES lasted three years with the objective to learn more about the ecosystem services in the Alps (AlpES, 2018).

Several studies have focused their work on ecosystems and services with the aim to understand the consequences of human action on natural ecosystems. Up to now, the interconnection between socio-ecological systems (e.g., Cazalis et al., 2018; Grêt-Regamey et al., 2019) and how trends in destabilization of ecosystems affect people's well-being and access to raw materials (e.g., Huber et al., 2013; Schröter et al., 2005), has been discussed to a great extent. From regional (e.g., Rahmonov et al., 2021; Shakya et al., 2021) to global scales (e.g., Cerretelli et al., 2018; Grêt-Regamey & Weibel, 2020; Verburg et al., 2015), scientists have conducted investigations to find out more about the synergies and trade-offs of ecosystem services and to better understand the underlying systems.

However, compared to other ecosystems, only a small number of studies was performed in mountain regions with an emphasis on ecosystem services. A focus was predominately put on tropical ecosystems in non-mountain areas, due to their heterogeneous characteristics (Glushkova et al., 2020; Grêt-Regamey & Weibel, 2020; Klein et al., 2019). Still, Schirpke et al. (2019) studied the spatial connection of supply and demand of ecosystem services in mountain regions to find out where people profit from the available services. Egarter Vigl et al. (2021) investigated how external drivers affect mountain ecosystems. However, when scientific projects were conducted with a focus on alpine areas, the research scope was mostly narrowed down to solely study the ecosystem services of one ecosystem present in mountain areas. Predominantly forest ecosystems were examined in these studies, because of their large offer of provided services compared to other ecosystems in mountain regions (Felipe-Lucia et al., 2018; Glushkova et al., 2020; Rahmonov et al., 2021). Hardly any publications focused their research specifically on protected mountain regions, as due to their remoteness and untouched nature, a limitation in material benefits of economic value (i.e., provisioning services) can be detected (Grêt-Regamey & Weibel, 2020; Sayre et al., 2020). Whereby precisely these preconditions guarantee people living in and visiting these areas a wide range of important ecosystem services, which without the protected area, might not be preserved. Already Mori et al. (2013) emphasized that the identification of functioning ecosystems and the related key ecosystem services is essential to protect biodiversity and the environment, which provide important resources for humans and hence should be prioritized in conservation policies. Only Schirpke et al. (2021a) pointed out the potential challenges that may arise in protected areas when the demand for mountain ecosystem services increases.

Therefore, this master's thesis has the aim to address this knowledge gap and provide more information regarding ecosystem services in protected areas. Furthermore, it examines what ecosystem services are perceived and recognized by visitors of the region. The wilderness area Sulzbachtäler was selected as a case study area for this master's thesis. It is located in the Eastern Alps in the Nationalpark Hohe Tauern, Austria and has a stricter protection status compared to national parks (Dudley, 2013). Its geographic location is depicted in Figure 1.

The wilderness area Sulzbachtäler was classified as an IUCN wilderness area in 2019, featuring the second highest level of the IUCN nature protection management categories (Dudley, 2013). As it has only been designated as a wilderness area in 2019, little research has been conducted in this region so far and no research on ecosystems and ecosystem services (Salzburger Nationalparkfonds Hohe Tauern, 2016). The area has not been directly affected by anthropogenic activities in the past centuries, because of its remote location, high elevation, and particularly the long-term protection measures in place since 1913 (Salzburger Nationalparkfonds Hohe Tauern, 2016).

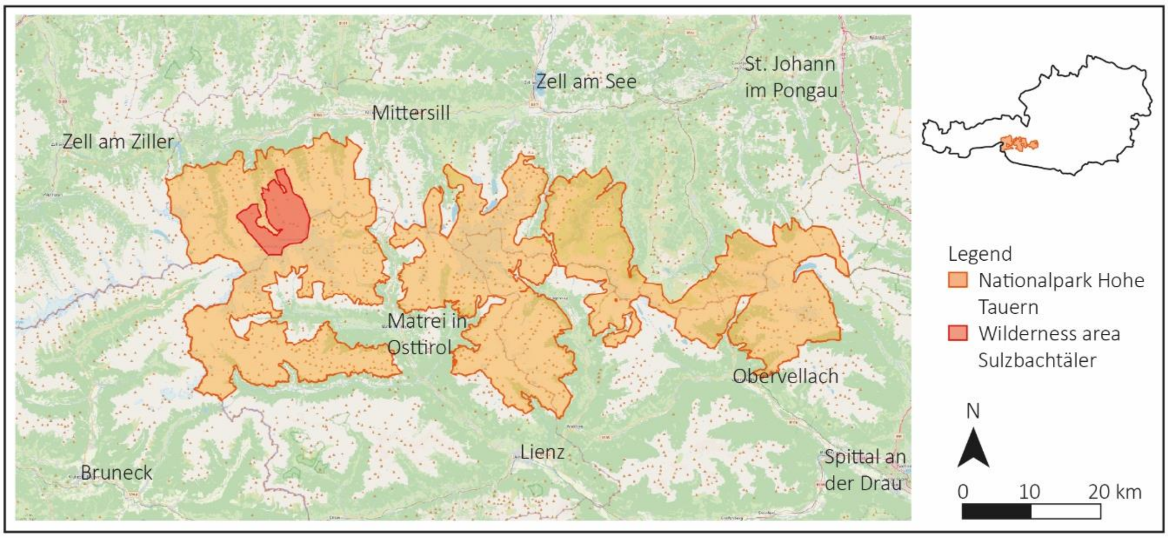


Figure 1: Visualization of the wilderness area Sulzbachtäler in the Nationalpark Hohe Tauern, Austria (source: own representation; data: Land Tirol - data.tirol.gv.at, 2013; OpenStreetMap).

Although, it is located in the otherwise predominately densely populated region of Central Europe it belongs to one of the rare areas of nearly untransformed nature. Moreover, it is the only region with this protection status in Austria, besides the wilderness area Dürrenstein in Lower Austria. As the area of the Nationalpark Hohe Tauern is a popular holiday destination and the valleys surrounding the park are moderately populated, the provided natural resources are of high value for people interacting in this region. These preconditions and the wilderness area's attributes make it particularly interesting for the research of this study.

1.2 Research Aim and Research Questions

The research objective is to investigate the ecosystems and the available ecosystem services, as well as the services' perception in the wilderness area Sulzbachtäler, in the Nationalpark Hohe Tauern by applying an integrative approach. This consists of a manual land cover classification and a self-administrated questionnaire. Former has the aim to identify the available ecosystems in the wilderness area. For this purpose, remotely sensed data in the form orthophotos were analyzed to map the ecosystems in the case study area. Latter was performed to find out more about the awareness, conscious perception, and the visitors' demand regarding the provided services. The ecosystem services available in the wilderness area Sulzbachtäler were derived from relevant literature to associate each ecosystem type with the corresponding services.

Based on this objective, derived from the identified knowledge gap, the following research questions were phrased:

1. Which ecosystem services can be identified in the wilderness area Sulzbachtäler based on a remote sensing data analysis?
    a. Which ecosystems can be found in this wilderness area?
    b. To which ecosystem services can these ecosystems be linked?
2. Which available ecosystem services are perceived by visitors of the Sulzbach Valleys?
    a. Which is the most important service available for visitors in the wilderness area according to the conducted questionnaire?
    b. How do the perceived ecosystem services reflect the services derived through the natural-scientific analysis in the wilderness area?

1.3 Social and Scientific Relevance

This research contributes to increase the knowledge about ecosystems and ecosystem services in mountain regions, particularly in the wilderness area Sulzbachtäler. This is of scientific interest, because protected areas provide humans in and outside of mountain areas with essential services that can only be maintained with the functioning of these systems (Mori et al., 2013). Furthermore, the key ecosystem services also protect the diversity of local fauna and flora, mitigate climate change and also reduce the risk of natural hazards (Grêt-Regamey & Weibel, 2020). However, these services can only be preserved and are available in this quality, when ecosystems remain in their natural structure and are not modified (IPBES, 2019). Furthermore, the study is also of relevance for the interdisciplinary management of the Nationalpark in the fields of Biology, Geography and Ecology. In addition, the results point out the importance of human-nature interaction and add valuable information to this relevant topic. Since the number of people who want to experience nature and enjoy recreational activities in natural environments increases, the potentials for conflicts between protected area management authorities and visitors of protected areas rises as well (Schirpke et al., 2021a). With this study’s outcome, information about the visitor’s perception of services is gained. That can help to reach clarification what services are actively perceived and why people mainly visit protected areas.

Moreover, the importance of this topic is also reflected in the Sustainable Development Goals (SDGs) published by the United Nations in 2015 (United Nations, 2020b). Goal number 15 deals with the topic ‘life on land’ and the main targets of this objective are the protection and conservation of natural ecosystems. Moreover, it aims to reduce desertification and biodiversity loss (United Nations, 2020a). Also, Goal 3 ‘good health and well-being’, Goal 12 ‘responsible consumption and production’, as well as Goal 13 ‘climate action’ can be linked to the topic of land protection, which goes hand in hand with the conservation of ecosystems and natural resources (United Nations, 2020b).

Besides the scientific relevance of this study, this topic is also of interest for the non-scientific community. Often natural resource and land use management is planned and performed without the participation of the public community. Therefore, this project, that studies the availability and perception of ecosystem services is of importance for policy makers, municipalities, and other involved stakeholders in the spatial surrounding of the case study area and helps to improve socio-ecological decision-making processes. Additionally, the methodological approach used in this study can also be adopted and applied in regions with similar geographic preconditions.

2 Theoretical Background

This master's thesis' theoretical framework is based on several definitions and concepts that are presented in this chapter. First, the Earth's ecosystems are displayed and the interaction of humans with natural ecosystems discussed. Second, the two main ecosystem services frameworks are delineated and the applied terminology in this context is determined. Third, the need for protected areas, particularly wilderness areas is discussed. In addition, the IUCN classification system for protected areas is introduced. Finally, the case study area is presented, including some historical background information of the wilderness area's establishment as well as its geographic preconditions.

2.1 Ecosystems and their Importance for Humans

Humans' existence is dependent on nature, and it is secured by the resources provided by it. The various types of terrestrial and marine ecosystems supply society with their underlying ecosystem services, which are vital for survival, as well as a good quality of life (IPBES, 2019; Verburg et al., 2015). According to the Millennium Ecosystem Assessment (MA) (2005) these services can divided into four categories. They are introduced and discussed in more detail in Chapter 2.1.2.

A good quality of life or "human well-being" , how it is called in the Millennium Ecosystem Assessment report (2005), depends on multiple factors. First, the basic material needs, such as a roof above your head, sufficient nutrients, clothing, and access to basic goods should be available. Second, being able to live a healthy lifestyle. This includes access to non-polluted air, clean drinking water and a healthy physical surrounding. Third, a positive social environment, where one feels comfortable, respected, and helped, is also part of a good quality of life. Fourth, security in terms of secure access to available resources, but also personal safety, is listed. Finally, "freedom of choice and action" (Millennium Ecosystem Assessment, 2005, p. 5) is named as a main constituent of human well-being, according to the MA (Millennium Ecosystem Assessment, 2005). All in all, a sustainable use of ecosystems and their services, is an important factor in reaching a good quality of life. This emphasizes how important the ecosystems' stability is for the survival of humans. With the steady increase in population number, also the demand for resources (e.g., agricultural materials) rises. This results in the process that nature's self-regulation is challenged by an increase of management strategies to maximize the output (DeFries & Nagendra, 2017).

2.1.1 The Earth's Ecosystems

According to the UN Convention on Biological Diversity (1992, p. 3) ecosystems are defined as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". This definition highlights the complexity of these systems and the importance that living organisms and their environment act as one framework. The individual components are directly or indirectly influencing the development of each other (IPBES, 2019). Depending on numerous different parameters, such as climate, topography, and species occurrence, just to name some, ecosystems can be extremely diverse or more homogenous in their natural existence. Furthermore, there is no standardized norm regarding the size of ecosystems. They can range from small fields, such as green areas in the center of roundabouts to large regions, such as grasslands, deserts, or glaciers. The entire Earth's surface cover consists of a network of connected ecosystems, which are separated by their different interacting local parameters. It needs to be remembered that also humans are part of ecosystems (IPBES, 2019). Humans have been interacting with the Earth's ecosystems since the beginning of the Holocene and this has led to the development of their personal ecosystems, called urban ecosystems. These represent high diversity, heterogeneity and high spatial dynamics that are predominately constructed by humans (Kapoor et al., 2020). However, also in other ecosystems humans are part of these.

Even though humans are considered as part of ecosystems, they also represent a major threat to the maintenance of these systems. According to Wilson (2016) and Dinerstein et al. (2017) 30 to 70% of an ecosystem have to be in its natural state to not record a decrease in biodiversity. In addition, studies have confirmed that human interference is the main driver for biodiversity loss (Kormos et al., 2018; Mori et al., 2013). Land cover and land use change, as well as exploitation of raw materials destabilize the natural balance of ecosystems and threaten the local species (DeFries & Nagendra, 2017; Verburg et al., 2015). Not only direct anthropogenic drivers but also indirect impacts (e.g., pollution and climate change) challenge the natural development of ecosystems. Numerous publications have revealed that only by maintaining their natural structure without interference, the resilience of ecosystems and their underlying services is preserved (Morimoto & Negishi, 2019; Oliver et al., 2015; Tilman et al., 2006). Furthermore, a high species richness, diverse biodiversity, as well as generally large ecosystems and high intactness support the ability to cope with natural stress and pressure (Grêt-Regamey et al., 2019; Kormos et al., 2018; Mori et al., 2013). However, it is important that not only small reservoirs are protected, but also large ecosystems need conservation measures. They are essential for seasonally migrating wildlife and most often inhabit a greater number of species (Kormos et al., 2018).

Still, it needs to be considered that ecosystems conserved in their current state are not stable either. Studies from the 1980s, already published results that ecosystems are in a continous state. Natural stressors, such as forest fires and floods are essential to maintain the natural cycle of an ecosystem (DeFries & Nagendra, 2017; Pickett & White, 1985). These natural drivers help to revitalize the services provided by nature to secure human survival.

2.1.2 Ecosystem Services and Different Frameworks

The ecosystem services framework was coined by the initiative ‘Ecosystem Millennium Assessment’. In 2001, this organization was established to investigate the consequences of how the modification of ecosystems affects human life and well-being. Specific research was conducted between 2001 and 2005 with the objective to phrase a scientific set of measures that should support the protection and resilient use of ecosystem services with the goal to encourage human well-being (IPBES, 2019; Millennium Ecosystem Assessment, 2005).

The MA identified four different categories of ecosystem services: provisioning, regulating, cultural and the critically discussed fourth category of supporting services. These will be introduced and discussed in detail later in this chapter. They imply material and non-material supplies that humans receive from ecosystems (IPBES, 2019), while contributing directly or indirectly to human well-being (Braat & Groot, 2012). However, not every good is available in each ecosystem and their appearance, as well as ratios, depend on the local ecosystems and are not equally distributed worldwide. Furthermore, some nations and cultures depend on certain services more than others. The named examples for explanatory purposes are only a small selection. Relevant examples for this study are presented in section 4.3.

Since its publication, the ecosystem services framework has gained increasing attention from the scientific community, as it provides a basic natural resource management approach (Matzdorf & Meyer, 2014). Not only in the natural science context, but also economists have studied and applied this framework. Early estimations of the global ecosystem services’ value have already been conducted in the late 1990s by Constanza et al. (1997) and numerous more studies followed after the MA’s publication (for current examples see Jiang et al. (2021), Schutter et al. (2021) and Taye et al. (2021)). In certain sectors of the non-scientific community, this approach also finds approval. Policymakers, for example, incorporate the ecosystem services framework during the development of management strategies (IPBES, 2019). However, also certain criticism arose around the MA's framework. Scientists criticized the one-sided natural science approach, which did not address more interdisciplinary fields of research. Furthermore, a lack of open worldviews apart from the Global North was mentioned. Moreover, missing conditions for not as far developed governances were pointed out (Ellis et al., 2019; Pascual et al., 2017). The non-consideration of the negative side effects and losses of ecosystem services was also assessed critically, as services is the MA's framework are predominately considered as beneficial (IPBES, 2019). Finally, the focus on measurable services that are of exclusive economic value for market systems was criticized, as other values did not fit the "capital stock/economic benefit flow framing" (Ellis et al., 2019).

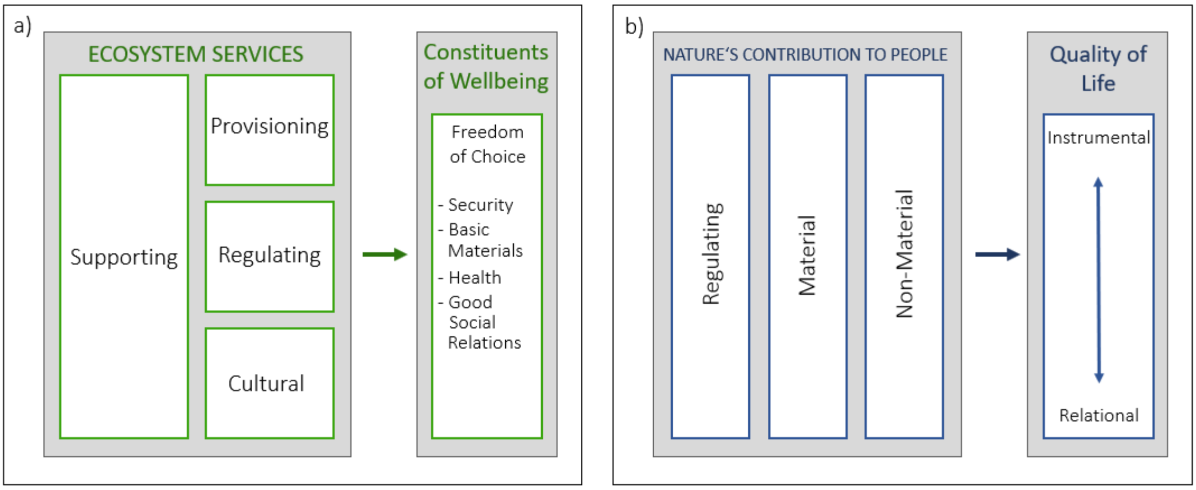


Figure 2: A visualization of the similarities and differences between a) the MA's framework and b) the NCP's framework (source: adopted representation from MA,2005; IPBES, 2019).

Hence, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) developed a new concept. The 2012 founded, independent intergovernmental organization developed the 'Nature's Contributions to People' (NCP) concept (IPBES, 2019). It is based on the idea of the ecosystem services framework, but works with a more inclusive and holistic approach (Ellis et al., 2019; IPBES, 2019; Pascual et al., 2017). It is developed beyond natural sciences and includes more diverse stakeholders from social sciences and humanities, additionally to the knowledge of local communities, as well as their worldviews and "human-nature' relations" (e.g., Mother Earth) (IPBES, 2019, p. 2). The concept works with three distinctive categories, which are also based on the first three ecosystem services mentioned above: material NCP (provisioning services), non-material NCP (cultural services) and regulating NCP (regulating services). However, the borders between the different categories are not so strict, depending on the context (Ellis et al., 2019). The controversial fourth category, the supporting services, is not included in this framework. Furthermore, additionally to the beneficial contributions of these services, also negative aspects and potential losses are considered (IPBES, 2019; Pascual et al., 2017). Figure 2 visualizes the basic similarities and differences between the ecosystem services framework (see Figure 2a) and the NCP framework (see Figure 2b). The main objective of the IPBES is to offer various stakeholder groups including governments and the private sector, scientifically sound and contemporary assessments of the current development regarding biodiversity and ecosystem services. This includes separated studies on global and regional basis to improve the available knowledge for decision making processes of new policies or the development of management strategies. Shortened publications in the form of "summaries for policymakers" (IPBES, 2019, p. 2) should make it easier for responsible people to work with these publications (IPBES, 2019).

Raw materials such as food, water, fibers, and minerals belong to the more obvious services provided by ecosystems that can be classified as provisioning services or material NCP. On a global scale, the consumption of these physical goods has increased drastically over the 20th century, and it continues to grow, even faster than population growth. In multiple cases, such as mineral mining, fisheries, or deforestation, these services are used at unsustainable rates, which unbalance the natural state of these ecosystems. Anthropocentric management strategies frequently lead to trade-offs, as the modification of one service results in adaptions of other ecosystem services, because the natural preconditions shift. However, also positive synergies are possible to achieve. If specific services are protected and maintained, also other services can benefit from this action (DeFries et al., 2004; DeFries & Nagendra, 2017; IPBES, 2019; Millennium Ecosystem Assessment, 2005).

Next, regulating services or regulating NCP include climate regulation, air and soil quality, pollination, as well as prevention of natural hazards and biodiversity conservation, to name some examples. These services regulate and control the ecosystem. To obtain the maximal output of provisioning services, humans have continually modified these services for their personal needs (IPBES, 2019). For example, changes in land cover and land use lead to an imbalance in the natural climate regulations. As a result, more GHGs are released into the atmosphere and less carbon can be stored. These adoptions also lead to a higher chance of soil erosion and floods and as a consequence to a decreased natural hazard prevention (IPBES, 2019; Millennium Ecosystem Assessment, 2005).

Furthermore, cultural services or non-material NCP are part of the framework. They form the non-material goods, such as recreational, spiritual, and aesthetic values that an ecosystem provides for the people's benefits. Formal and informal educational values, as well as cultural features belong to this category. In the case of the NCP framework certain goods can belong to more than one category. For example, food that represents a provisioning service in the MA's context, could be allocated to non-material or/and material NCP in the NCP's framework. This should leave more space for interpretation of different cultures (Ellis et al., 2019). Even though, the demand for cultural services has been growing, as more people use nature for recreational purposes, the ecosystems providing these benefits have decreased steadily over the past years. Changes in natural ecosystems caused by e.g., land use change, can contribute strongly to the loss of important cultural services (IPBES, 2019; Millennium Ecosystem Assessment, 2005).

Finally, supporting services represent the fourth category in the MA's framework. They form the base and support the existence as well as the development of the other three services. Their indirect or long-term influence on humans distinguishes supporting services from the other three categories. Examples are different biogeochemical cycles, (e.g., photosynthesis) or soil formation (Millennium Ecosystem Assessment, 2005). In certain cases, services can be classified as a supporting as well as another service. If supporting services should be included in studies as a separate category or not, is an issue that is often critically discussed by scientists, because its availability needs to be present for the survival of humans (Ellis et al., 2019; IPBES, 2019). Therefore, IPBES finally decided to not include this category in their framework (IPBES, 2019).

In the course of this master's thesis, the terminology of the MA's framework is applied, as it represents the original phrasing of the ecosystem services framework. Furthermore, the definitions of the individual services are more visually connotated. However, the category of supporting services is not considered as a separate class, because of its ambiguous status in literature. Moreover, the possibility to assign the non-material benefits of this category to other services, simplifies the analysis of the results. Still, the focus is shifted from the solely natural science focus to a holistic, more open-minded approach comparable to the NCP's framework with the aim to present a complete overview of the ecosystem services available in the case study area.

Since the development of these frameworks, numerous scientists have tackled the concept of ecosystem services from various standpoints and scientific fields. Investigations from the economic point of view, concerning the relations between stocks and flows of ecosystem services have been conducted (Kienast et al., 2009), as well as suggestions of how to identify the differences between the services' supply and demand have been framed (Burkhard et al., 2012). How species richness and ecosystem services are interlinked is illustrated in the publication by Bastian (2013), while Bürgi et al. (2015) combine the topic with the subject of landscape history. Furthermore, the importance of investigating only single services, such as cultural services is also outlined in certain publications (Tratalos et al., 2016). This implicated the development of numerous different methods how to derive and assess ecosystem services in real-life situations.

The aim and scope of the study play an important role when choosing a specific methodological approach (Harrison et al., 2018). In most cases multiple methods are combined to a mixed-method approach to achieve the best possible result (Pătru-Stupariu et al., 2020). How ecosystem services can be assessed, which methods are available, and which are applied in the course of this study is discussed in Chapter 3.2

2.1.3 Ecosystems in Mountain Regions

Environments in mountain regions play an essential role, when it comes to climate regulation, carbon sequestration, conservation of species richness, providing products and resources important for human well-being, as well as access to recreational areas that promote mental and physical health, to name some examples (Egarter Vigl et al., 2021; Glushkova et al., 2020; Grêt-Regamey & Weibel, 2020; Klein et al., 2019; Pătru-Stupariu et al., 2020; Schirpke et al., 2020). The ecosystems found in mountain areas are often predominantly sparsely populated, because of topographic (e.g., dominance of steep slopes) and climatic (e.g., cold winters and moderate summers) preconditions (Grêt-Regamey & Weibel, 2020; Pătru-Stupariu et al., 2020). However, this is predominately valid in the moderate zone, but does not need to apply to tropical areas. Still, they are extremely diverse. Due to the high elevation gradient, which is reflected in climate, hydrology and vegetation, these regions form a habitat for a great number of different native species (Rahbek et al., 2019). Moreover, mountain ecosystems supply the population living in and close to mountain areas with crucial services (Huber et al., 2013). According to Viviroli et al. (2020) almost one fourth of the global population will be dependent on water supplies in form of runoff from alpine areas. Furthermore, the high elevation gradients feature great species richness (Quintero & Jetz, 2018).

Moreover, besides provisioning services, such as access to timber and water supply that are securing subsistence for parts of the local population, also essential regulating services, such as protection against natural hazards and regulation of air quality are present. Finally, mountain regions have a high standard in cultural services, as many people use these areas for recreational purposes and tourism (Egarter Vigl et al., 2021; Grêt-Regamey et al., 2012; Grêt-Regamey & Weibel, 2020; Klein et al., 2019; Schirpke et al., 2020). Particularly in the Alps, cultural services generate an essential economic factor when it comes to touristic offers for summer and winter tourism. Depending on the location of the mountain ecosystem, spiritual and aesthetic aspects can also be of high value for visitors and the local population (Schirpke et al., 2020).

However, various external drivers threaten the resilience of mountain ecosystems and consequently humans' quality of life. A global survey performed with stakeholders of mountain regions conducted by Klein et al. (2019) identified the following parameters as the main impacts that endanger mountain ecosystems: land use and land cover change, adaptions in market policies, as well economic crisis. Furthermore, they named climate change and extreme weather events associated with landslide processes and floods. Other authors also name the rise in population numbers, urbanization (Schirpke et al., 2020), invasion of non-native species and pollution as crucial threats of these ecosystems (Egarter Vigl et al., 2021). However, these impacts occur on different scales. While climate change has effects on a global basis, extreme weather events only influence mountain regions in certain areas (Klein et al., 2019).

As Mori et al. (2013) outlined in their publication the interconnection between ecosystems, their services and climate change is extremely complex. Due to the fact that each individual component of this system is reacting differently to slight adaptions, the consequences of changes in mountain ecosystems can hardly be predicted (Pătru-Stupariu et al., 2020). One successful approach to limit the impact of certain external drivers, such as excessive land use change, is the protection of mountain regions (Glushkova et al., 2020).

2.2 The Need for Protected Areas

With the rise in anthropogenic activities driven by the constant growth of the global population and technological improvement, the pressure on natural resources advances constantly. Therefore, more remote regions need to be accessed to extract raw materials as other resources are already depleted (Cazalis et al., 2018). However, not all raw materials provided by nature are able to be replaced or recover within the lifetime of one generation (IPBES, 2019).

Since the 1980s, people's awareness has increased that the rapid changes in the natural environment also have critical impacts on their quality of life, apart from the consequences on native fauna and flora (Dudley, 2013). Therefore, the protection of threatened landscapes and species has turned into a relevant issue and has gained further importance. According to the International Union for Conservation of Nature (IUCN) protected areas are defined as "clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values." (Dudley, 2013, p. 8). These areas are recognized as a key element in the maintenance of natural ecosystems and ecological processes aside from otherwise intensively managed and populated environments. Also, humans can take advantage of protected areas, as they create space for socio-ecological interaction, such as for recreational and educational purposes in the otherwise often densely populated World. Moreover, protected areas are of high value for indigenous cultures, as traditional living areas and spiritual natural sites are conserved (Dudley, 2013).

Even though, the term ‘protected area’ has been defined by the IUCN and this definition is internationally accepted, it still needs to be remembered that it applies to a wide variety of landscapes and water bodies. It describes an area that from the humans’ perspective is worth being protected, because of a certain characteristic. Additionally, a wide range of established management strategies are being performed in these regions. Some areas are strictly protected, and people are not allowed to visit them, while others are welcoming guests, or the management is even embedded in the daily lives of the local population. Furthermore, severe differences regarding the management strategies can be found when comparing on land, marine or in-land water bodies protected areas (Dudley, 2013).

2.2.1 Protected Area Management Categories

Since the past century until today, approximately 12% of the Earth’s surface including land and water bodies have been assigned a certain land protection status. Even though, an increase in protected areas can be recorded, there is still an imbalance between marine and terrestrial areas, as much more focus is put on in-land water or land areas (Dudley, 2013). In the 20th century, countries started to define their individual protected regions, based on specific definitions without looking for a global, universal solution. This resulted in a diverse terminology, describing similar situations, while only partly considering one of the various international or national protected area systems that had been developed so far. These systems are based on different definitions how to specify and define protected areas (Dudley, 2013). All in all, they have the common target of biodiversity conservation and environmental protection. However, apart from this, additional management strategies can vary from providing recreational and educational input for visitors to improving the living conditions for local communities (ALPARC, 2019). As an example for an European agreement, the Natura 2000 network can be named. It coordinates on-land and marine protected areas in the European Union with a focus on native species and natural habitat protection (European Commission, 2013). On an international level examples are UNESCO World Heritage sites, UNESCO Global Geopark and UNESCO Biosphere Reserve initiated by the United Nations (UNESCO, 2021).

Furthermore, the IUCN developed a categorization system for protected areas. Their aim was to develop a Protected Area Management Categories system, which can be applied globally and creates an international common understanding regarding the definition of protected areas. Furthermore, it should help communities and governments to plan and establish protected areas, as well as to develop management approaches based on individual regional preconditions (Dudley, 2013). Today, these six categories are widely accepted by international and national organizations, such as the United Nations and the Convention of Biological Diversity. In addition, they are increasingly included in national governmental policies (ALPARC, 2019; Dudley, 2013). Therefore, the IUCN classification system will be used for this master's thesis and will be introduced more detailed below.

The Protected Area Management Categories system was developed in 1994 and adopted to the current state since then. However, already in the early 1930s the first categories for protected areas were defined. At the International Conference for the Protection of Flora and Fauna in 1933, four different categories were published: national park, strict nature reserve, fauna and flora reserve, and huntig reserve where hunting was forbidden (Holdgate, 1999). These categories were updated and revised several times until they were replaced by a more complex ten-level system in 1978 (IUCN, 1978). This formed the base for the following six categories currently in place:

I Strict protection
 Ia: Strict nature reserve
 Ib: Wilderness area
II Ecosystem conservation and protection
III Conservation of natural features
IV Conservation through active management
V Landscape/seascape conservation and recreation
VI Sustainable use of natural resources

Category I forms the toughest protection class. In a strict nature reserve visits of people are strictly controlled. Besides the aim of natural habitat and biodiversity protection, these areas might also be used as reference areas for scientific purposes. Wilderness areas often represent regions, where little to no human interaction has occurred in the past, so native species and landscapes can be protected in their natural state. As wilderness areas are of specific importance for this master's thesis, a more detailed description and explanation can be found in Chapter 2.2.2. Class II represents national parks, where large natural areas are protected with the aim to preserve native species and ecosystems, alongside cultural values and make these accessible for visitors. However, this definition can be confusing, because the first national parks have already been established long before the IUCN categories were developed. Therefore, numerous national parks have divergent objectives and management strategies than the ones represented by Category II. Furthermore, reasons for naming an area 'national park' can be ascribed to political reasons or depend on granting possibilities. For example, the Dipperu National Park in Australia is categorized as an Ia area according to the IUCN classification system, even though its name misleadingly includes the term 'national park' (Dudley, 2013). Conservation of natural features forms the third category. These are often only small sized areas with high touristic attraction, such as natural monuments or specific sea sites. Category IV has the main objective to "maintain, conserve and restore species and habitats" (Dudley, 2013, p. 19). The protection of landscape and seascape represents class V. In this case the interplay between humans and nature has created a unique land- or seascape. Therefore, a balanced management is needed to conserve this cultural, ecological, or societal value. Finally, category VI forms the least strict protection class, according to the IUCN classification system. In this case, parts of the otherwise natural ecosystems and resources are used by humans in a sustainable, non-industrial manner (Dudley, 2013).

2.2.2 Wilderness and Wilderness Areas

Since the beginning of the Holocene when people started to settle down, wilderness, forests and grasslands have been replaced by pasture lands and agricultural areas. Moreover, natural streams have been regulated, and marshes have been drained. The regions where untouched nature exists are steadily declining. In the time period between 1993 and 2009 alone, an area of 3.3 million km^2 has been replaced by human constructed infrastructure (Watson et al., 2016). The same applies to marine areas; regions free of industrial mass fishing and highly frequented shipping routes can almost only be found close to polar regions (Halpern et al., 2015).

On the one hand, areas that are difficult to access or are not of any economic value, still show unmodified natural environments. On the other hand, land that is in the ownership of one family since generations already, might not reveal traces of anthropogenic modification. In this case, an example is the Wilderness area Dürrenstein in Lower Austria. A small extent of today's wilderness area of almost 3,500 hectares, was already put under natural protection by Albert Rothschild in 1875, the former owner of the forest. Since that time, nature in this area is developing without the interference of humans and the protected stretch of land has been extended over the years (Wildnisgebiet, 2021).

Historically, the protection of wilderness and wild, natural places has evolved through a movement in the United States. This group of people was focusing on the beauty and singularity of nature before European settlers started to construct villages and cities. Through this movement the first US-American national parks were established, namely Yellowstone and Yosemite National Park. As national parks turned into more popular tourist destinations, the US-American landscape planner Arthur Carhart searched for a new concept to conserve nature and wilderness. Together with Aldo Leopold, an ecologist and biologist, they developed the first idea of a wilderness area. It should represent a state-owned region that has merely been used for human purposes. Based on this idea the first wilderness area 'Gila Wilderness' was established in 1924 in New Mexico. At the beginning, the aim of wilderness areas was mainly to give visitors the possibility to visit natural and unchanged nature, only later the scientific relevance and the importance of natural protection emerged. In 1964, the United States (US) Wilderness Act took place, here the foundation of the legal management of wilderness areas was laid (WWF Österreich, 2016).

In Europe, the relevance of wilderness only increased in the late 1980s. People started to notice that the extensive use of natural resources and the increase in infrastructure also reached areas that had barely been used for economic purposes before. Furthermore, it became obvious that intensive agricultural activities and forestry are a threat to the local biodiversity and that the pressure on threatened species increased steadily. Since 2005, the Wild Europe Initiative is internationally organizing and managing the coordination of European wilderness areas, as well as researching for further potential wilderness areas (WWF Österreich, 2016). The non-profit NGO European Wilderness Society has the aim to identify undiscovered, untouched spots of nature. The organization developed a system to determine wilderness with standardized measures based on scientific knowledge and research. With the help of the 'Wilderness Quality Standard and Audit System', they define wilderness areas in Europe according to the wilderness definition of the Wild Europe Initiative (European Wilderness Society, 2021).

Still today, scientists are researching why it is essential that wilderness should be conserved and maintained and what would happen without conservation measures. It is discussed, if humans need to change nature in order to live a satisfiable lifestyle or if using the provided resources without the modification of the environment would also be sufficient (WWF Österreich, 2016). However, it became clear that it is necessary to protect natural and semi-natural environments, as numerous studies have revealed that the natural functioning of these areas is crucial (D'agata et al., 2016; Jones et al., 2018; Watson, Evans, et al., 2018; Watson, Venter, et al., 2018). The Earth's remaining wilderness areas act as increasingly important buffer zones against the influence of anthropogenic climate change and other human pressures (Watson, Venter, et al., 2018). Due to their intact and undisturbed natural cycles, these unmodified ecosystems are important drivers for climate change mitigation. For example, when it comes to carbon sequestration, boreal forests store approximately one third of the global carbon and are the greatest carbon sinks (Watson, Venter, et al., 2018). Moreover, these undisturbed ecosystems are important habitats for native fauna and flora. They are also the only regions that maintain ecological processes that preserve the local species richness over long timescales (Soulé et al., 2004). Furthermore, wilderness areas act as refuges for species that have formerly predominately lived in areas that are now populated by humans (Betts et al., 2017). Intact ecosystems also have a much higher resilience factor when it comes to external stresses and pressures (Thompson et al., 2009). Next, these areas without human interventions hold important evidence to track the development of ecosystems and the interaction of native flora and fauna, as well as the spread of invasive species (WWF Österreich, 2016). These regions gain particular importance during the time of rapid environmental change due to human activities, where barely any regions are free of human traces, like it is the case in Austria. In these situations, wilderness areas can be utilized to observe the renaturalization and rewilderness process of former anthropogenically used areas (WWF Österreich, 2016). They are also increasingly considered and visited as a support for physical and mental health issues (Kormos et al., 2018). Moreover, areas with little to no human traces from the past can be studied as models, when modified regions should be "rewilded" (Watson, Venter, et al., 2018). Finally, wilderness areas are important for longtime monitoring and specific scientific studies, as well as educational purposes (WWF Österreich, 2016).

In general, the word 'wilderness' defines a "wild natural environment not managed or controlled by humans" (Kormos et al., 2018, p. 31; Nash, 1967). However, several definitions to explain 'wilderness' have been developed so far. The IUCN's definition is widely accepted and often provides the base for more specific definitions. According to the IUCN wilderness "protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition" (Dudley, 2013, p. 14). The Wild Europe initiative has used this phrasing to develop an even more accurate definition for Europe. "A wilderness is an area governed by natural processes. It is composed of native habitats and species, and large enough for the effective ecological functioning of natural processes. It is unmodified or only slightly modified and without intrusive or extractive human activity, settlements, infrastructure or visual disturbance." (Wild Europe, 2020). In contrast, for Natura 2000 areas a different definition of wilderness is applied: "A wilderness is an area governed by natural processes. It is composed of native habitats and species, and large enough for the effective ecological functioning of natural processes. It is unmodified or only slightly modified and without intrusive or extractive human activity, settlements, infrastructure or visual disturbance." (European Commission, 2013, p. 10).

As the case study area of this project is located within an IUCN certified wilderness area, the characteristics and features of this class are described in detail in the following paragraphs. The principal objectives of a wilderness area according to the IUCN are "to protect the long-term ecological integrity of natural areas that are undisturbed by significant human activity, free of modern infrastructure and where natural forces and processes predominate, so that current and future generations have the opportunity to experience such areas." (Dudley, 2013, p. 14). Furthermore, public access is limited to the extent that the main objective can be accomplished, while at the same time indigenous cultures should be able to continue living their traditional lifestyle. This might include livestock grazing and low-level use of natural resources. However, also their way of living might need to be adjusted to the additional protection measures. Next, the protection of cultural and sacred sites needs to be guaranteed and scientific research, as well as educational workshops are allowed, if they cannot be performed at an alternative site outside the wilderness area (Dudley, 2013).

When a new wilderness area is in the process of discussion, it is checked if certain characteristics are present, as wilderness areas have to feature some distinguishing characteristics that cannot be found in other regions. No modern infrastructure and industry are allowed to be located within this area. The area of interest should be featuring mainly intact, unmodified ecosystems and a balanced population of native fauna and flora. Visitor’s access to wilderness areas is limited, as no supporting infrastructure is allowed to be located within the borders of the protected areas (e.g., paved roads and mountain cabins). Furthermore, touristic use of these areas is prevented. Motorized means of transportation are forbidden, so people can only travel by foot, skis, or cross water bodies by non-motorized boats. The size of wilderness areas is not predefined and varies from the individual areas. However, it should be big enough to maintain and protect the local biodiversity and ecosystems. Furthermore, in the wilderness area’s stretch of land a buffer against stresses from the outside, such as climate change and invasive species, should also be considered. The wilderness area should be able to persist and develop in its current form. However, certain spots that have slightly been modified by anthropogenic activities before can also be included in bigger wilderness areas, if the possibility of restoration exists. In any case, all the above-introduced features and objectives need to be present and fulfilled, so an IUCN wilderness area can be certified (Dudley, 2013).

The diverse understandings and interpretations of the term ‘wilderness’ makes it particularly difficult to develop a common approach to measure and evaluate it. Depending on the scope and aim of individual studies, various indicator sets are applied in a so called Multi-Criteria-Analysis (Orsi et al., 2013). Most frequently geographic data with various information input are merged, such as high resolution spatial data, data of demographic information, data about local fauna and flora, the local infrastructure network and geology, to name some (Hannah et al., 1994; Mittermeier et al., 2003). One of the first scientific approaches, how to measure wilderness was developed by Roderick Nash in 1973 (WWF Österreich, 2016). His concept of ‘the wilderness continuum’ was extended by Lesslie and Taylor (1985) and has since then been applied in different studies, such as Carver et al. (2012), as well as Carver et al. (2013). However, the ‘wilderness continuum concept’ has also been criticized for its subjective view of the operator. This concept depends on researcher’s perception and decision-making skills to place a certain area on a scale between complete wilderness and urban sites (Orsi et al., 2013). In other studies wilderness is defined through various indicators, such as remoteness, pollution, natural composition, and solitude to name some. However, also in these cases the selection of the individual parameters, as well as their loading depend on the perception of researchers and managers conducting the study (Carver et al., 2002; Comber et al., 2010; Orsi et al., 2013). Furthermore, the scope, available data and size of the research area are also taken under consideration when deciding on the parameters' weighing. Until February 2022, no universal method how to measure wilderness has been developed.

2.3 Case Study Area: The Wilderness Area Sulzbachtäler

In fall 2019, the wilderness area Sulzbachtäler was classified as a protection area according to the IUCN nature protection management category Ib. During the classification process, the presence of above-described natural preconditions was evaluated, alongside with the management objectives planned for this protected area. A key criterium during the identification process was that the main objective must fit at least 75% of the area. This means, three-quarters of the area need to feature uninterrupted, natural stretches of land, where local fauna and flora dominate the landscape so also future generations can experience unmodified nature (Dudley, 2013).

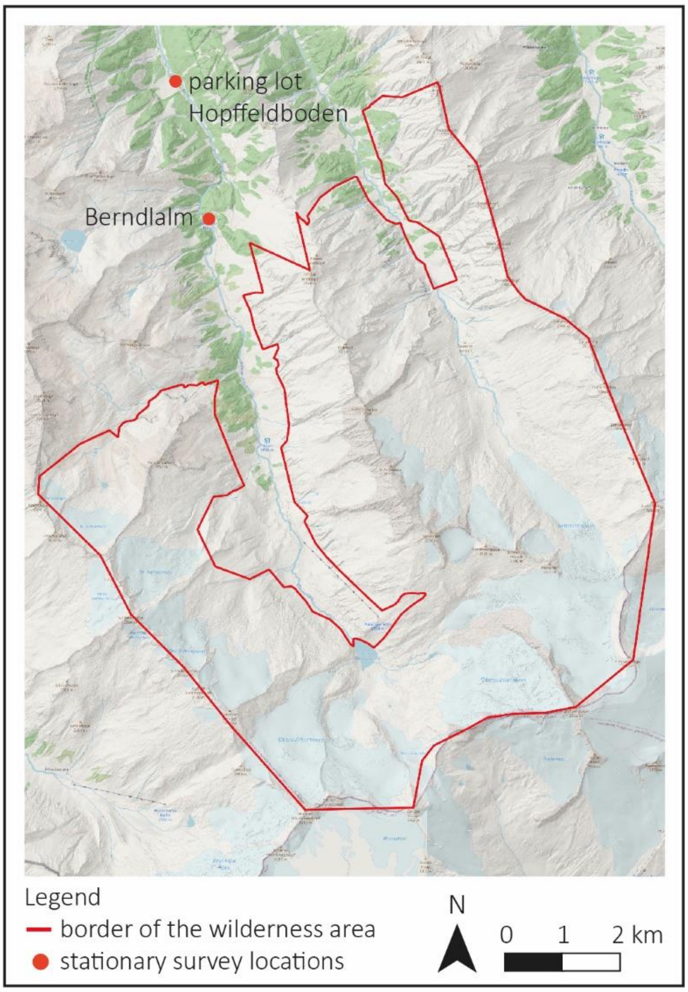


Figure 3: Overview map of the wilderness area Sulzbachtäler including the stationary survey locations at Berndlalm and parking lot Hopffeldboden (source: own representation; data: OpenStreetMap)

The wilderness area Sulzbachtäler is located in the Eastern Alps in the state of Salzburg and is included in the Nationalpark Hohe Tauern. An overview map is depicted in Figure 3. Besides the wilderness area Dürrenstein, it is the only internationally recognized wilderness area in Austria. However, until it reached this international classification level, it took several years and numerous administrative and legal steps (Salzburger Nationalparkfonds Hohe Tauern, 2016).

2.3.1 Historical Background

The base for the establishment of this wilderness area was already initiated more than a hundred years ago. In 1909, the organization 'Naturschutzpark Lüneburger Heide' wanted to develop the first Austrian national park. At this time, the US-American national parks served as a model for the organization. To accomplish their goal, they bought some potential areas that were of interest for environmental protection within the borders of today's Nationalpark Hohe Tauern (Salzburger Nationalparkfonds Hohe Tauern, 2016).

However, World War I and II delayed the establishment of the project. After World War II, the acquired land gained the interest of authorities for the construction of hydropower plants. At this time, the improvement of the economic situation was much more valuable than environmental protection, so the organization had to swap the land and received the Sulzbach valleys in return. In 1984, when the Nationalpark Hohe Tauern was established, the areas belonging to the organization 'Naturschutzpark Lüneburger Heide' became an important part of it. Already in 1995, the Southern parts of the Untersulzbach Valley gained a more specific and strict protection level, with the idea to apply for IUCN recognition status in the future (Salzburger Nationalparkfonds Hohe Tauern, 2016). In 2013, World Wide Fund for Nature (WWF) Austria conducted a study in today's wilderness area Sulzbachtäler to examine the potential for an international recognized wilderness area. After the European Wilderness Society assessed the area by the European Wilderness Quality Standard, they could confirm the results of WWF's study that the area would be well suited due to its natural preconditions and geographic location (Kohler et al., 2014). In 2015, the planning phase for the wilderness area Sulzbachtäler started (Salzburger Nationalparkfonds Hohe Tauern, 2016).

Already in September 2017, a special protection act for today's wilderness area Sulzbachtäler was released with the aim to increase the environmental protection measures in parts of the Unter- and Obersulzbach Valleys that were predefined as potential wilderness areas by the European Wilderness Society. This process had the result that a long-term agreement with the Austrian Federal Forests forbids any hunting, forestry, and agricultural exploitation in this area. The same also applies to fishing (Salzburger Nationalparkfonds Hohe Tauern, 2016). In 2016, to facilitate the process, the Nationalpark Hohe Tauern bought the land from the organization

'Naturschutzpark Lüneburger Heide'. One year later, the special protection act was extended. Since 2017, 6,628 hectares of land in the Ober- and Untersulzbach Valleys are under special protection. Two years later in fall 2019, also the IUCN recognized this area as a wilderness area according to their standards (Salzburger Nationalparkfonds Hohe Tauern, 2016).

As part of the application process a set of measures was implemented that should be implicated and accomplished during the establishment of the wilderness area and can be viewed as long-term and short-term goals. This management plan includes measures from the topic areas of environmental management, science, and research, as well as education and visitor information. They aim for a sustainable and steady development of the wilderness area's management (Salzburger Nationalparkfonds Hohe Tauern, 2016).

2.3.2 Geographic Information of the Wilderness Area

Today, 60% of the wilderness area are located within the Obersulzbach Valley, while 40% are in the Untersulzbach Valley. From East to West, it extends 11 km and from North to South 13 km. The highest point of the wilderness area is the peak of Großvenediger (3,657 meters above sea level (a.s.l.)), the highest mountain of Salzburg. This mountain's summit is illustrated in Figure 4. The lowest point can be found at 1,389 meters a.s.l. This results in an average height of 2,557 meters a.s.l. and approximately 75% of the wilderness area's region are located within the alpine altitudinal zone.

Figure 4: Photo of Großvenediger taken Southeast of Kürsinger Hütte on July 6, 2021 (source: own photograph).

Furthermore, around 20 km² are covered by 17 glaciers. The climatic conditions can be allocated to the temperate humid intermediate alpine zone. The maximum precipitation level is approximately 1,500 mm with abundant precipitation in summers and moderate levels in winters. The average temperature lays at approximately 1.4 degree Celsius (°C) (Salzburger Nationalparkfonds Hohe Tauern, 2016).

The valleys are orientated in a North-South direction and enter the Salzach Valley in the municipality of Neukirchen am Großvenediger (Salzburger Nationalparkfonds Hohe Tauern, 2016). Geologically, the wilderness area is located within the Hohe Tauern Window, which ranges between the Brenner in the West and the Katschberg in the East. Due to missing rock layers in this region, the Penninic nappes crop out. Therefore, the dominating rock types are Central Gneiss and slate. This geologic phenomenon occurred only in the Austrian Central Eastern Alps. Geomorphologically, both valleys are V-shaped valleys. Today's landscape form of the valleys is strongly influenced by the growth and retreat of the local glaciers during the past Ice Ages. On the one hand, the erosion of the ice left its traces. On the other hand, the deposition of rocks and debris are determining factors for the shape of the valleys. While the asymmetric characteristics of the cross-section that is common in the surrounding valleys can be found in the Obersulzbach Valley, is not featured by the Untersulzbach Valley. Here, both sides of the valley reveal steep slopes. This is supported by the erosion of the Gneiss, which results in regular landslide processes, as depicted in Figure 5 (Salzburger Nationalparkfonds Hohe Tauern, 2016).

Figure 5: Photo of the Untersulzbach Valley taken North of Stockeralm on July 6, 2021. The border of the wilderness area Sulzbachtäler runs along the bottom of the cliff (source: own photograph).

Due to its forbidding preconditions, the Untersulzbach Valley has never been used for long-term human settlement. Still today, tourism can predominately be found in the Obersulzbach Valley, as several cabins and numerous hiking paths with a small number of educational trails are located at its valley floor. Furthermore, it can easily be reached by local taxi companies that allow visitors comfortable access to more alpine regions. However, the modern infrastructure needed for cars and cabins is not located within the wilderness area, but in its border region. Even though, the Untersulzbach Valley can barely be used for agricultural purposes, mining activity can be traced back to the time of the Roman Empire. However, also these traces were found at the border of today's wilderness area. The vegetation inside the wilderness area does not show traces of human activity, as the meadows within this protected area have not been used as pasture lands for numerous decades before the establishment of the wilderness area. This also applies to the Obersulzbach Valley with one exception, where the farming activity was only abandoned with the establishment. Even though, the borders of the wilderness area, particularly in the Obersulzbach Valley, can easily be reached, there is only a small number of hiking paths present within its borders. For authorities it is a challenge to secure the safety of tourists and hikers by marking the hiking paths without interfering at a too high level with the natural environment. In both valleys, close to the wilderness area's border the Nationalpark Hohe Tauern owns a cabin (i.e., Hofrat-Keller-Hütte and Aschamalm), which are used for monitoring and research purposes (Salzburger Nationalparkfonds Hohe Tauern, 2016).

From the entrance of the two valleys up to their highest peak, which is in both cases the Großvenediger, the local flora and fauna represents various altitudinal levels from the montane to nival zone (Salzburger Nationalparkfonds Hohe Tauern, 2016). Due to the diverse climatic preconditions in the two valleys, differences in occurrence and growth densities of certain species can be detected. Below the tree line both valleys are dominated by real hardwoods and mixed forests. At the Untersulzbach Valley’s entrance also beeches can be found, an exception for this area and this species is also not represented in the Obersulzbach Valley. Both valleys feature less coniferous forest than commonly detected in the alpine zone. The higher resistance against landslide processes of non-coniferous species can be seen as a reason for this appearance. In contrary, the subalpine zone in the Obersulzbach Valley reaches a much lower elevation compared to the Untersulzbach Valley. Therefore, fir and pine trees can only be found at the lowest level of this valley. Larches are another dominate species that are commonly found at this elevation level. However, due to the high precipitation during summer months, this species is not growing in the Obersulzbach Valley. Close to riverbeds alders, mosses, and ferns, as well as lichens and herbaceous vegetation grow. In steeper slopes that are affected by annual snow avalanches, elders (*Alnus alnobetula*) and partly birches dominate. In the Obersulzbach Valley, the forest grows almost exclusively on the less steep left side of the valley. However, in both valleys the tree line is located between 1,800 and 2,00 meters of elevation and is formed by Swiss Pine (*Pinus cembra*). Figure 6 illustrates the Western valley side of the Obersulzbach Valley showing several vegetation zones.

Figure 6: Photo of the Western slopes of the Obersulzbach Valley taken from the gravel road outside the wilderness area close to the goods cable lift's bottom station on July 6, 2021 (source: own photograph).

Above the tree line dwarf shrub heaths and species-rich alpine grassland are growing. The least vegetation is present in the alpine scree slopes, where only mosses and crustose lichens can survive due to their resilience to long periods of snow cover. The glacier forefields are of particular interest when it comes to the local species richness. The steady transition of this biome, due to the seasonal melting of glacial ice, long periods of snow cover and occasional rockslides, results in the fact that only a little number of species can survive in this area. The local flora needs to cope with irregular stresses and a steady change of its habitat. Still, as a result of the constant glacial retreat and a decrease of the snow cover period, more species settle, and the soil formation increases (Salzburger Nationalparkfonds Hohe Tauern, 2016). Figure 7 shows a glacial lake located in the wilderness area at the glacial educational trail in the Obersulzbach Valley.

Figure 7: Photo of a glacial lake located in the wilderness area in the Obersulzbach Valley taken from the hiking path on July 6, 2021. The summit of Große Geiger is visible in the background of the picture (source: own photograph).

Also, the wildlife in the wilderness area reveals a high species diversity, because of the variety of local ecosystems. The higher the elevation, the more resistant and specialized to extreme weather events and little nutrients the local species need to be. This applies to mammals, reptiles, fish, birds, and amphibians alike. Therefore, a decrease in species richness is recorded with the increase of elevation. Only a little number of species can survive in alpine ecosystems during the entire year (e.g., rock ptarmigan (*Lagopus mutus*)). The wildlife in the wilderness area represents the local fauna of the Hohe Tauern. Particularly common are chamois (*Rupicapra rupicapra*) that, like a small local population of ibex, spend the winter at lower elevations compared to their habitat in the summer months. Furthermore, the wilderness area provides an ideal habitat for a number of feral chickens, (e.g., Rock Ptarmigan) and lagopus. These birds do not shift their habitat during winters but remain in the same region. Moreover, marmots and golden eagles belong to the local wildlife of the wilderness area. However, the above-named species are only a small selection of the local fauna. Many more invertebrates live in the water bodies or on land in the wilderness area. All in all, almost the complete potential species spectrum can be found in the case study region, apart from bears, lux, and wolves (Salzburger Nationalparkfonds Hohe Tauern, 2016).

Due to the fact that local ecosystems can develop without any human interaction, natural processes and lifecycles proceed in their natural, uninterrupted manner. However, this is not limited to only peaceful processes, but could also include sudden events, such as landslide processes and floods. Furthermore, also a protected area is influenced by the “direct drivers of change in nature” defined by the IPBES (2019, p. 12) as land use change, overexploitation, climate change, air pollution and invasive species. Indeed, only the last three are of relevance in the wilderness area Sulzbachtäler. These factors result in an increase of natural hazards and glacial retreat. An additional challenge for this area is livestock grazing on surrounding pasture lands. These animals sometimes enter the wilderness area by accident and run into danger to transmit diseases. To reduce this threat, a buffer zone between the wilderness area and the external border of the national park exists (Salzburger Nationalparkfonds Hohe Tauern, 2016). Still, national park authorities, who are also responsible for the wilderness area, need to resist the urge to maintain the environment’s current state but rather observe the dynamics of nature. Certainly, this implicates a chance that without human interaction fast environmental changes might occur.

3 Methods

This section introduces and explains the applied methods of this master's thesis in the chronological order of the workflow. The choice of the individual methods is described and discussed. At the end of this chapter, a graphical description of the research framework (see Figure 8) was added to visualize the performed work steps.

Numerous methods how to define and assess ecosystem services have been developed by scientists so far (European Environment Agency, 2021; IPBES, 2019). Therefore, appropriate methodological approaches were derived from relevant literature to tackle the identified research gap. A study published by Harrison et al. (2018) introduced various strategies how to select a suitable method to assess ecosystem services. This study revealed that the main reasons how methods get selected, heavily depend on the potential stakeholder inclusion and the initial background of the study (e.g., aim and purpose of study). Certainly, also availability of data, time, human, technical and natural resources, play an essential role (Harrison et al., 2018). One can differentiate between three main approaches: First, biophysical methods, such as matrix or modelling approaches, which also include using spatial data as input. Second, socio-cultural methods are based on the concept to understand the social values and preferences of the community. Finally, monetary techniques aim to estimate the economic value of ecosystem services (Harrison et al., 2018). The selection of the best method for a report, depends on numerous factors. Besides the ones mentioned above, the size of the study area, the availability and limitations of data, as well as expertise can influence this decision (Harrison et al., 2018). Two of these three approaches are of relevance for this research.

First, the initial step of this master's thesis was to determine the ecosystems present in the wilderness area Sulzbachtäler. This needed to be performed, because based on these ecosystems, the most essential available ecosystem services could be derived. Therefore, a manual land cover classification was performed. Remote sensing data in the form of orthophotos were the main input source for the classification. According to Harrison et al. (2018) this biophysical modelling approach is called "Simple GIS mapping" (Harrison et al., 2018, p. 484). More detailed information about the data input and this method's execution is explained in Chapter 3.1. Second, after determining the ecosystems present in the wilderness area Sulzbachtäler, the next step involved the identification of the available ecosystem services for each represented ecosystem. These were derived from relevant peer-reviewed scientific journal articles. Key reasons for the selection of articles were a performed ecosystem services analysis in a mountain region with similar characteristics to this study's case study area. After the main services were derived, a simple ranking was developed with the aim to identify to what extent a service is available in each ecosystem. This research process is further elaborated in Chapter 3.2. Third, to investigate which ecosystem services are perceived by visitors of the Sulzbach Valleys and if these align with the services' provision, a socio-cultural approach was applied. Therefore, a self-administrated questionnaire was designed and later asked to be filled in by visitors. A more precise description of this method's performance can be found in section 3.3. Finally, the collected data from the questionnaire were statically analyzed, so they could be related with the results of the biophysical modelling approach.

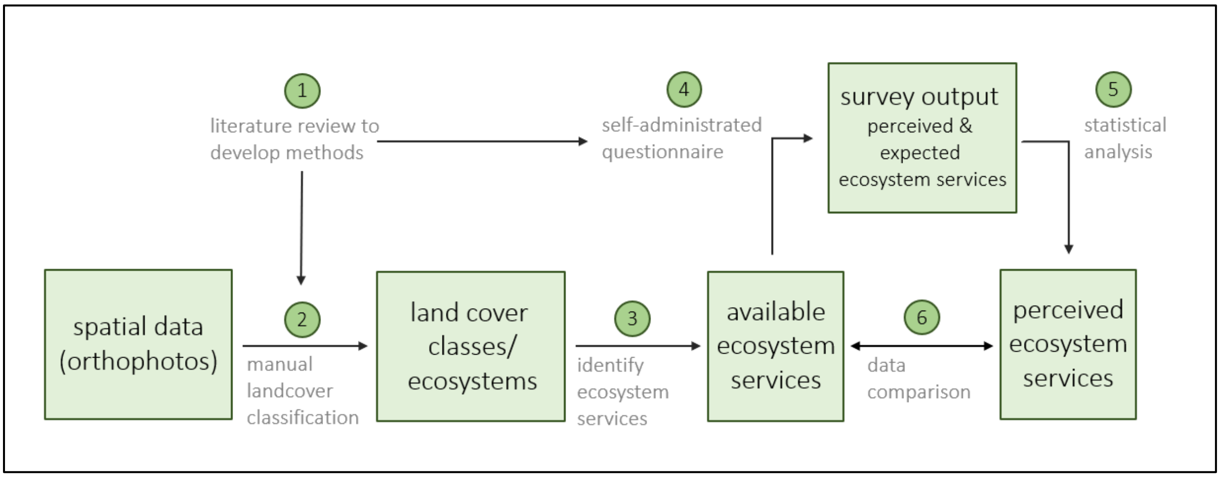


Figure 8: A visualization of this master's thesis' research framework. This step-by-step process shows each work step of this study with the aim to answer the proposed research questions. The numbers indicate the order of the work steps. The input or output of the methodological approaches are depicted in boxes. The individual work steps and the applied methods are represented as grey text and arrows between the in- and output boxes (source: own representation).

3.1 Land Cover Classification of the Wilderness Area

To map the ecosystems, available in the wilderness area Sulzbachtäler, first a land cover classification was generated. The decision to apply this method was supported by the data availability that was provided by SAGIS Land Salzburg. Furthermore, the expertise of the operator and the scope of the study were important aspects during the decision-making process. A land cover classification accompanied by a literature analysis, as it is combined in this study, is a simplified approach of classifying ecosystems.

Still, it provides accurate enough results for this master's thesis project. More complex classifications involve precise evaluations and interdisciplinary approaches including the acquisition of the represented flora, fauna as well as geology and would go beyond the scope of this study. D'Urban Jackson et al. (2020) pointed out the complexity of this process in their publication.

3.1.1 Database and Methodological Approach

The input for this classification were revised remote sensing data in the form of orthophotos. 82 processed areal pictures of the latest data collection performed on the August 28, 2018 and September 11, 2018, with a spatial resolution of 0.2 meters were analyzed with the geospatial information system software QGIS. This is a well-established and frequently used method to map land cover (Copernicus, 2019). More information about the provided orthophotos is displayed in Table 1.

Table 1: Basic parameters of the provided and applied orthophotos (source: Bundesamt für Eich- und Vermessungswesen, 2014)

projection	MGI/Austria GK M31
map projection	Austria Gauss-Kruger M31
projection method	Transverse Mercator
false easting	450000
false northing	-5000000
unit	meters
EPSG code	31258

The decision to use remote sensing data as a data input for this method was based on the availability of high-resolution data. Furthermore, the otherwise high logistic and time-consuming effort that has to be taken, if a study area needs to be visited, is simplified due to remote sensing data analysis. This particularly applies to mountain regions, where rough terrain and therefore limited accessibility is a predominant topographic characteristic (Moser, 2008). Moreover, additional information layers combined with orthophotos (e.g., a hill shade), can be used as supplementary input to improve the quality of the result.

To conduct the land cover classification, the method of a manual image interpretation was applied. Contrasts, edges, lines, and colors are used to distinguish between and define individual polygons. However, this method also relies on the operator's visual and subjective decision-making behavior and interpretation skills (Albertz, 2007). In addition to the above-named characteristics, also a surface's brightness, shading and texture, the size and shape of objects, and the polygon's relative position need to be considered. The advantage of a manual interpretation, in contrast to semi-automatic or automatic classification methods is that complex assessment tasks can be performed without time-consuming post-processing of the results. This is of particular relevance in mountain regions, where due to the topographic preconditions increased shadow casts, small-area land class patches and hardly differentiable contrasts are present. However, for homogenous lowlands or big areas with similar characteristics (e.g., glaciers) automatic classifications are also of advantage due to a set of valuable support tools (Kääb et al., 2005).

Since the wilderness area Sulzbachtäler features a mountainous topology, the benefits of the manual interpretation outweigh the other possible methods.

3.1.2 Development of the Classification Key

Before the start of the classification process, a visual screening of the data set was performed to develop a classification key for the case study area's data. A classification key or interpretation key describes the systematic combination of areas with similar characteristics in one data set. These are grouped as one category in the process of the classification (Schneider, 1974). A classification key can either be based on land cover or land use categories or even a combination of both. The predefined classes were adopted and extended in the progress of the classification. The applied classification key is predominately based on the internationally recognized land cover classification CORINE Land Cover. This data set is seamlessly available for 39 European countries and consists of 44 different land cover classes including natural and anthropogenically influenced surfaces. The CORINE data have a minimum mapping unit of 25 hectares and the semi-automatically generated raster has a spatial resolution of 100 meters. The data set was last updated in February 2020 (Copernicus, 2021). However, in the case study area only six classes of the CORINE data set are represented: pastures, coniferous forests, natural grasslands, bare rocks, sparsely vegetated areas, as well as glaciers and perpetual snow (Copernicus, 2021). The available orthophotos and the target of this study allow and aim for a more precise classification, to identify additional land cover classes and furthermore ecosystem services. Therefore, the available CORINE data have not been used for this project's analysis, but rather twelve different land cover classes were identified and distinguished. The two-level, hierarchical structure of these land cover categories is depicted in Table 2. More detailed information to the individual classes and how they differentiate from each other is addressed in Chapter 4.1.

Table 2: Classification key of the land cover classification of the wilderness area Sulzbachtäler (source: own representation).

Level 1	**Level 2**	**Grid Code**
1. VEGETATION	1.1 Dense Forest	112
	1.2 Loose Forest, Shrubs and Bushes	123
	1.3 Grasslands and Open Fields	124
2. ROCKS	2.1 Bare Rocks	21
	2.2 Scree Fields and Gravel	22
	2.3 Transition Scree and Grassland	23
3. WATER BODIES	3.1 Water Bodies	31
	3.2 Water Courses	32
	3.3 Outwash Plains	34
4. GLACIERS AND PERPETUAL SNOW	4.1 Debris-Covered Glaciers	41
	4.2 Uncovered Glaciers	42
5. ANTHROPOGENIC REMAINS	5.1 Anthropogenic Remains	50

In the following chapters, the first level of the classification key's hierarchy is written in italic letters to reduce the risk of confusing the two levels, because of similar terminology. The mapping of the classification was conducted in the scale of 1:2,000. It should guarantee a precise enough differentiation between the individual classes to define the most essential available ecosystems.

3.2 Identification of the Underlying Ecosystem Services

After defining the individual land cover classes and conducting the land cover analysis, the mapped categories were assumed to represent the most essential ecosystems at the working scale of this thesis. This approach is described in the publication of Burkhard and Maes (2017). The next step involved the identification of the most essential local ecosystem services. A common method to select the key ecosystem services of a case study area is to conduct workshops and seminars with the local population and experts (Schirpke et al., 2021b). However, this process is extremely time consuming and exceeded the scope of this study.

Therefore, an alternative method was applied, and the most essential ecosystem services were derived from relevant literature. In this process, numerous scientific journal articles were identified and screened. These covered the individual ecosystems as outlined in Table 2. The main selection criterium was that the case study area of these publications was characteristically similar to the wilderness area Sulzbachtäler (i.e., located in mountain regions in temperate climates). For each ecosystem several studies were examined to derive the most relevant and widespread services. The results of the respective studies are considered as expert opinions relevant for this case study area. The services identified in this process were integrated to this master's thesis for further analysis.

Several scientific methods are available for application to evaluate to what magnitude the identified ecosystem services are available and how they are spatially distributed in the local ecosystems. A commonly applied approach involves the analysis of spatial matrices for each defined ecosystem service. For each service one or multiple specific indicators are selected that represent and describe its condition. For example, for the provisioning service timber, tree density and deforestation data could be applied as indicative data sets. Spatial data sets should preferably be available for these indicators, so they can be combined in a mapping tool to represent the distribution of certain ecosystem services in specific regions. To use this method would have been an obvious choice, as spatial data were this study's main data source. However, this approach implicates several uncertainties. First, limited data access or availability can restrict a comprehensive and complete ecosystem services analysis (Burkhard & Maes, 2017). Some data, such as detailed habitat maps, might not even be available in specific regions. Second, a lack of comparability arises, if data sets with different spatial and temporal resolutions are solely available for the case study area. This makes the modelling and combining of the data more complex and through the aggregation process of multiple data sets a new error source arises (Burkhard & Maes, 2017). Third, also seasonal adaptations of the environment to climatic preconditions need to be considered, when data sets are merged to one final assessment. Depending on the date of the data collection, for example water bodies might carry more or less water than the annual average (Burkhard & Maes, 2017). This affects the evaluation of the ecosystem services. Finally, certain ecosystems can be visualized and mapped easier than others. Data of provisioning and regulating services can more likely be represented through graphics and maps, while cultural ecosystem services cannot always be visualized (Burkhard & Maes, 2017).

Since the described method displays a number of limitations and the data availability for the wilderness area Sulzbachtäler was not given for each ecosystem service, an alternative method was applied. Each ecosystem service was rated according to an assessment scale derived from and based on the study published by Burkhard et al. (2009). They developed a matrix displaying each land cover class from the CORINE Land Cover data set on one axis and 29 different ecosystem services on the other axis. The intersections represent the capacities to provide one ecosystem service on a rated scale from 0 to 5 (Burkhard et al., 2009). For this study the scale was simplified to three instead of six different categories, because the accuracy of such a detailed categorization cannot be guaranteed without further data analysis. Furthermore, as not all ecosystems of this study, can be represented through a CORINE land cover layer, some of the ratings are based on the service's proportional availability in this ecosystem compared to other ecosystems. The results of this analysis are represented in detail in section 4.3.

3.3 A Survey on the Perception of Ecosystem Services in the Sulzbach Valleys

The following work step of this research framework was performed in the form of a self-administered questionnaire. A blank form of the questionnaire is attached in Appendix A. Due to the Covid-19 pandemic, it was decided that this method was most suitable, as visitors of the case study area did not need to talk to each other and could keep a comfortable distance if intended. The aim of this survey was to find out what visitors know about ecosystem services in the wilderness area Sulzbachtäler and which services they expect to find.

3.3.1 Structure of the Questionnaire

The questionnaire was structured into four separate sections. First, socio-demographic information (i.e., age, gender, education) was collected. Second, basic knowledge and information regarding the wilderness area (i.e., frequency and purpose of visit, traveling time from at home, basic knowledge about the wilderness area) was addressed. Third, questions that targeted topics related to protected areas in general, acceptance of and perceived knowledge about climate change as well as attitude towards consumption of regional products were added. The participants were asked to agree or disagree to the corresponding items on a 5-level Likert-scale (5 = totally agree; 1 = do not agree at all), but could also tick a box saying, “no answer”. The final two questions were stated as open questions, asking about the expected natural resources and natural features in this area. These items were partly selected or derived from literature. Brudermann et al. (2019) conducted a similar survey to assess the acceptance of wind parks in Austrian mountain areas. Their questionnaire’s format and content served as a model for this questionnaire’s layout. Moreover, the questions were prepared in the form of statements. Since the goal of this questionnaire is to evaluate, which ecosystem services are perceived by visitors close to the wilderness area, a descriptive-statistical analysis of the results is sufficient to achieve this objective. Therefore, not all items were derived from validated scales. Finally, the last section of the questionnaire included questions related to the individual ecosystem services available in the wilderness area Sulzbachtäler derived from the ecosystem analysis. Likewise, these items were phrased as statements and should be answered based on a 5-level Likert scale with the possibility to tick “never thought of this before”. The collected data of the questionnaires were further processed by applying the software IBM SPSS for statistical data analyses.

3.3.2 Preparation and Data Collection

The survey was conducted on September 2 and September 3, 2021. The target group of this study were visitors of the wilderness area Sulzbachtäler, which is accessible for hikers, and the local community. Before the performance of the questionnaire a pretest with participants of the possible target group was conducted, to test the understandability and the weighing of the items. As only a limited number of visitors enter the wilderness area due to the poorly developed hiking path network, people close to the border of the wilderness area in the Ober- and Untersulzbach Valley were asked to fill-in the self-administrated questionnaire. Since the respondents of this study partly were passing-by hikers with limited time to complete the survey, it consisted of one A4 double-sided page with 32 items and additional space to leave a short comment. The questionnaire was prepared in German and English, to also give international guests the chance to participate. Both versions are attached in Appendix A. Respondents who did not wish to fill in the questionnaire during their hike, were kindly asked to participate during their rest in the outdoor area of the Berndlalm or on the parking lot Hopffeldboden. The parking lot is commonly used as the starting point for hikes and is located at the entrance of the Obersulzbach Valley. Respondents, who did not complete the essential questions of the survey were excluded. In the end 114 questionnaires could be used for further analysis.

4 Results

In this section the results obtained during this master's thesis are introduced. First, the differences between the individual land cover classes defined in the course of the land cover analysis are outlined and explained. Second, the ecosystems derived from the remote sensing data analysis are presented and visually illustrated. Third, the findings about the local ecosystem services are displayed and the distribution of each ecosystem service in the wilderness area is graphically depicted. Finally, the results of the conducted survey are introduced and statistically analyzed to outline the visitors' perception regarding ecosystem services and the natural environment in the Sulzbach Valleys.

4.1 Differentiation Between the Ecosystems

As it was assumed that the defined land cover classes correspond to the local ecosystems, the descriptions of the land cover classes likewise represent the local ecosystems. The following sub-chapter introduces each land cover category in the chronological order of the classification key (see Table 2) and explains how it is distinguishable from the other land cover classes. To better understand the differences between the individual land cover categories visual examples were added to each category's explanation. The colors applied in these figures are coherent with the ones used for visualization in the overview map of the Sulzbachtäler, where the complete land cover classification is depicted. This map is attached in Appendix B.

Vegetation

The first division of the land cover classification features *Vegetation* (1). This category includes the following land cover classes: Dense Forest (1.1), Loose Forest, Shrubs and Bushes (1.2), as well as Grasslands and Open Fields (1.3). The first-named category Dense Forest includes coniferous and mixed forest, depending on the elevation level of the case study area. For the scope of this master's thesis, a dense forest with either type of vegetation can be considered as one ecosystem, therefore no differentiation between these two forest types has been made. This decision is supported by the results of a study published by Burkhard et al. (2009), which suggest that broad-leaved, coniferous, and mixed forests provide comparatively similar ecosystem services. For more details about the local vegetation, see Chapter 2.3. According to the CORINE land cover classification, the predominant parameter used for identifying the difference between land cover classes that are mainly covered with vegetation is the tree crown density (Copernicus, 2021). In this case it features more than 80%. Therefore, only small to no patches of grassland or rocks are visible in the applied remote sensing data of this category. This is also the main indicator how to differentiate this class from other vegetation classes. However, the dark green color and the treetop's texture are also important evidence for the classification process.

The class of Loose Forest, Shrubs and Bushes (1.2) includes small and loose tree populations of coniferous and broad-leaved trees, shrubs, and bushes. The trees of this category feature a lower density of tree populations (tree crown density < 80%) compared to category 1.1. Moreover, the height of representative trees is predominately lower than in the above-introduced land cover class. Numerous patches of grassland or rocks are visible between the tree crowns. Furthermore, this category also represents bushes and shrubs growing in dense populations. However, their similarity to loose woodland is the relatively low height of these bushes, such as dwarf mountain pine shrubs. These trees are found on the mountain slopes of the Sulzbach Valleys and only reach a height of 2 to 2.5 meters (Kosztra et al., 2019). Also damaged forest, which is regenerating from wind, snow avalanches or landslide processes, is added to this class. Furthermore, bushes and trees in the transitional stage are located in this category (Kosztra et al., 2019). This class does not include rocky areas or open fields and grassland. It can visually be recognized and differentiated from other classes due to the heterogenous texture, shapes and multiple shades of green. How the categories 1.1 and 1.2 are visually distinguishable, as shown in Figure 9a and Figure 9b.

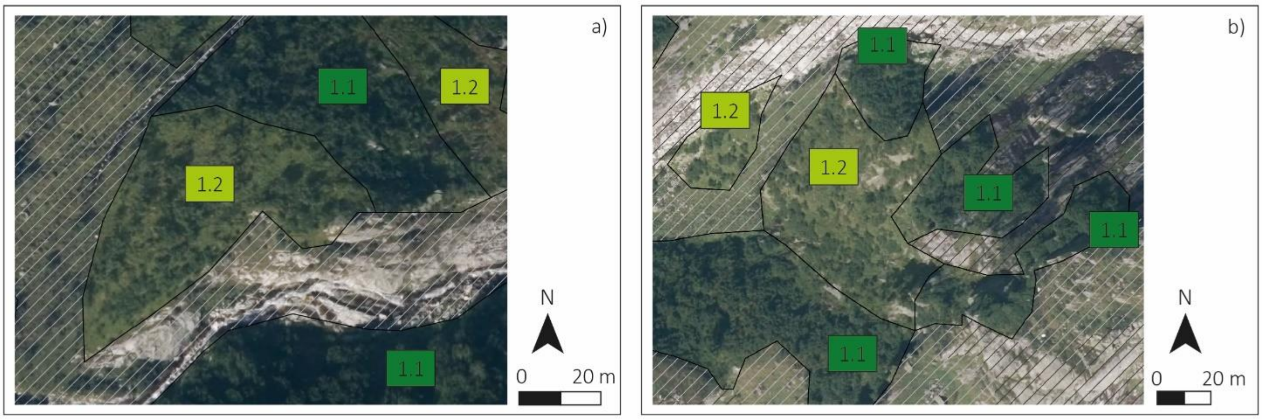


Figure 9: Two examples for the visual distinction between Dense Forest (1.1) and Loose Forest, Shrubs and Bushes (1.2). Both extracts, a) and b), show similar neighboring land cover classes. (source: own representation; data: SAGIS).

Grasslands and Open Fields form the final and most open category of the three vegetation classes. Two main types of grasslands can be found in the wilderness area Sulzbachtäler and are grouped together as one category. The first type represents alpine grasslands that feature a high biodiversity of local species (Kosztra et al., 2019). These meadows are located at lower elevation levels of the case study area. The other type is found at higher elevation levels in often rough, steep and uneven terrain. Due to the climatic conditions, these grasslands are not as rich in biodiversity as the former-described. This land cover category features herbaceous vegetation

(> 90%) predominately grasses and low bushes (e.g., alpine roses) with rocks and gravel (< 10%) or shrubs and trees (< 10%). The main characteristics are the large spatial extent and irregular shape, but homogenous texture (Kosztra et al., 2019). How this class can visually be differentiated is depicted in Figure 10a and Figure 10b.

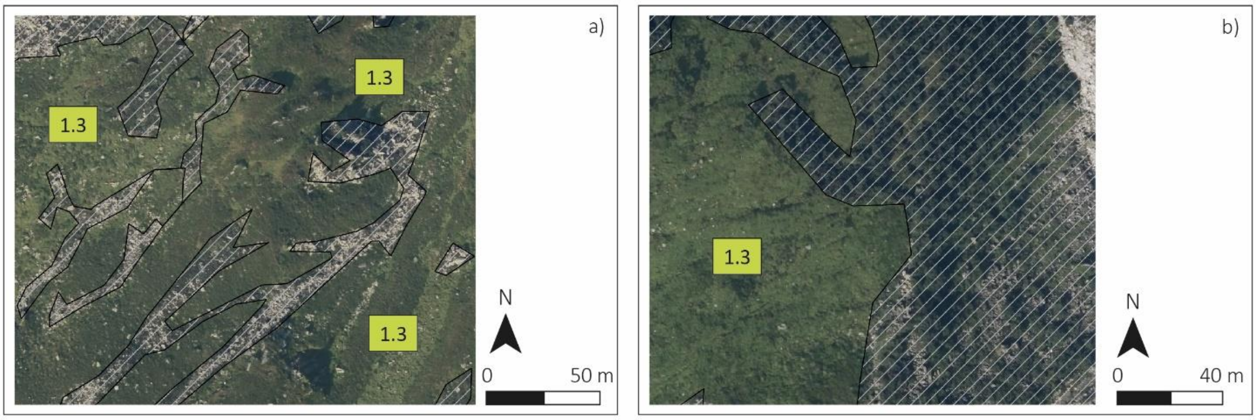


Figure 10: Two examples for the differentiation between Grasslands and Open Fields (1.3) and neighboring classes. a) The adjacent class consists predominately of Scree and Gravel (2.2). b) The neighboring categories consists mainly of Dense Forest (1.1) (source: own representation; data: SAGIS).

Rocks

The second category of the classification key is named *Rocks* (2). Three different classes are combined in this category: Bare Rocks (2.1), Scree Fields and Gravel (2.2) Transition Scree and Grassland (2.3), as listed in Table 2 . First, areas classified as Bare Rocks are only sparsely vegetated and at least 90% of the land surface is rock-covered. Slabs of rocks, cliffs and debris-covered rocks are part of this category. An example of the class and how it is distinguished is visualized in Figure 11a and Figure 11b. This class can be differentiated from neighboring classes due to its extensive occurrence of rocky material and particularly its texture. In some cases, it is hard to distinguish between class 2.1 and 2.2, because of the seamless transition between these two, as shown in Figure 11a. Above the tree line this class is more clearly identifiable, because it is not covered by treetops.

Second, Scree Fields and Gravel form another class of this category. In the CORINE land cover classification this class is combined with the above-described category (Copernicus, 2021). However, since these two classes predominately occur in the case study area, and they can be distinguished in their visual appearance, it was decided to develop two distinct categories. This class includes moraines, gravel beds, and gravel bars along river sides, as they are not represented in category 3.2 (see Figure 11a and Figure 11b). Sparse vegetation covers less than 15% of these areas. The angular texture of scree fields and the distinct color of gravel makes it simple to identify this category.

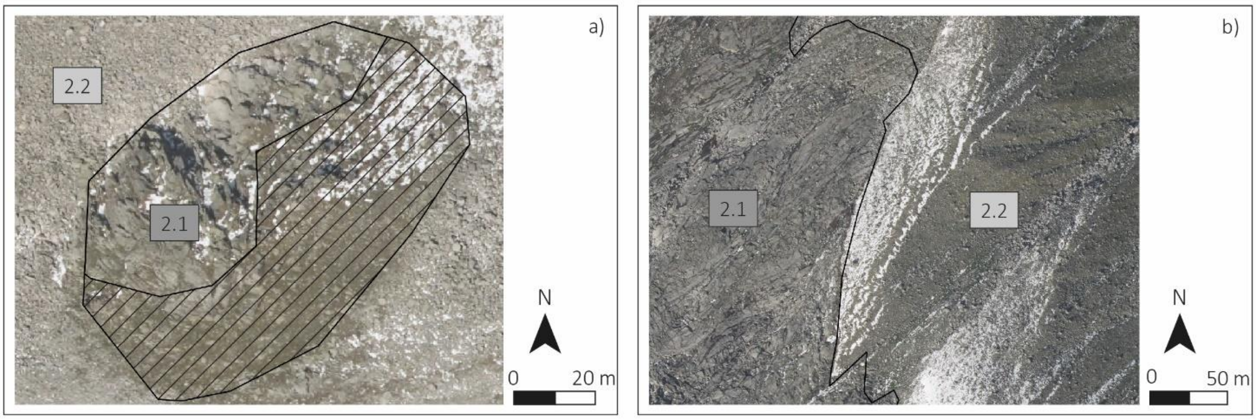


Figure 11: Two different examples for the visual distinction between Bare Rocks (2.1) and Scree Fields and Gravel (2.2). In a) the hachured land cover class represents Transition Scree and Grassland, while in b) no other land cover classes are depicted (source: own representation; data: SAGIS).

Third, a transitional class was defined. It represents the transitional zone between gravel and grasslands and is therefore called Transition Scree and Grassland. However, throughout the study area different ratios of stony areas combined with vegetation occur. Therefore, this category cannot be defined as straightforward as the other classes. Depending on the elevation level, this class might include areas with >70% gravel, rubble on steep slopes and scree fields combined with scattered high-altitude flora. While in lower regions more than 70% of sparsely vegetated land might be represented in the same category. The heterogenous texture of these areas helped to identify the class 2.3. Still, it can easily be distinguished from the other two classes, because of the high vegetation ratio, as illustrated in Figure 12a and Figure 12b.

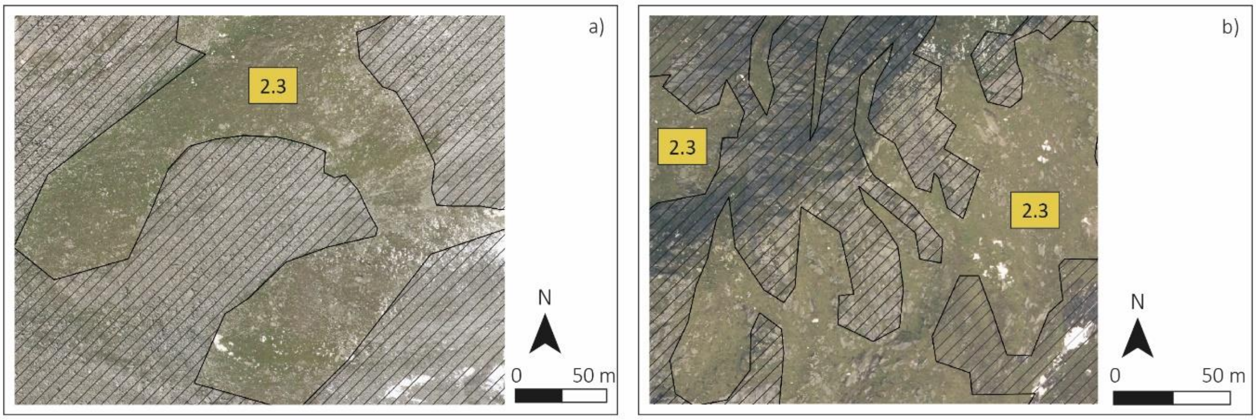


Figure 12: Two examples for the visual differentiation of the class Transition Scree and Grassland (2.3). a) Differentiation between category Transition Scree and Grassland (2.3) and Scree and Gravel (2.2). b) Differentiation between category Transition Scree and Grassland (2.3) and Bare Rocks (2.1) (source: own representation; data: SAGIS).

Moreover, also the differentiation from 1.3 is possible, as this class features a vegetation ratio of more than 80%. Not included in this class are regions with sparse forest of more than 10%. Even though, the land cover class Transition Scree and Grassland is comparatively proudly defined, it was still decided to not separate it into additional smaller categories for the purpose of the study.

Water Bodies

The category *Water Bodies* (3) is divided into three subcategories. Following classes are merged in this category: Water Bodies (3.1), Water Courses (3.2) and Outwash Plains (3.3). Areas covered with water at the time of the areal data collection are represented as Water Bodies (e.g., lakes and ponds) or Water Courses (e.g., alpine rivers, streams and braiding glacial rivers). The color of water bodies and their shape are the main characteristics how to distinguish these classes from others. Water Bodies can be differentiated from Water Courses based on their visual appearance. The shape of Water Bodies is extensive compared to line-shaped appearance of Water Courses. Furthermore, the visual movement of mountain rivers supports the differentiation between these two classes, as shown in Figure 13a. Water Bodies that are naturally connected to water courses are artificially separated from each other, based on a visual interpretation, since often no clear border between these classes is predefined. This is visualized in Figure 13b. Gravel bars along river sides are excluded from category 3.2, as they provide different ecosystems and ecosystem services.

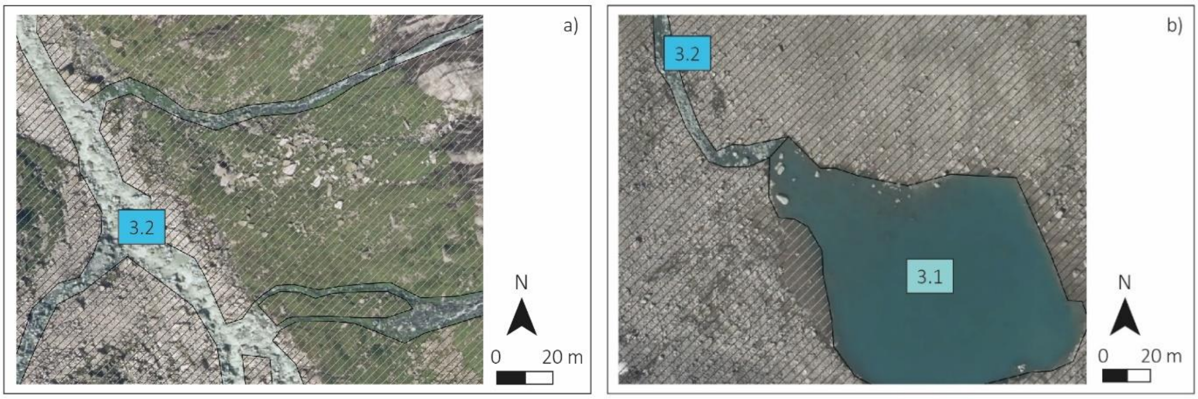


Figure 13: Two examples for the visual distinction between Water Courses (3.2), Water Bodies (3.1) and neighboring land cover classes. a) Visualization of Water Courses (3.2) and various other neighboring classes. b) Illustration of the transition from Water Bodies (3.1) to Water Courses (3.2) (source: own representation; data: SAGIS).

The third subcategory represents Outwash Plains. This class is included in the category of *Water Bodies* due to the dependence on streams to transport glaciofluvial sediments. Outwash plains are sedimental deposits located in proglacial areas. They are often located in topographically flat areas and the sediments are transported and deposited by braided river streams. Changing water levels caused by extreme events (e.g., floods) support the relocation of sediments and in the long-run generate outwash plains (Gornitz, 2009). Visually, these homogenous areas can easily be distinguished from the other classification categories, due to their proximity to water bodies and greyish color. A visualization of Outwash Plains is depicted in Figure 14.

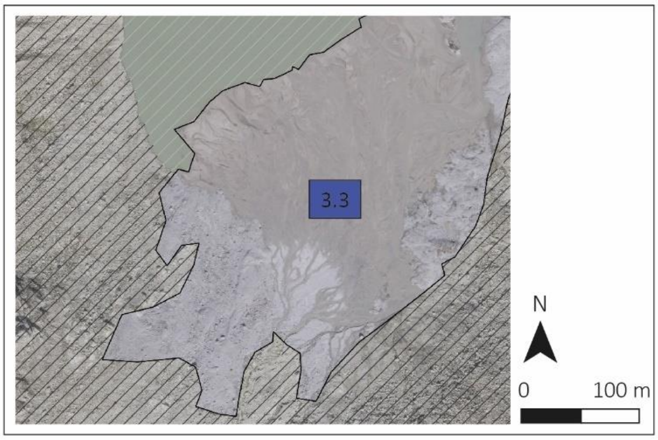


Figure 14: A visual distinction between Outwash Plains and neighboring classes. (source: own representation; data: SAGIS).

Glaciers and Perpetual Snow

Category 4 represents *Glaciers and Perpetual Snow*. Since the data of the applied orthophotos were collected in late August and early September little to no temporal snow cover is depicted, as this is also the perfect time to capture the minimum snow cover of the year. This category is divided into the subcategories Debris-Covered Glaciers (4.1) and Uncovered Glaciers (4.2). Debris-Covered Glaciers only occupy a small surface area in the wilderness area in comparison to Uncovered Glaciers. Uncovered glaciers are easy to detect and to distinguish visually. The reason for this is their distinctive bright color compared to other features located above the tree line.

Rock- and debris-covered glaciers are harder to detect because they are often directly connected to scree fields and gravel that do not have glacier ice as substratum. However, their proximity to visible glacier ice is often evidence for the classification. Examples for the distinction between Debris-Covered and Uncovered Glaciers is depicted in Figure 15a and Figure 15b.

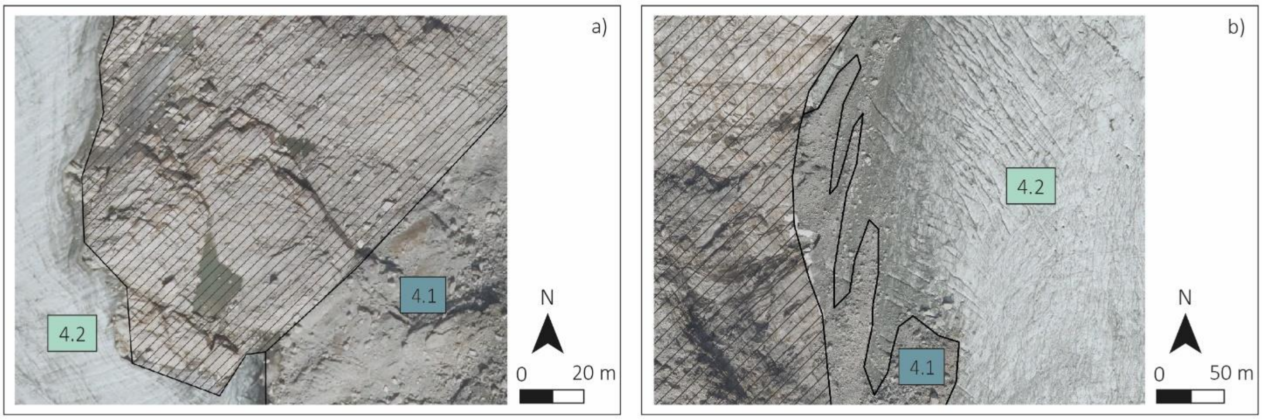


Figure 15: Visualization of the differences between Debris-Covered Glaciers (4.1) and Uncovered Glaciers (4.2), as well as the neighboring categories. In both examples, a) and b), the predominate neighboring classes are Bare Rocks (2.1) (source: own representation; data: SAGIS).

Anthropogenic Remains

Remains of anthropogenic activities (5.1) are only visually present at one spot in the Untersulzbach Valley. The stone walls and small shelters are traces of the formerly used grazing lands, as show in Figure 16. This category can easily be distinguished because of its distinctive human-constructed shape.

Figure 16: Visual distinction between Anthropogenic Remains and neighboring classes (source: own representation; data: SAGIS).

4.2 Distribution of the Ecosystems

The wilderness area Sulzbachtäler is located in an Alpine terrain and therefore, the distribution of the individual ecosystems heavily depends on the locally represented elevation levels. These and the corresponding climatic conditions that turn harsher with increasing elevation, influence the occurrence of local vegetation and wildlife.

In the overview map depicted in Appendix B, the extensive land cover classification is illustrated for the entire wilderness area Sulzbachtäler. The different colors represent the individual ecosystems. Appendix B illustrates that the ecosystems are related to the different elevation levels, as they are predominately represented along “elevation belts”. Below the tree line, which is on average located slightly above 2,000 meters a.s.l., Dense Forest forms the most prevalent ecosystem type. It counts 187.1 hectares (2.8%) of the wilderness area. While Loose Forest, Shrubs and Bushes can also be found in higher elevations up to 2,180 meters a.s.l. This class makes up 60.7 hectares (0.9%) of the protected region’s surface area and is one of the least represented ecosystems. The final vegetation class, Transition Scree and Grassland features 397.3 hectares (5.9%) and therefore is the most extensive and widespread ecosystem with a vegetated character. All in all, the ecosystems pooled in the category *Vegetation* barely represent 10% of the wilderness area’s total stretch of land.

Bare Rocks exist at any elevation in the case study area. However, the size of the individual patches increases with the rise in elevation level. This can be traced back to the fact that less vegetation is covering rocky areas at higher elevations, while this is not the case when the climatic preconditions are milder. With an absolute area of 1896.7 hectares (28.1%), this ecosystem features the greatest share in the wilderness area Sulzbachtäler. Scree Fields and Gravel form the second largest ecosystem type with 1,640.4 hectares (24.3%). Such as Bare Rocks, also this class can be found below and above the tree line, however, a larger share is located above it. The class Transition Scree and Grassland is also located at any altitudinal level, as it combines vegetation and rocks to one common ecosystem. Its absolute area counts 807.0 hectares (12.0%), and it is the fourth largest represented category of the wilderness area. Transition Scree and Grassland forms the final ecosystem type allocated to the category of *Rocks*, which in total feature the most dominant ecosystems in the case study area.

Glaciers and Perpetual Snow can only be found at an elevation approximately above 2,500 meters a.s.l., with one exception in the Untersulzbach Valley, where the glacier reaches down to 2,270 meters a.s.l. Together, Uncovered and Debris-Covered Glaciers almost form one fourth (23.9%) of the Sulzbach Valley’s area. However, Debris-Covered Glaciers represent a much smaller share with only 23.9 hectares (0.4%), while Uncovered Glaciers count 1,586.6 hectares (23.5%). This ecosystem is one of the fastest changing categories of the wilderness area when it comes to a decline in size. Due to the increasing annual temperatures caused by climate change, the surface area of glaciers is constantly decreasing.

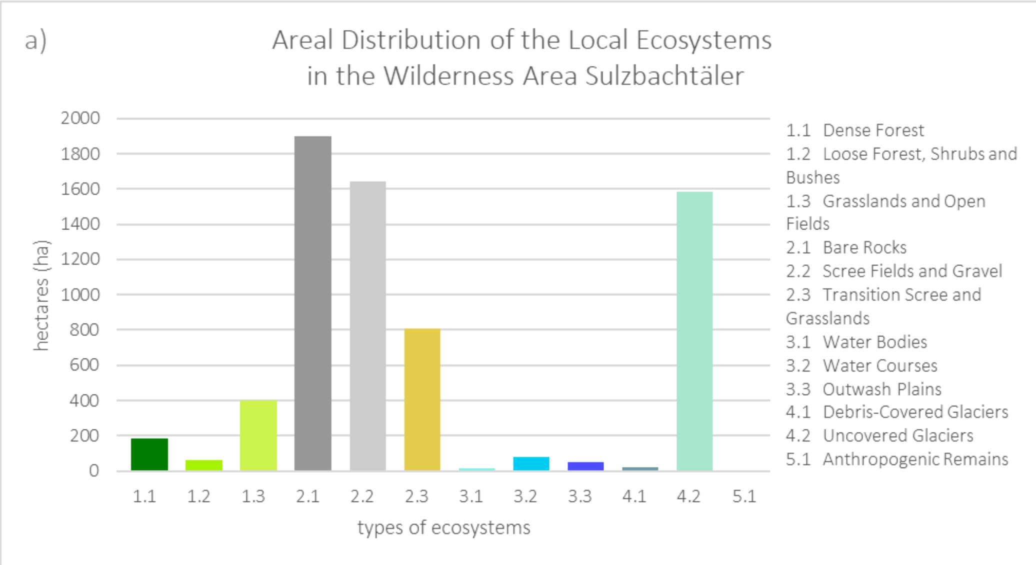
Water Bodies only cover a small area, featuring 16.2 hectares (0.2%), while rivers and streams (Water Courses) count 82.2 hectares (1.2%). The final land cover class that counts to the category of *Water Bodies* represents one of the least represented ecosystems in the wilderness area. Outwash Plains make up 49.2 hectares (0.7%). This ecosystem has the special characteristic that it can change its shape and size in short periods of time due to fluctuating water levels. Therefore, it is important to remember that this land cover analysis only represents a snapshot in time of the case study area. All in all, 2.1% of the wilderness area's stretch of land is temporarily or constantly covered with water.

The final ecosystem type features the rarely present human-shaped ecosystem. Anthropogenic Remains can only seldomly be found in wilderness areas, as generally no agricultural activities are allowed within its borders (Dudley, 2013). However, these remaining stone walls are the leftovers from the time prior the establishment of the wilderness area and can only be found at one specific location in the Untersulzbach Valley. They cover an area of 0.05 hectares (0.0007%) and form the smallest ecosystem represented in the case study area.

Table 3: Area size and percentual distribution of the local ecosystems in the wilderness area Sulzbachtäler (source: own representation).

ID	Name	Area (ha)	Share of total Area (%)
1.1	Dense Forest	187.1	2.8
1.2	Loose Forest, Shrubs and Bushes	60.7	0.9
1.3	Grasslands and Open Fields	397.3	5.9
2.1	Bare Rocks	1,896.7	28.1
2.2	Scree Fields and Gravel	1,640.4	24.3
2.3	Transition Scree and Grassland	807.0	12.0
3.1	Water Bodies	16.1	0.2
3.2	Water Courses	82.2	1.2
3.3	Outwash Plains	49.1	0.7
4.1	Debris-Covered Glaciers	23.8	0.4
4.2	Uncovered Glaciers	1,586.5	23.5
5.1	Anthropogenic Remains	0.05	0.0007

Table 3 depicts a summary of the individual ecosystem's sizes (in hectares) as well as the corresponding shares of the total surface area in percent. Furthermore, Figure 17 illustrates a graphical representation of the ecosystems' areal distribution. Each local ecosystem is shown in Figure 17a, while Figure 17b only visualizes the seven least represented ecosystems, as they can hardly be differentiated in Figure 17a. The colors of the bars correspond to the coloring of the maps depicting the local ecosystems. The bars are ordered in the same chronology as the land cover analysis' classification key. The upper graph clearly indicates that the ecosystem types 1.3, 2.1, and 2.2 as well as, 2.3 and 4.2 feature the largest represented shares and collectively cover 93.8% of the wilderness area Sulzbachtäler. The other seven classes, shown in the lower graph only represent the remaining 6.2% of the total case study's area.



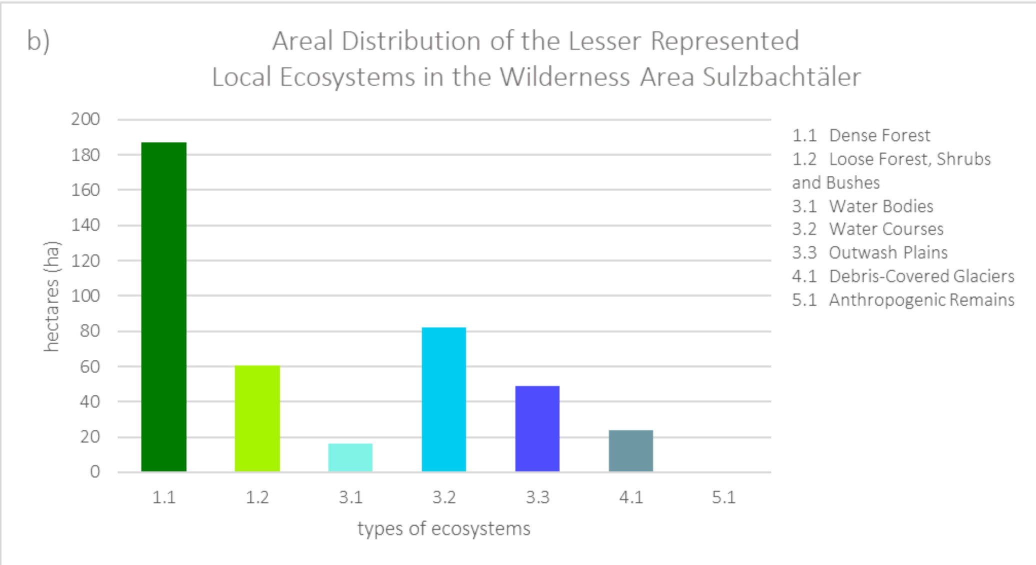


Figure 17: Distribution of the local ecosystems in the wilderness area Sulzbachtäler according to the land cover analysis. Based on remote sensing data from 2018. a) All local ecosystems compared. b) Zoom-in of the seven least represented ecosystems (source: own representation).

4.3 Ecosystem Services in the Sulzbach Valleys

Table 4 depicts the most relevant ecosystem services available in the wilderness area Sulzbachtäler as derived from relevant literature. In this sub-chapter the individual ecosystem services are introduced and the services' distribution within the wilderness area is displayed. The color code applied in Table 4 and Figure 18 to Figure 25 represents the 3-level rating scale. The rating scale is adopted based on Burkhard et al.'s (2009) study. It visualizes to what extent a specific ecosystem provides the identified ecosystem services compared to this service's availability in other ecosystems. Grey represents no availability of this service, yellow stands for a relevant provision and green features a high relevance of this service in the corresponding ecosystem.

Table 4: Matrix of the local ecosystem services' distribution in the wilderness area Sulzbachtäler based on the individual ecosystems. The color code features the services magnitude (grey = not available, yellow = relevant, green = highly relevant) (source: own representation).

Ecosystems/Land Cover Classes	Ecosystem Services								
	Regulating					Provisioning	Cultural		
	Pollination	Water Regulation	Biodiversity Conservation	Climate Regulation	Disaster Risk Reduction	Water Provision	Educational and Scientific Relevance	Recreation in Nature	Spiritual Value and Aesthetics
1.1 Dense Forest	green	yellow	green	green	green	grey	green	green	green
1.2 Loose Forest, Shrubs and Bushes	green	yellow	green	yellow	green	grey	green	yellow	green
1.3 Grasslands and Open Fields	green	yellow	green	green	green	grey	green	green	green
2.1 Bare Rocks	grey	grey	yellow	grey	grey	grey	green	green	green
2.2 Scree Fields and Gravel	grey	grey	yellow	grey	grey	grey	green	yellow	green
2.3 Transition Scree and Grassland	yellow	grey	green	yellow	yellow	grey	green	yellow	green
3.1 Water Bodies	grey	green	green	yellow	grey	green	green	green	green
3.2 Water Courses	grey	green	green	yellow	yellow	green	green	green	green
4.1 Debris-Covered Glaciers	grey	green	yellow	yellow	yellow	green	green	yellow	green
4.2 Uncovered Glaciers	grey	green	grey	green	yellow	green	green	green	green
5.1 Anthropogenic Remains	grey	grey	grey	grey	grey	grey	green	grey	green

Eleven types of ecosystems were derived that are essential for the ecosystem services analysis. In the course of this evaluation, the category of Outwash Plains (Table 3) is combined with the class Water Courses, as their provided services are tightly interlinked.

Based on literature, nine different ecosystem services could be derived that are available and of importance in the wilderness area Sulzbachtäler. Five regulating services, namely Pollination, Water Regulation, and Biodiversity Conservation, as well as Climate Regulation and Disaster Risk Reduction could be identified. Furthermore, only one provisioning service, Water Provision was detected in the wilderness area Sulzbachtäler. Moreover, Educational and Scientific Relevance, Recreation in Nature as well as the service Spiritual Value and Aesthetics were recognized as cultural services.

According to the data derived from the ecosystem services analysis, the availability of certain services is higher compared to others and not every service is available in each ecosystem. Furthermore, certain ecosystems feature a greater number of services, while others do not contribute with a variety of aspects to humans' well-being. A numeric overview of Table 4 is illustrated in Table 5. It shows that particularly cultural services are of high relevance, even though Spiritual and Aesthetic Value show lower values compared to the other two available services. Nevertheless, this spatial analysis revealed that also the regulating service Biodiversity Conservation is relevant in 52.8% and highly relevant in additional 23.7% of the wilderness area. 47.6% of the total case study area provides Climate Regulation and 47.3% Disaster Risk Reduction (summed up values from relevant and highly relevant). The two services linked to hydrological aspects, Water Regulation and Water Provision are each of high relevance in more than one quarter of the case study area, 25.8% and 26.1%, respectively. The least provided service in the Sulzbach Valleys is Pollination which is available in 21.5% of the area.

Table 5: Distribution of the individual ecosystem services available in the wilderness area Sulzbachtäler according to the individual services in percent (source: own representation).

Ecosystem Services	not available (%)	relevant (%)	highly relevant (%)
Pollination	78.5	12.0	9.5
Water Regulation	64.6	9.6	25.8
Biodiversity Conservation	23.5	52.8	23.7
Climate Regulation	52.4	15.4	32.2
Disaster Risk Reduction	52.7	37.7	9.6
Water Provision	73.9	0.0	26.1
Educational and Scientific Relevance	0.0	0.0	100.0
Recreation in Nature	0.0	37.5	62.5
Spiritual and Aesthetic Value	0.0	0.0	100.0

Pollination

Pollination belongs to the important regulating services in the wilderness area Sulzbachtäler. Forests and grasslands, as well as loose woodlands, shrubs and bushes provide a habitat for insect populations such as bumblebees and honeybees, which are known as wild pollinators (Burkhard & Maes, 2017; Lamarque et al., 2011; Zhao et al., 2020). To a certain extent the ecosystem type Transition Scree and Grassland also offers a living space for pollinating species (Burkhard et al., 2009; Burkhard & Maes, 2017). These insects are able to pollinate plant species that depend on insect pollination. Therefore, this process enhances the preservation of species richness and furthermore, contributes to an increase in crop (IPBES, 2019; Zhao et al., 2020). At the monitoring site close to Aschamalm in the Untersulzbach Valley, an ecological monitoring was conducted between 2016 and 2020. It covers the period before and after the establishment of the wilderness area. The study revealed that the number of plant species increased from approximately 80 different to more than 150 species (Aigner, 2020). This rise in number is certainly linked to the withdrawal of grazing animals, as stated in the study report (Aigner, 2020). However, it can also be linked to the presence of local pollinators. Farmers outside the borders of the wilderness area benefit from a rise in yield.

Within the borders of the wilderness area, in 12.0% of the area, the regulating service Pollination is relevant, while it is highly relevant in 9.5% of the area. The spatial distribution of this ecosystem service is depicted in Figure 18. Since this service is closely connected to the presence of vegetation, it is only available up to approximately 2500 meters a.s.l.

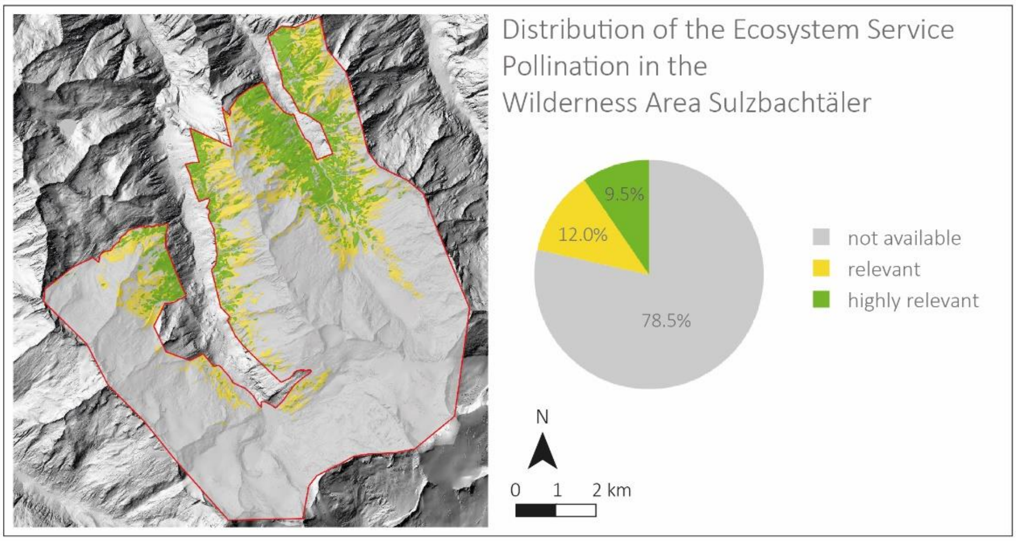


Figure 18: Distribution of the ecosystem service Pollination in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

Water Regulation

Water Regulation is the next regulating ecosystem service introduced, available in the Sulzbach Valleys. It is strongly affected by the presence of vegetation, the space to prevent floods or the ability to store water (Burkhard & Maes, 2017; Jenkins & Schaap, 2018; Tiel et al., 2020). In the case study area glaciers form one of the major water regulating bodies. The glacier compensation effect outbalances runoff fluctuations, as glaciers provide more runoff in hot and dry periods, while less runoff is recorded during periods of cold weather and high precipitation. This effect is of relevance in the wilderness area, but the consequences are also visible further downstream in rainfall dominated runoff regimes (Lamarque et al., 2011; Tiel et al., 2020). Therefore, the ecosystems Debris-Covered Glaciers and Uncovered Glaciers regulate the water flow.

Furthermore, rivers, streams and adjacent outwash plains contribute to the local flood regulation. Outwash plains are only completely flooded when the runoff is above average, such as during periods of high precipitation or melt periods. Therefore, they are essential contributors to the local water regulation. Also water bodies contribute to this service during melt periods, as their storage capacity prevents floods in lowland regions (Schirpke et al., 2021b).

Next, ecosystems with a predominate vegetation cover, such as Grasslands and Open Fields, Forests, as well as Loose Woodlands Shrubs and Bushes are also important for the regulation of local and regional water discharge (Jenkins & Schaap, 2018; Lamarque et al., 2011; Millennium Ecosystem Assessment, 2005).

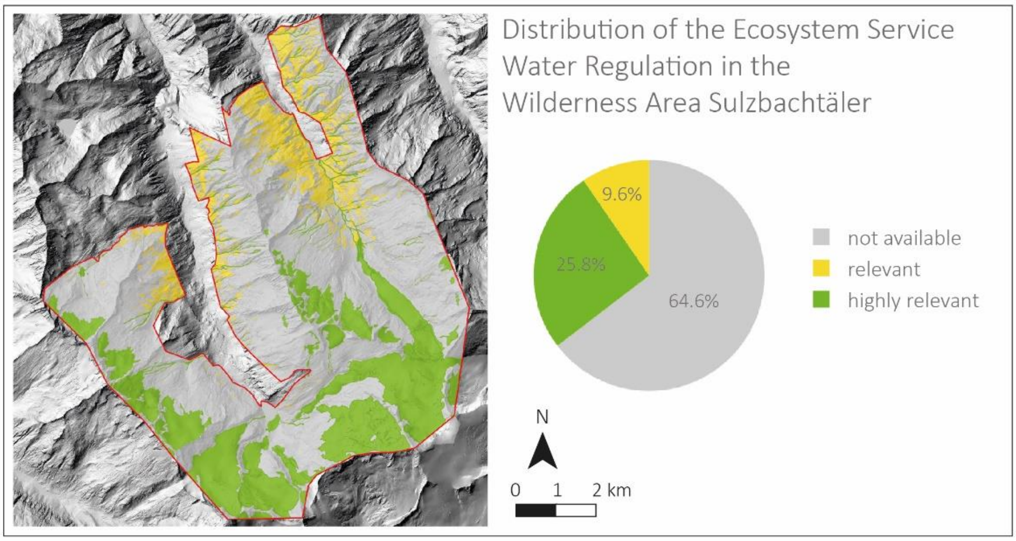


Figure 19: Distribution of the ecosystem service Water Regulation in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

These ecosystems can filter pollutants out of the groundwater and influence the surface runoff. Moreover, they contribute to the groundwater recharge (Jenkins & Schaap, 2018; Zhao et al., 2020) and provide the close surrounding with a sufficient amount of water, while at the same time regulating the flood regime (Burkhard & Maes, 2017). Additionally, the water regulation of the population in adjacent lowlands, rely on the water regulation in mountain regions (Pătru-Stupariu et al., 2020). When water regulation is not working properly, the chance for floods or droughts increases (Burkhard & Maes, 2017).

In the wilderness area Sulzbachtäler, the service Water Regulation is highly relevant in 25.8% of the area. In additional 9.6%, this ecosystem service is relevant. Figure 19 illustrates the distribution of this service.

Biodiversity Conservation

Several ecosystems encompass the ability to promote Biodiversity Conservation, which is another regulating ecosystem service provided by the wilderness area. The conservation of species richness includes manifold aspects and life forms, implicating local plants and wildlife, as well as micro-organisms. It promotes the health and resilience of local ecosystems. Moreover, its lack leads to a negative feedback loop that results in an instability of ecosystems and a loss of biodiversity (Jenkins & Schaap, 2018). Depending on the ecosystem, life on land or in the water is supported by this service. It provides appropriate habitats and sufficient nutrition for local species (Schirpke et al., 2021b). A heterogenic structure of ecosystems (e.g., alpine forests and meadows) and high-quality components (e.g., high water quality of rivers) promote the functioning of ecosystems (Blattert et al., 2017; Jenkins & Schaap, 2018). However, also ecosystems with little organic matter, such as bare rocks or debris-covered glaciers can provide habitats for specific plants or animals. The positive effect of Biodiversity Conservation is supported by the results of the monitoring study close to Aschamalm, where an increase in species richness could be recorded during the period 2016 and 2020 (Aigner, 2020).

Dense Forest, Loose Forest, Shrubs and Bushes, as well as Grassland and Open Fields significantly contribute to this service in the wilderness area Sulzbachtäler. The same applies to the ecosystems Transition Scree and Grassland, Water Bodies and Water Courses. In these ecosystems the availability of this services is highly relevant. The connecting link between these ecosystems is their heterogenic structure. They amount to 23.7% of the case study area, as depicted in Figure 20. While Bare Rocks, Scree Fields and Gravel, as well as Debris-Covered Glaciers consist of less diverse components, this service is also relevant in these ecosystems (52.8%). They also provide habitats for certain plants and wildlife.

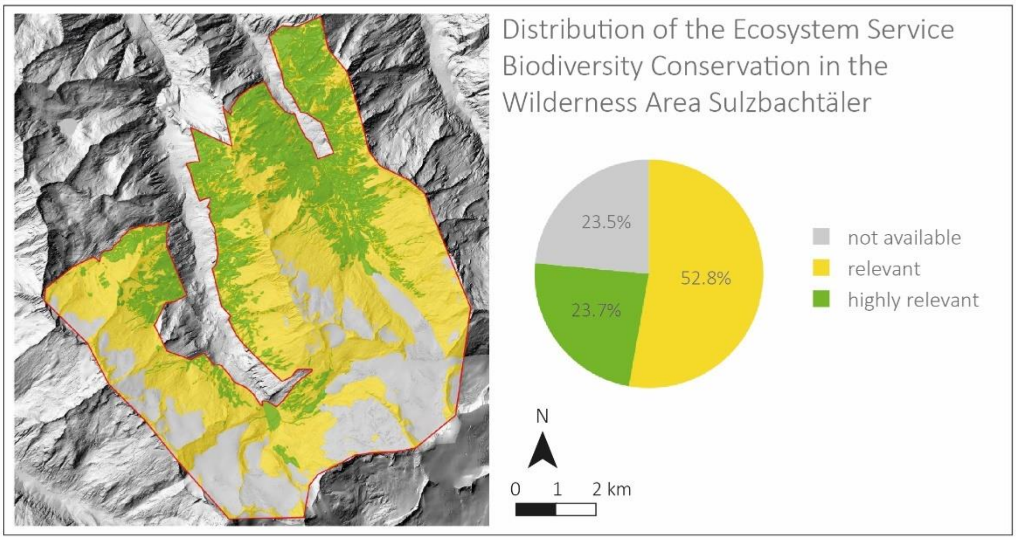


Figure 20: Distribution of the ecosystem service Biodiversity Conservation in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

Climate Regulation

The next regulating service available in the wilderness area Sulzbachtäler is named Climate Regulation. It consists of numerous different parameters that have an influence on the global and local extent. Through the regulation of air and surface temperatures, atmospheric conditions (e.g., the GHG effect and the ozone layer) and carbon sequestration, to name some of this service's components, climate is regulated to a certain scale (Burkhard & Maes, 2017; Constanza et al., 1997). This ecosystem service is particularly important for climate change mitigation and reveals the best outcome in natural, undisturbed ecosystems.

Trees, forests, grasslands, as well as glaciers and water bodies help to regulate local temperatures and former is also able to filter polluting particles from the air (Burkhard & Maes, 2017; Lamarque et al., 2011; Zhao et al., 2020). Forests, grasslands, and glaciers are known as important carbon sinks (Jenkins & Schaap, 2018; Zhao et al., 2020) and plants even convert CO_2 from the atmosphere to oxygen (O_2) (Jenkins & Schaap, 2018). Furthermore, carbon sequestration is another relevant part of this ecosystem service and can be found in local forests and grasslands (Blattert et al., 2017; Jenkins & Schaap, 2018; Zhao et al., 2020). Even though the carbon stocks of grasslands are smaller than the ones of forests, their areal distribution exceeds latter and has therefore a certain effect. Still, the productivity of these ecosystems decreases with an increase in elevation (Blattert et al., 2017).

Above the tree line other components support climate regulation. For example, the high surface albedo of glaciers and certain types of light rock results in a high reflection of solar radiation. However, this effect decreases drastically with glacial retreat (Zhang et al., 2021). Furthermore, in alpine areas the high albedo is supported by long lasting seasonal snow covers.

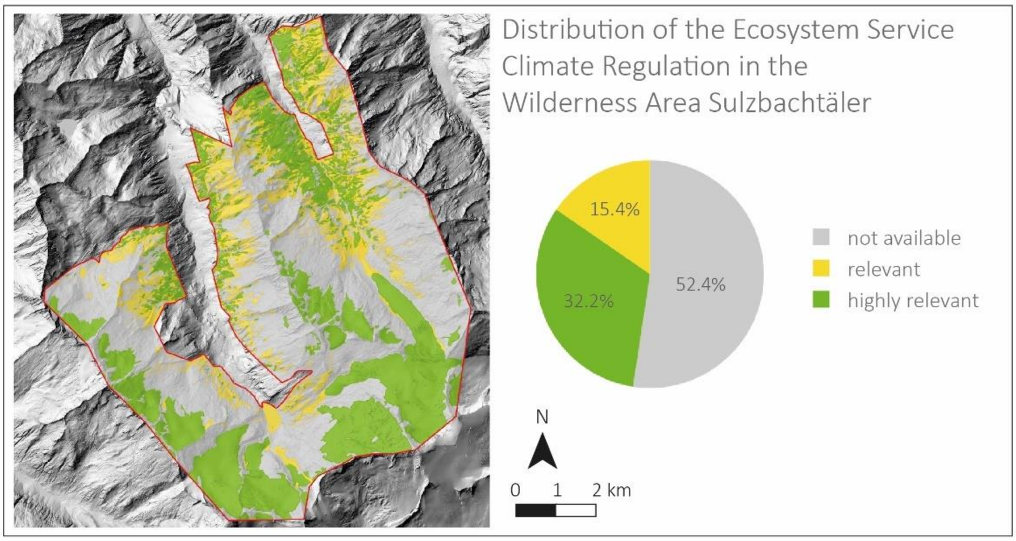


Figure 21: Distribution of the ecosystem service Climate Regulation in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

In the case study area Climate Regulation is relevant in the following ecosystems: Loose Forest, Shrubs and Bushes, Transition Scree and Grassland, as well as Water Bodies and Water Courses. These make up for 15.4% of the area (see Figure 21). Dense Forest, Grasslands and Open Fields, as well as Uncovered Glaciers represent highly relevant ecosystems regarding the provision of the service Climate Regulation and cover an area of 32.2%.

Disaster Risk Reduction

The final regulating service available in the case study area is called Disaster Risk Reduction and combines any kind of natural elements that reduce the risk of natural hazards. In Alpine regions, natural hazards are often related to mass movements, such as snow avalanches or different types of landslide processes (Schirpke et al., 2013). The hazard of these is influenced by numerous basic conditions (e.g., steepness of the slope, aspect, and vegetation cover). Moreover, the root network of grasslands and forests plays an important role in reducing the possibility for soil erosion and landslides. This also includes the ecosystem Loose Forest, Shrubs and Bushes (Burkhard & Maes, 2017; Schirpke et al., 2013; Zhao et al., 2020). The chance for natural hazards in the form of landslide processes is further minimized by forests' natural buffers and other higher growing vegetation. Furthermore, they also absorb water and reduce the chance for floods (Blattert et al., 2017; Glushkova et al., 2020; Jenkins & Schaap, 2018). Forests are therefore a more ecologically friendly and cost efficient alternative to technical protective measures (Blattert et al., 2017). Moreover, glaciers form a long-lasting terrain cover, which stabilizes the rocky material underneath and therefore also reduces the possibility for landslide processes. Finally, water courses reduce the chance for floods, since outwash plains surrounding rivers are able to provide space for additional runoff.

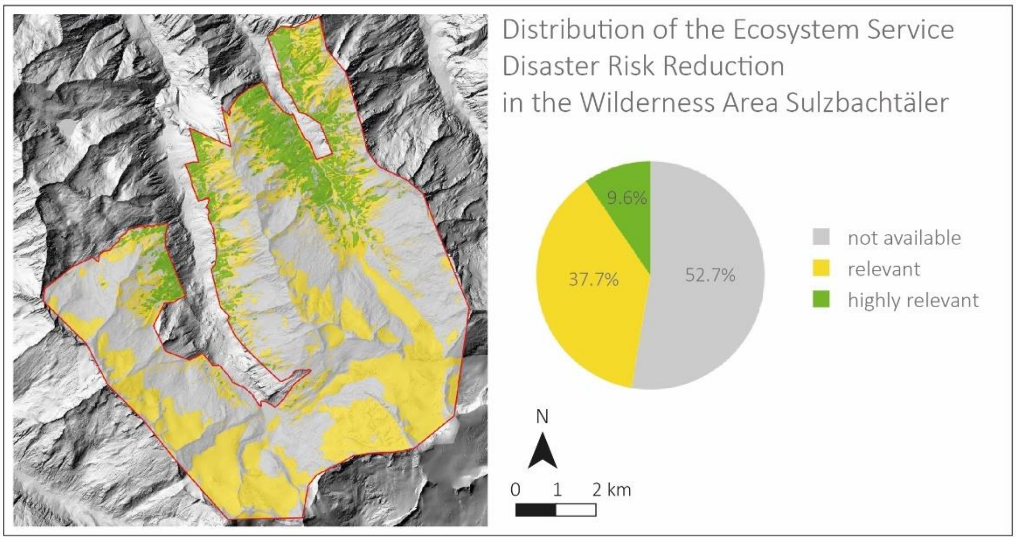


Figure 22: Distribution of the ecosystem service Disaster Risk Reduction in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

In the wilderness area Sulzbachtäler the availability of the ecosystem service Disaster Risk Reduction is relevant in 37.7% of the area, while it is highly relevant in additional 9.6%. The distribution is illustrated in Figure 22.

Water Provision

The only provisioning service available in the wilderness area Sulzbachtäler is provided as Water Provision. It refers to the supply of surface water for drinking and non-drinking purposes (e.g., energy production) (Burkhard & Maes, 2017; Schirpke et al., 2021b). The case study area mainly provides people outside the borders with drinking water. For example, the Kürsinger Hütte, a highly frequented Austrian Mountain Club cabin located at the border of the wilderness area in the Obersulzbach Valley, draws its demand of water from the wilderness area.

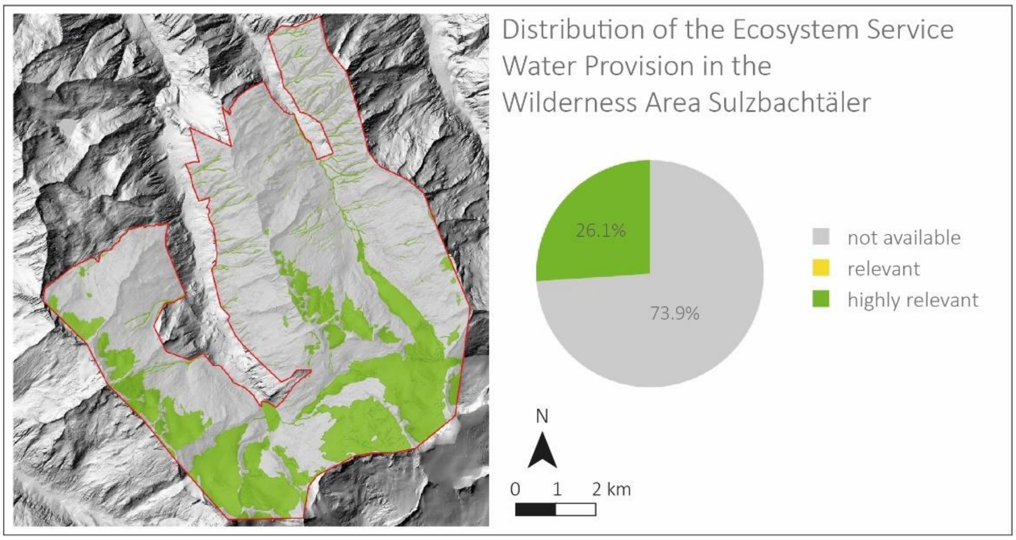


Figure 23: Distribution of the ecosystem service Water Provision in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

Water Bodies, Water Courses, as well as Debris-Covered and Uncovered Glaciers provide water in the wilderness area Sulzbachtäler. These ecosystems, where this service's availability is highly relevant, contribute 26.1% to the complete surface area, as shown in Figure 23. In this case, no other ecosystems can provide this service to another extent based on the applied methods, therefore no qualitative differentiation can be made.

Educational and Scientific Relevance

Educational and Scientific Relevance is one of the derived cultural services provided by the wilderness area Sulzbachtäler. This service refers to the possibility to use the environment's natural features to support scientific research or educational projects. Education does not need to take place on site, but photos and data can also be applied in classroom settings. It is hard to measure and evaluate the educational or scientific value of a specific area, as it depends on the people’s interests and the specific scope of scientific studies. However, the inspection of local fauna, flora and environment (e.g., bird watching and field courses) is a possible educational and scientific activity practicable in the Sulzbach Valleys. Due to the impossible precise differentiation between the individual ecosystems regarding the service Education and Scientific Relevance, 100% of the area are viewed as important landscapes for educational and scientific activities (see Figure 24).

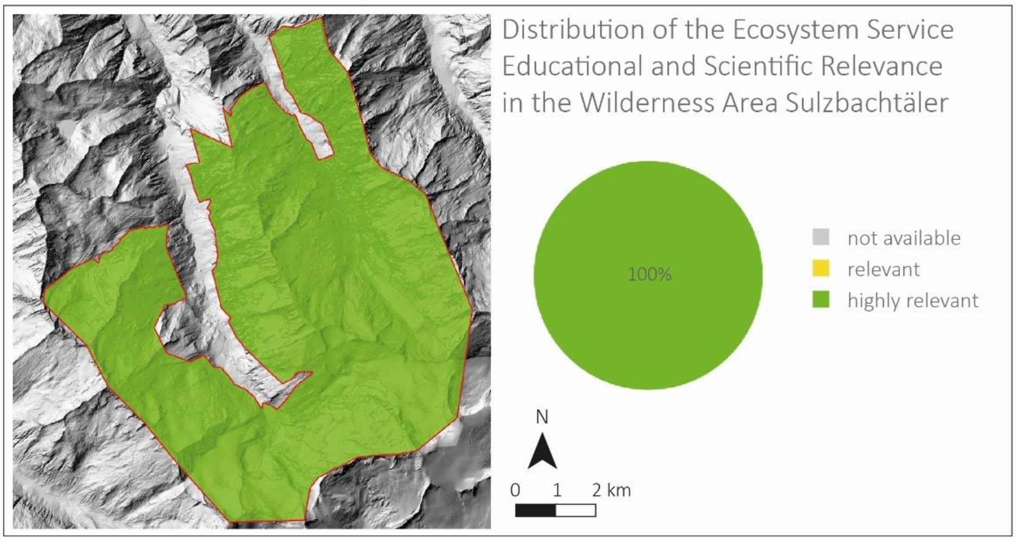


Figure 24: Distribution of the ecosystem service Educational and Scientific Relevance in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

This is the case, because for educational and scientific purposes the spot does not need to be visited, but an observation from a distance also falls into this category. Moreover, the spatial patterns of various ecosystems represent a value by themselves, as they display aspects such as elevational gradients or the successional stages of the glacier forefield, highly important for integrated research and education.

Recreation in Nature

Recreation in Nature is a manifold cultural service, since it combines sports and relaxing activities that can be performed by visitors of the wilderness area “as physical interaction with the natural environment” (Haines-Young & Potschin, 2018, p. 1; Schirpke et al., 2021b). This can include hiking, mountaineering, climbing and observing local wildlife, to name some examples (Blattert et al., 2017; Jenkins & Schaap, 2018). Despite the limited accessibility of certain regions of the wilderness area, which are consequently not suitable for recreational activities (e.g., Scree Fields and Gravel or Debris-Covered Glaciers) people enter it with the aim to experience nature and alpine landscapes. Therefore, in these hardly accessible ecosystems, this service is only present, but not important. The only ecosystem that does not feature Recreation in Nature is Anthropogenic Remains, as this ecosystem is only located at one single spot, which is hard to access.

Within the borders of the wilderness area Sulzbachtäler, in 37.5% of the area, the ecosystem service's provision is relevant, while additional 62.5% of the area represent highly relevant availability to perform recreational activities. The distribution of the service is illustrated in Figure 25.

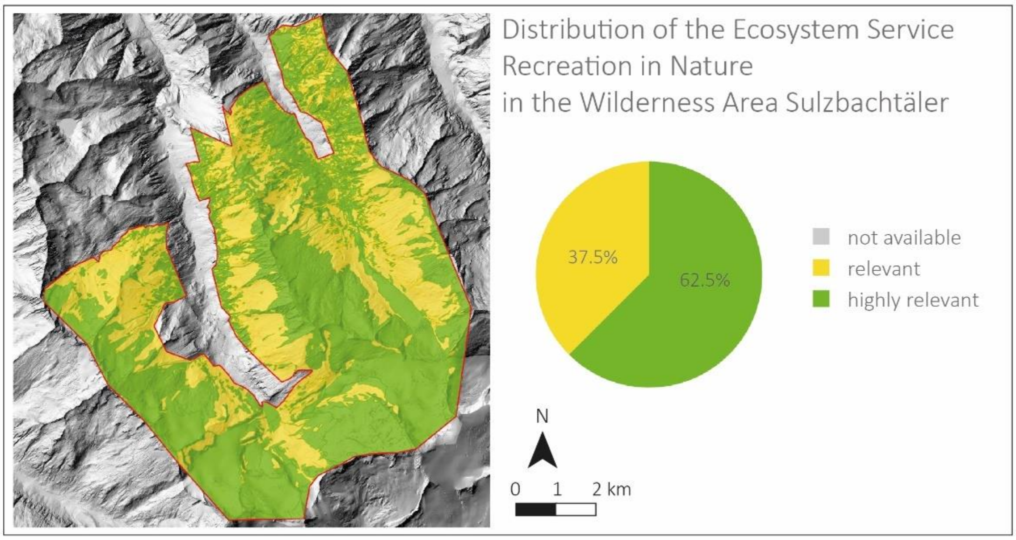


Figure 25: Distribution of the ecosystem service Recreation in Nature in the wilderness area Sulzbachtäler. Graphical representation of the distribution (left) and relative values (right) (source: own representation).

Spiritual Value and Aesthetics

Spiritual Value and Aesthetics forms the final category of cultural services in the wilderness area. It refers to the synergy of environment and culture, as well as "characteristics […] that enable aesthetic experiences" (Haines-Young & Potschin, 2018, p. 1). This service is particularly hard to analyze in a qualitative, let alone quantitative way, as it highly depends on the subjective perception of an individual. Still, the scenic beauty of mountains offers a service supply that is linked to local cultural traditions and attracts visitors. This also applies to the wilderness area Sulzbachtäler. Similar to Educational and Scientific Relevance, this cultural service is also highly relevant in 100% of the area, due to the above-described reasons.

4.4 Perception and Expectations of Ecosystem Services

This sub-chapter introduces the results of the questionnaire. First, the demographic information of the respondents is outlined, followed by background information concerning the frequency of visits and reasons for the stay. Second, results about the participants' acceptance rate regarding protected areas and climate change are stated as summarized in Table 6. Finally, the outcome of the survey dedicated to the ecosystem services in the wilderness area is presented.

Table 6 depicts the demographic information of the survey's sample. These data revealed that of the total number of participants (*n = 114*), 56 (49.1%) male and 58 (50.9%) female respondents filled in the survey. This reflects an almost even distribution of gender. Regarding the self-reported highest completed education level, the majority of participants (45.6%) completed a university degree, followed by 29.8% who named high school and vocational/technical schooling (13.2%) as their highest level of education. The average age of all participants is 49 years, while the youngest respondent was 12 years old and the oldest 84 years.

Table 6: Demographic and background information of the questionnaire's respondents (source: own representations)

Gender (*n* = 114)		**Age (*n* = 114)**		**Education level (*n* = 108)**		**Frequency of visit (*n* = 113)**	
Male	56 (49.1%)	Mean	49.3	University	52 (45.6%)	First time today	55 (48.2%)
Female	58 (50.9%)	Max	83	High School	34 (29.8%)	1-2 times per year	47 (41.2%)
		Min	12	Apprenticeship	15 (13.2%)	Several times per year	11 (9.6%)
				Mandatory school	7 (6.1%)		
Driving distance to residence (*n* = 114)				**Reason for visiting the area (*n* = 114, multiple answers possible)**			
< 1h	32 (28.1%)			Sports activities	72 (36.9%)		
1-2h	20 (17.5%)			Recreation	83 (42.0%)		
> 2-4h	17 (14.9%)			Culinary reasons	12 (6.2%)		
> 4h	45 (39.5%)			Interest in local flora and fauna	26 (13.3%)		

48.2% of the participants visited the Sulzbach Valleys for the first time, when they filled in the survey. While 41.2% visit the area more regularly (i.e., once, or twice a year). More frequent visits only make up the smallest number of responses (9.6%). The majority of respondents (54.3%) need more than 2 hours to reach the parking lot Hopffeldboden at the entrance of the Obersulzbach Valley. The most often mentioned reason for the visit was recreation (42.0%), followed by sports activities (36.9%), while culinary reasons were less frequently mentioned. The participants of the survey were also asked to state if they have heard about the wilderness area Sulzbachtäler, before attending this survey. The data revealed that most respondents (60.5%) have not heard about the wilderness area before their participation. However, this was not a reason for being excluded from the survey, as the ecosystem services available at the borders of the wilderness area can either be compared to the ones available within its borders or are provided by the case study area and can also be used outside its borders (e.g., water provision). How the participants, who have heard about the wilderness area before, received their knowledge varied. Almost one quarter (24.6%) knew about it from friends and 14.9% read about it online. Others named the information center of the Nationalpark Hohe Tauern, their hiking guide or the school as the medium, where they had heard about the wilderness area first.

An overview of the statistical output of chosen items in represented in Table 7. The abbreviation ‘PA’ used in the table for space-saving reasons, stands for ‘protected areas’. All in all, a high acceptance for protected areas can be derived from this survey's sample, as 60.5% of the respondents consciously visit areas with environmental protection. Mainly protected areas and national parks in Austria with a dominance of valleys and places in the Nationalpark Hohe Tauern (e.g., Habachtal, Innergschlöß) were named, in addition to regions in Germany (e.g., Nationalpark Bayerischer Wald, natural reserve Teutoburg Forest). Moreover, 84.9% of the respondents stated that they believe it is good that parts of landscapes are protected. Furthermore, the importance of the protection of rare species and their habitat is widely agreed on by the participants of the survey (83.3%). However, it cannot be said that the majority of respondents enjoys nature more in areas with environmental protection than without, since this statement reflects an acceptance rate of only 2.3 (Standard Deviation (SD) =1.1) on a 5-level Likert-scale. The acceptance rate represents the mean of the individual item’s responses (1=totally agree, 5= not agree at all). As this number reflects the average score of the respondents’ answers, without the participants who indicated that they had not thought about this statement before or did not want to respond, the acceptance rate (i.e., mean) depicts a meaningfulness in terms of how the respondents' overall basic attitude is towards each item.

Table 7: Mean and standard deviation of the questionnaire's responses for chosen items. The sample size (n) varies because some respondents consciously chose to answer with 'no answer' or 'never thought of this before' and are therefore excluded from statistical analysis (source: own representation).

Items	**Mean**	**Standard Deviation**	**Sample Size (*n*)**
conscious visits of PA	1.4	0.5	114
greater enjoyment of nature in PA	2.3	1.1	112
approve environmental PA	1.1	0.4	110
approve species and habitat protection	1.2	0.6	113
approve human-induced climate change	1.6	0.9	111
feel well informed about climate change	2.3	1.0	110
conscious consumption of regional products	2.1	0.9	113
reg. products for climate change mitigation	1.6	0.7	112
humans benefit from nature	1.4	0.6	112
protected areas benefit humans	1.4	0.6	112
perceive water quality as high	1.4	0.7	106
perceive vegetation as hazard protection	2.2	0.9	99
perceive vegetation as climate balance	1.4	0.6	111
perceive glacier as water resource	1.4	0.6	108
perceive springs as water supply	1.5	0.9	111
perceive educational relevance	1.6	0.7	113
perceive spiritual value	2.3	1.3	94
perceive recreational possibilities	1.1	0.4	111
perceive value for health	1.4	0.6	112
perceive value for sports	1.3	0.5	113

PA … protected areas

Still, the survey results reveal that protected areas, such as national parks and wilderness areas, strongly benefit the population according to two thirds of the respondents (66.7%) who totally agree, while additional 28.1% agree. Concerning climate change the survey's participants support the statement that anthropogenically induced climate change exists (mean=1.6, SD=0.9). Concurrently, the opinion regarding personal knowledge about climate change is moderate (mean=2.3, SD=1.0).

Figure 26: Word cloud generated based on expected natural features in the Sulzbach Valleys named by the survey's respondents. The size of the words is indicative of the relative frequency of its occurrence (source: own representation).

Figure 26 shows what natural features the participants of the survey would expect to find in the Sulzbach Valleys. The word cloud illustrates that people mostly state what they obviously see in their surroundings, such as 'waterfalls', 'mountains', and 'water', as well as 'forests', 'fauna and flora', and 'glaciers'. This corresponds to the local ecosystems derived from the land cover classification. However, rocks and stones do not belong to the most frequently named terms, even though they also represent visible natural features in the case study area. The majority of terms is linked to the regulating and provisioning services available in the Sulzbach Valleys. Still, the words 'paths' and 'viewpoints' can be connected to cultural services in the case study area, as these aspects promote recreation, education and sports activities. However, the complete set of key words can also be seen as important for the cultural identity of the Sulzbach Valleys.

Figure 27 visualizes the expected resources that nature provides in the Sulzbach Valleys according to the participants' perception. 'Water' was the most often mentioned term and additionally, related words such as 'waterfalls' and 'rivers' were listed. This also correlates with the perceived quality of the local ecosystems connected to Water Provision and Regulation. The acceptance rate of the perceived local water quality is 1.4 (SD=0.7) which shows that 59.6% of the respondents totally agree with a high water quality. In addition, glacial runoff is mentioned as an important local water resource with an acceptance rate of 1.4 (SD=0.6). Even though the statement that local springs are a great potential to use water for human usage (e.g., for power generation or drinking water), is only accepted at a rate of 1.5 (SD=0.9). Despite the acceptance rate is nearly the same, the cumulated percentage of the answers reflect that 90.4% agree with glaciers as a water source, while only 86.8% see the potential of local springs.

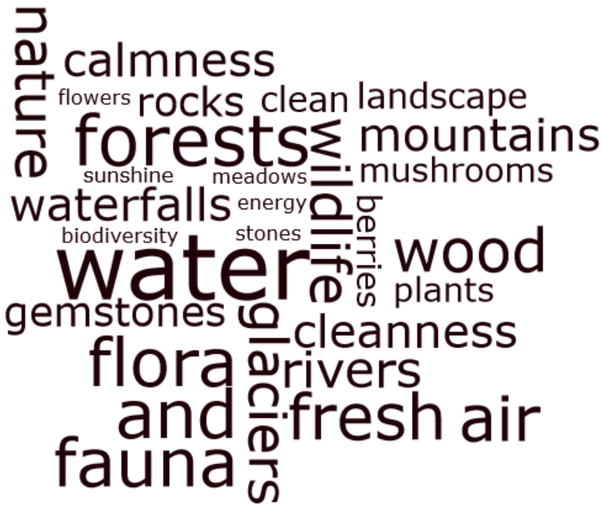


Figure 27: Word cloud generated based on expected natural resources in the Sulzbach Valleys named by the survey's respondents. The size of the words is indicative of the relative frequency of its occurrence (source: own representation).

Next, based on the world cloud of Figure 27 'forests' and 'wood' are also experienced as important natural resources. However, the services linked to these resources were not perceived that strongly. Still, higher agreement can be found in vegetation's role related to climate regulation (mean=1.4, SD=0.6), while a lower agreement can be detected when vegetation is proposed as a protection against natural hazards in mountain regions (e.g., landslide processes) (mean=2.2, SD=0.9).

Other mentioned natural resources refer to the local biodiversity, such as 'fauna and flora', 'wildlife' and 'berries', as well as 'flowers' and 'mushrooms'. The acceptance for biodiversity and habitat conservation was already introduced above.

Even though respondents did not mention cultural services as part of the expected natural resources in the Sulzbach Valleys, the reason why they come to visit this area corresponds with their perception of cultural services. The recreational value of the region has a high acceptance rate in various aspects. The possibility for recreation and relaxing was rated considerably high (mean=1.1, SD=0.4) and the same applies at a slightly lower rate for the option to practice sports activities (mean=1.3, SD=0.5). Also, the region's advantage for physical and mental health was widely accepted by the participants (mean=1.4, SD=0.6). Moreover, the educational value of the participating visitors was evaluated moderately high (mean=1.6, SD=0.7). Still, this cultural service has a lower acceptance rate compared to the recreational aspect. Finally, the spiritual value of the case study area was only perceived to a small extent with a mean of 2.3 (SD=1.3). This rating indicates an almost neutral approach regarding this topic on a 5-level Likert-scale.

5 Discussion

Ecosystem services in mountain regions and particularly in protected alpine areas have a high significance for visitors and the local community. Not only people living in the area's close surroundings, but also the population of lowlands profit from the services provided by these ecosystems (Grêt-Regamey et al., 2012; Millennium Ecosystem Assessment, 2005; Viviroli et al., 2020). How people perceive these ecosystem services does not need to coincide with the services' availability. In this chapter the identified ecosystem services available in the wilderness area Sulzbachtäler are discussed and their potentials are pointed out. Furthermore, the results are compared with relevant literature and similar studies. Next, visitors' perception regarding the local ecosystem services provided by the results of the self-administrated questionnaire are evaluated and associated with the ecosystem services derived through the analysis of relevant literature. This evaluation outlines the differences between provided and perceived ecosystem services in the case study area. Next, the challenges of protected wilderness and available ecosystem services are outlined, with a focus on cultural services. Finally, the limitations of the research framework and the methodological approaches are presented, and potential aspects for future research are introduced.

5.1 Evaluation of the Local Ecosystems and Services

In the course of this master's thesis, twelve different ecosystems and nine distinguishable ecosystem services were identified as essential for the wilderness area Sulzbachtäler. Since the elevation gradient in this area ranges from 1,389 meters a.s.l. to 3,657 meters a.s.l., this leads to a high diversity in ecosystems, as they are partly located below and/or above the tree line.

However, the ecosystem's variety decreases drastically at an elevation above 2,500 meters a.s.l. Below this elevation, each type of the defined ecosystems is represented, while at a higher elevation, the dominating ecosystems are reduced to Bare Rocks, Scree Fields and Gravel, as well as Debris-Covered and Uncovered Glaciers. The surface areas of these categories summed up together contribute to more than threequarters (76.3%) of the total wilderness area. Even though, the category Debris-Covered Glaciers only forms a small share of the case study area (0.4%), it was decided to not combine it with the class Uncovered Glaciers or Scree Fields and Gravel due to two main reasons. On the one hand, Debris-Covered Glaciers are not comparable to pure scree fields and gravel due to the missing ice layer underneath. On the other hand, Debris-Covered Glaciers can provide habitat to a greater number of species than Uncovered Glaciers (Tampucci et al., 2017). Therefore, the ecosystem services provided by Debris-Covered Glaciers differ to an extent that it is worth to consider them separately.

Still, the size of the individual ecosystems does not need to align with the variety and number of services it has to offer. Even though, Bare Rocks as well as Scree Fields and Gravel make up the largest represented ecosystems in the case study area, they only provide people with one identified service, the regulating service Biodiversity Conservation. Nevertheless, this service is only available on a small scale compared to other ecosystems, the living space provided by Bare Rocks as well as Scree Fields and Gravel form an important habitat and refuge for specific alpine species (e.g., chamois). Therefore, they are important for the conservation of biodiversity in the wilderness area Sulzbachtäler. Furthermore, Uncovered Glaciers contribute to a large scale (23.5%) to the studied stretch of land. In comparison to the classes categorized as *Rocks* (i.e., Bare Rocks, Scree Fields and Gravel, as well as Transition Scree and Grassland), this ecosystem has considerably more services to offer. Uncovered Glaciers provide Water Provision and Regulation, as well as Climate Regulation and to a certain extent also Disaster Risk Reduction. The diverse provision of ecosystem services combined with its large share of the wilderness area's stretch of land, demonstrate the significance of glaciers in alpine regions. The steady progress of human-induced climate change expedites the glacier retreat due to several reasons (e.g., increasing air temperatures). Therefore, glaciers belong to the fastest changing ecosystems in the wilderness area (Hock et al., 2019). To point out the interconnectedness of mountain ecosystems among each other, the effect of glacier retreat on the ecosystems Water Courses and Water Bodies can be mentioned due to fluctuations of hydrologic conditions (Cramer, 2008). In comparison to Uncovered Glaciers, Debris-Covered Glaciers feature a different set of ecosystem services. Water Provision and Regulation, as well as Disaster Risk Reduction are also provided by this ecosystem, but the additional debris or scree cover on the glacier surface reduces its ability for climate regulation due to lower albedo values, while the possibilities for Biodiversity Conservation increase.

The results of the ecosystem services analysis revealed that in general the more diverse an ecosystem is, the more services it can provide. This can be supported by the findings of Gratzer and Keeton (2017). They stated in their publication that the presence of varied geologic, geomorphologic, and climatic, as well as biologic conditions supports the development of multi-facetted ecosystems in mountain regions. Additionally, the elevation where the ecosystems can be found is an important key factor for the variety of services it can provide. At lower elevations in alpine areas, a higher diversity of services is present. Particularly ecosystems that are predominately covered by vegetation offer a broad range of services, as depicted in Table 4. Compared to other local ecosystems, Dense Forest, Loose Forest, Shrubs and Bushes, as well as Grasslands and Open Fields feature a high variety in their structure. Since they can be found at elevation levels below 2,500 meters a.s.l., they inhabit a great collection of local plants and wildlife. Furthermore, more biotic, and abiotic materials are available to support biogeochemical cycles, such as photosynthesis. Therefore, each of the defined regulating and cultural services is available in the vegetation-dominated categories. Even though, some are more pronounced than others. Regardless their diverse offer of services, these three categories, combined in the category *Vegetation*, only make up a small share (9.6%) of the wilderness area's total surface cover.

Water Bodies form an exception in the introduced statements about the distribution of services since their occurrence is not limited to certain elevations. Rivers and streams are needed to transport surface and glacier runoff from mountain regions to lowlands. Furthermore, alpine lakes often emerge in glacier forefields, but can also be found at lower elevations. In the case of Water Bodies and Water Courses, the results showed a similar set of services provided by them. Water Regulation and Provision, as well as Biodiversity Conversation are relevant services of both categories. Furthermore, each of the identified cultural services is represented and climate regulation is also available to a certain extent. It needs to be remembered that the two categories Water Courses and Outwash Plains were combined to one category for the ecosystem services analysis. Since outwash plains are sedimental deposits that regularly change in shape and size, depending on the water levels of water courses, they are highly reliant on the rivers' runoff (Gornitz, 2009). Due to this dependency, their services are closely connected, and they were viewed as one relevant ecosystem for further analysis. Outwash plains work as buffer zones for rivers and streams during melt periods or extreme weather events (Gornitz, 2009). They strongly support rivers' ability for Water Regulation and Disaster Risk Reduction (e.g., floods), as they are located in topographically flat areas and work as natural detention reservoirs. This function is particular important in the wilderness area Sulzbachtäler, because heavy rainfall during the summer months regularly leads to landslide processes, mainly debris flows in the valleys and floods in the close by lowlands (Feuerwehr Neukirchen a. Grv., 2021).

When evaluating the provisioning services provided in the wilderness area Sulzbachtäler, it turns out that only one service, namely Water Provision, is of relevance in the case study area. Other scientific studies that conducted an ecosystem services analysis in mountain regions identified a greater number of services compared to this study. For example, Klein et al. (2019) as well as Grêt-Regamey and Weibel (2020) additionally named "Forage", "Food" and "Timber" as available provisioning services. The natural resources that provide these services would also be available in the wilderness area Sulzbachtäler, because 9.6% of the area are predominately covered with vegetation, forests and grasslands which are the main providers of the prior-mentioned services. Furthermore, the alpine meadows in the Sulzbach Valleys' lower elevations have formerly been used as pasture lands (Salzburger Nationalparkfonds Hohe Tauern, 2016). Other provisioning services that could be provided by the area include minerals, sediments, and gravel for construction material, as well as medical plants. However, the limited supply of provisioning ecosystem services in the case study area is strongly connected to the main objective of IUCN classified wilderness areas. According to this target, the natural character of the protected region needs to be retained, without the influence of human settlements or interactions (Dudley, 2013). This also forbids the extraction and use of raw materials. In the wilderness area Sulzbachtäler, the national park authorities arranged a long-term agreement with the Austrian Federal Forests to regulate the restriction of natural resources (Salzburger Nationalparkfonds Hohe Tauern, 2016). Therefore, solely the natural resource water is provided by the case study area since it flows out of the wilderness area. As described in Chapter 4.3, the Austrian Alpine Club’s cabin Kürsinger Hütte draws its demand of water for drinking and non-drinking purposes (e.g., hygienic measures) from the case study area. Moreover, this provisioning service is also used for energy production. For more than 35 years already, a small hydropower plant is located at the Obersulzbach Valley's valley floor to provide electricity for the Alpine Club's cabin (Schmuck, 2020). Furthermore, plans for a hydropower plant at the entrance of the Obersulzbach Valley already exist since the mid-2000s, with the aim to also control the runoff and reduce the flood hazard (Minichberger, 2021; Salzburg ORF, 2005). However, this idea has been heavily criticized by environmental organizations. Their main argument is the power plant’s negative impact on local fauna and flora also within the borders of the wilderness area (Minichberger, 2021). Until February 2022, the construction plans have not been implemented. Still, the runoff provided by the wilderness area enters the Salzach and provides an important resource needed for the run-of-river hydropower plant in Gries, located approximately 65 km downstream from the case study area’s borders (Salzburg AG, 2019).

In the wilderness area Sulzbachtäler, cultural services are strongly represented, as depicted in Table 4. Particularly the alpine scenery and mountain panorama which attract numerous visitors during the summer months to the Ober- and Untersulzbach Valley’ valley floors, need to be named in this context. However, the complexity of evaluating and measuring cultural ecosystem services in general, has been pointed out by several scientists such as Dickinson and Hobbs (2017) and Schirpke et al. (2020) and also led to uncertainties in this study. Its underrepresentation in scientific literature made it difficult to derive information about these ecosystem services from relevant publications. Even though literature that highlights and discusses the knowledge gaps related to cultural services exists, little progress in tackling these knowledge gaps has been registered so far (Dickinson & Hobbs, 2017). This issue can be linked to the fact that these services strongly rely on the subjective opinion and perception of individuals and can vary from person to person. Foreign visitors might perceive recreation as more important, while cultural identity is of value for the local population (Schirpke et al., 2021b).

The difficulties to evaluate the distribution of cultural services in the course of this study led to the decision to combine the otherwise often separately viewed cultural services: educational and scientific relevance. According to the conducted classification, these two services occur in the same ecosystems in the wilderness area. Furthermore, studies' scientific output often leads to educational relevance, so these topics are tightly interlinked.

The Austrian Alps are a tourist hotspot and also attract numerous foreign visitors, according to Schirpke et al. (2019). In the case study area only a small number of people that visit the easily accessible valley floors of the Sulzbach Valleys prolong their hikes and cross the borders to the wilderness area. Nevertheless, the aesthetically pleasing mountain panorama of the summit of Großvenediger and Großer Geiger, both located in the terrain of the wilderness area, are attractive reasons why the valley floors are visited. However, no major tourist destination is located in the wilderness area, except for summits that are higher than 3,000 meters a.s.l. In addition, the hiking path network is strongly restricted, and almost half of the wilderness area (47.8%) is covered with barely passable glaciers or scree and gravel fields. These preconditions only enable experienced alpinists our guided tours to climb the summits. However, to provide certain cultural services (e.g., recreation) to people, the accessibility of an area is crucial. Even though, other cultural services (e.g., aesthetic value) can already be perceived from a distance. Beside mountaineers, only a small number of people enter the wilderness area. For example, the Nationalpark Hohe Tauern offers guided wilderness tours for visitors during the summer months. Also, wilderness summer camps for kids are provided by the national park (Becile, 2020). Moreover, researchers, who conduct scientific field research or maintain monitoring sites, enter the case study area.

All in all, people predominately benefit from cultural services from outside the borders of the wilderness area, similar as with the provisioning service. However, compared to the latter, there are no legal regulations regarding former's use, but it is rather the factor of accessibility that limits its usage. The observation from outside the borders particularly applies to the services Spiritual Value and Aesthetics, as well as Educational and Scientific Relevance. These two services can also be utilized without visiting the area, while this is not possible for the third class, Recreation in Nature. This natural experience is connected to sporty and/or recreational activities that enhance the physical and/or mental health.

One ecosystem class has not been categorized according to its visual appearance (i.e., land cover), but based on its former usage. The ecosystem Anthropogenic Remains represents leftover stone walls from former agricultural activities in these areas. Due to its position, no regulating services can be provided by this ecosystem and its physical appearance restricts the provision of water. Still, these remains can be viewed as important educational and scientific material, as they provide historic information from the time prior to the establishment of the wilderness area. Therefore, it can also have spiritual and aesthetic value for certain people.

5.2 A Scientific Comparison of Ecosystem Services in Mountain Regions

Other research projects have also studied the ecosystem services provided by mountain regions. In the following sub-chapter, the findings of this study are compared with the results of similar projects to line out the similarities and differences.

When observing the results of studies that target ecosystem services in mountain regions, numerous similarities can be identified. This particularly applies to the set of regulating services. The services “Disaster Risk Reduction”, “Climate Regulation”, as well as “Water Regulation” which are dominantly provided by the case study area, were also frequently listed by other publications (Grêt-Regamey et al., 2012; Schirpke et al., 2019). When analyzing the results of other studies, it is common that services that were combined to either Climate Regulation or Disaster Risk Reduction in the course of this master’s thesis, are split into separate classes. For example, Grêt-Regamey et al. (2012) listed “Natural hazard protection” and “Erosion prevention” as separate services in their result section. Furthermore, “Carbon sequestration” was individually named by Egarter Vigl et al. (2021) and Schirpke et al. (2019), even though this service is included in Climate Regulation in this study.

Why some studies name more individual services or combine them to one common service, depends on the project’s scope and data availability. This has already been discussed based on the publication of Harrison et al. (2018) in Chapter 3, but the following examples clearly visualize this statement. Schirpke et al. (2019) limited the number of services to two per ecosystem services’ category to simplify further analysis. Egarter Vigl et al. (2021) explained that their choice of services was strongly linked to data availability in the case study area. Klein et al. (2019) conducted a global study with 57 case study areas and multiple expert workshops. Their research design did not rely on spatial data, and compared to other studies, a larger set of services was derived. This master’s thesis does neither rely on expert interviews nor spatial data; therefore, the identified services are more openly phrased to cover several aspects of certain services.

Differences can also be viewed in regard to the provisioning services. Even though Water Provision was nearly always available, with an exception of the study published by Egarter Vigl et al. (2021). Still, a much wider range of services were presented in other publications, including “Food”, “Forage”, “Timber”, and in some cases “Grassland biomass” as well as “Genetic resources” (Egan & Price, 2017; Egarter Vigl et al., 2021; Grêt-Regamey et al., 2012; Klein et al., 2019; Schirpke et al., 2019). However, neither of these studies was performed in a mountain area with specific protection measures. Therefore, mountain regions can provide humans with a greater number of resources if no restrictions are in place. See Chapter 5.1 for more details.

The identified cultural services are more in line with other publications. “Outdoor recreation”, for example, was listed by all of the examined studies (Egan & Price, 2017; Egarter Vigl et al., 2021; Grêt-Regamey et al., 2012; Klein et al., 2019; Schirpke et al., 2019). Furthermore, mountain regions’ aesthetic and spiritual values were multiply named. The service Educational and Scientific Relevance, identified in the Sulzbach Valleys, was only referred to in Egan and Price’s (2017) study. Beside the services derived in this case study, publications referred to “symbolic plants and animals” (Schirpke et al., 2019) “cultural heritage” (Egan & Price, 2017), and “tourism” (Grêt-Regamey et al., 2012; Klein et al., 2019) as important cultural services in mountain regions.

All in all, no universal set of ecosystem services exists for mountain regions, even though similarities in appearance could be detected. Still, the number of defined and analyzed services highly depends on the local preconditions, the study’s geographic scope and the data availability.

5.3 Perception and Provision of Ecosystem Services

People predominantly visit the border region of the wilderness area Sulzbachtäler with the intention to perform recreational or sports-related activities (87.9%), which in most cases is hiking in regard to the questionnaire’s respondents. Still, during these activities people perceive a manifold range of different ecosystem services and resources provided by the valleys. Some more intentionally than others. Nevertheless, the availability of services does not always correlate with the perception of the visitors and therefore, the demand of these services could be higher than their availability. These deviations, but also similarities of perceived and available services are lined out in the following paragraphs.

When analyzing the questionnaire’s results regarding the perceived ecosystem services, a high acceptance rate concerning any of the asked questions was recorded. Why this is the case, is discussed in detail in Chapter 5.5.3. However, interesting findings were derived. The respondents of the questionnaire predominately approved that the population would benefit from nature and the natural resources provided by it (mean= 1.4, SD=0.6). The exact same numbers could also be obtained regarding the statement that protected areas (e.g., national parks and wilderness areas) benefit the population. This shows that the sample had an overall high acceptance rate concerning protected areas and the benefits from natural resources.

The questionnaire’s results align with the statistics of the ecosystem services’ distribution in Table 5 to a certain extent. The highest acceptance rates are recorded for the cultural ecosystem services.

In particular Recreation in Nature was perceived as an important service available in the Sulzbachtäler and received the highest scores of acceptability in comparison to the other services asked (mean=1.1, SD=0.4). This also correlates with the reasons why people visit the area, according to the questionnaire's sample. The region's potential to perform sports activities was approached in a separate question and revealed similar results. A high acceptance with a low variation was derived in this context. Even though, only a small number of respondents was equipped to enter the wilderness area for recreational or sporty activities, but the majority performed these in the border regions. Additionally, the area's value to support physical and mental health was rated high by the participants (mean=1.4, SD=0.6). This attribute is also included in the service Recreation in Nature.

According to the word clouds (Figure 26 and Figure 27) the aesthetically pleasing mountain panorama of the wilderness area represented an essential aspect for the visitors of the Sulzbach Valleys. Respondents repeatedly listed 'mountains' and the 'Großvenediger' as important natural features. How people perceive the aesthetic value of the region, was not asked separately in the questionnaire. However, the terms found in the word cloud show that the region's aesthetic value exists for visitors. However, the spiritual value of the region was rated the lowest of all cultural services (mean=2.3, SD=1.3). Still, it needs to be added that 20 participants stated in their responses that they have never thought of this service before, which reduces the sample size to 94. Eventually, the term "spiritual value" is connotated negatively for some people because they connect it with a lifestyle, they do not identify themselves with. Furthermore, it needs to be noted that the majority of respondents were tourists and almost half of them (48.2%) visited the Sulzbach Valleys for the first time, when they filled in the questionnaire. The responses in regard to the service Spiritual and Aesthetic Value could turn out differently, if the local population's share of the sample was higher. When cross-checking the responses with the results of the ecosystem services analysis, the service Spiritual Value and Aesthetics is available at a higher extent than perceived by the population. Still, it needs to be remembered that it strongly depends on the subjective opinion of an individual to what extent this service is perceived.

The service Educational and Scientific Relevance of the Sulzbach Valleys received the one of the lowest acceptance rates of all cultural services (mean=1.6, SD=0.7). Even though the area provides a high potential for educationally and scientifically relevant topics, these seem not to be of interest for the Sulzbach Valleys' visitors. This is also reflected by the answers why people come to the area. Only 13.3% named their interest in local fauna and flora as a main reason for their visit.

When comparing the availability and perception of other services it becomes obvious that water is perceived as a particularly important resource available in the Sulzbach Valleys by the survey's participants. As depicted in the word cloud of Figure 26, this word was most frequently named in relation to natural resources available in the Sulzbach Valleys. Words associated with 'water' were also listed repeatedly, such as 'waterfalls', 'rivers' and 'glaciers'. The same applies in regard to the perceived natural features, as 'waterfalls', 'glaciers', 'water' and 'lakes' were also multiply listed. These listed terms, which were not influenced by any pre-phrased statements, correlate with how people perceive the quality and potential of water in the Sulzbach Valleys. Even though, it needs to be mentioned that the main gravel road that leads into the Obersulzbach Valley is mostly located next to the Obersulzbach river. Therefore, visitors are constantly affected by the view and sounds of the torrent, which might influence their perception of related services. Still, Water Provision received a high acceptance rate (mean 1.5, SD= 0.9), since 86.8% of the respondents agreed on the potential to use the valley's water for drinking or non-drinking purposes. Two respondents additionally referred to the possible future construction of the hydropower plant at the valley entrance of the Obersulzbach Valley with a neutral opinion about it. The water quality was also perceived as very good with an acceptance rate of 1.4 (SD=0.7). Furthermore, the potential of glacier runoff as an important local water resource was also perceived at a high rate. The strong perception of ecosystem services related to water align with the derived availability of these services, since more than one quarter (26.1%) of the wilderness area provides water for drinking or non-drinking purposes. Water Regulation is even provided by 35.4% of the area.

Other regulating services were not perceived that consciously compared to Water Regulation, as shown in the results of the word clouds. However, Biodiversity Conservation needs to be discussed with some care. This regulating service was addressed in none of the predefined statements, but the word clouds revealed numerous words linked to the local wildlife and plants. In both figures (Figure 26 and Figure 27) the terms 'flora and fauna' were comparatively often mentioned according to their font size, also 'wildlife' can be found in both visualizations. According to the questionnaire, people named 'Pinus Cembra', 'marmots', 'insects', 'birds', 'flowers', 'berries', 'mushrooms', and 'forests' as natural resources linked to the local biodiversity. Furthermore, the participants approved to a high degree that parts of the landscape and environment should be protected (mean=1.1, SD=0.4) and it is important for them to conserve rare species and their natural habitat (mean=1.2, SD=0.6). Nevertheless, the numbers are lower for the protection of wildlife compared to environmental protection. Therefore, it can be concluded that the respondents support environmental and species conservation in general and according to the word clouds are aware of the high biodiversity in the Sulzbach Valleys. Still based on this study, it cannot be said to what extent people perceive the regulating service Biodiversity Conservation in the case study area.

Climate Regulation as well as Disaster Risk Reduction are two services that people did not consciously perceive while visiting the area. Still, some terms related to Climate Regulation can be detected in the word clouds, such as ‘climate’, ‘untouched nature’ and ‘fresh air’. The two latter ones result as this service’s output and are therefore connected to this service. However, it is not possible to assess with which intention these terms were listed. Still, the pre-phrased statement that the local vegetation is important for climate’s balance has a high acceptance rate (mean=1.4, SD= 0.6) and shows that people are aware of this process. Disaster Risk Reduction is even harder to evaluate because people name numerous important natural features and ecosystems that are essential to prevent natural hazards. For example, ‘forests’ and ‘meadows’ are multiply listed in the word clouds. However, the statement that vegetation prevents landslide processes in the Sulzbach Valleys was not agreed on to a high extent (mean= 2.2, SD=0.9). On a 5-level Likert-scale this mean almost displays the average of the scale. However, in the case of Disaster Risk Reduction, the answers could be influenced by the comparatively high number of debris flows that occurred during the summer months of 2021, before the questionnaire was performed. Heavy rainfalls led to numerous debris flows in the Oberpinzgau and visitors of the Obersulzbach Valley were affected by these events, as well. As a consequence of these events, the parking lot Hopffeldboden was closed and the road to the Obersulzbach Valley blocked. People had to prolong their stay in the Alpine Club Cabin until the risk of further natural hazards had declined (Feuerwehr Neukirchen a. Grv., 2021). This news was also printed in the newspapers and could therefore have influenced the questionnaire’s responses.

The ecosystem service Pollination forms the smallest share of the available services, since it is only available in 21.5% of the case study area. The survey’s respondents did not refer to this service in the word cloud. Even though, similar to Climate Regulation and Disaster Risk Reduction, terms tightly connected to this service were named in the word clouds. For example, ‘meadows’, ‘forests’ and ‘insects’ are displayed in these figures. However, as discussed in relation to Climate Regulation, it is not possible to assess upon what grounds these words were named, particularly as no separate statement was included in the survey that could give additional information about this service’s perception.

Overall, the availability of cultural services aligns with the respondent’s perception. They predominately entered the wilderness area Sulzbachtäler’s border region for experience of nature and exercise. Cultural services can also be viewed as the most essential services perceived by the area’s visitors. Nevertheless, the visitors do not require the area’s spiritual value to the same extent as other provided cultural services. The Sulzbach Valleys satisfy the visitors' needs by providing a great variety of hiking paths for different levels of fitness. Since these paths are predominantly located outside the wilderness area, people can still experience the panorama, while at the same time the stream of visitors in the wilderness area is regulated.

The perception of regulating and provisioning services is more complex to evaluate. However, the perceived need of these services never outranges its availability, based on the conducted questionnaire. Still, it also needs to be mentioned that the responses revealed that visitors predominantly refer to the services they can visually perceive (e.g., Water Provision) or directly experience (i.e., cultural services). Other services are more unconsciously or indirectly perceived. For example, the output of Climate Regulation in the form of 'fresh air' was named.

Furthermore, the sample size and the demographic information of the questionnaire's participants influences its outcome. The majority of respondents were tourists, who did not visit the Sulzbach Valleys frequently. Moreover, the educational level of all respondents was high, since 45.6% hold a university degree. If more local people had been asked to fill in the questionnaire, the results might have looked different, because they might perceive different available services more strongly.

5.4 Challenges of Protected Wilderness and Ecosystem Services

Protected areas, such as the wilderness area Sulzbachtäler, are known as relevant regions to support a high quality of various available ecosystem services. Due to little human interaction in these areas, the local ecosystems are able to function unrestricted and provide the full potential of their services (Schirpke et al., 2021a).

People's interest in natural environments is increasing, particularly to use these areas for recreational purposes (Blattert et al., 2017; Schirpke et al., 2021a). People want to visit protected areas to experience nature, exercise or relax. This rise in recreational activities in protected mountain ecosystems can lead to conflicts between different stakeholder groups. These are often caused by missing management strategies that include the population's desire for recreation as an important aspect in their targets. Most of the time, these conflicts emerge from diverse opinions how to use the available resources (Blattert et al., 2017). For example, disagreements between visitors of the wilderness area and the Nationalpark Hohe Tauern or the authorities responsible for the conservation management could be the result due to diverging interests. Furthermore, an increase of people in a protected region implicates the challenge to prevent visitors from littering or leaving other traces of human activity behind and keeping pollution to a minimum (Schirpke et al., 2021a). For the wilderness area it is an advantage that hunting, forestry and fishing is regulated with a long-term agreement. Otherwise also the related stakeholder groups of these sectors could be potential partners of conflict for either of the above-named stakeholders (Salzburger Nationalparkfonds Hohe Tauern, 2016). Another benefit is that the region, where the wilderness area Sulzbachtäler is located, has been under protection since long before the establishment of this specific protected area. Therefore, no conflicts between stakeholders of the agricultural sector and the management of the national park could originate due to new restrictions in farming practices.

Another challenge arises from the concept of combining local tourism and protected areas. In order to attract tourists, who enhance the local economy, the region needs to offer and provide attractive, as well as reachable destinations and activities for visitors. However, a regular flow of visitors can hardly be incorporated into areas with strict environmental and species protection measures in place. Therefore, the management strategies need to find a balance between providing required cultural ecosystem services, while not sacrificing local regulating and provisioning services. In the wilderness area Sulzbachtäler, as part of the Nationalpark Hohe Tauern, a management strategy is applied that tries to combine these two aspects (Salzburger Nationalparkfonds Hohe Tauern, 2016). People are provided with knowledge and information about the local wilderness area through offered fieldtrips and information boards. Furthermore, they can observe and experience wilderness from a distance. The well-developed hiking path network and available infrastructure for recreational activities (e.g., cabins, gravel roads for bikers), provides visitors with numerous attractive activities at the wilderness area’s borders. The steep valleys enable the majority of visitors to view the mountain tops from the valley floors without entering the protected zone. The remoteness of the wilderness area benefits the environment and the local wildlife. Furthermore, the visitor flows are regulated to only a small stakeholder and interest group (e.g., experienced mountaineers) (Schirpke et al., 2021a).

Even if the management strategies of a protected area are adopted to a steady stream of visitors and they abide the rules (e.g., not leave the marked tracks), several indirect anthropogenic pressures can still influence the main ecosystems and services. Relevant examples of these indirect drivers in the wilderness area Sulzbachtäler are climate change, invasion of alien species and, pollution (Burkhard & Maes, 2017). These external pressures are of global scale and cannot be solved by the management authorities of protected areas. Nevertheless, protected areas can provide information about the local ecosystem services and how they are influenced by these indirect drivers to increase the awareness of visitors regrading this topic.

The issue of indirect anthropogenic pressures is also connected to the topic of the spatial relation between the availability of services and where people benefit from these. This topic is difficult to grasp, because spatial and temporal supply do not always align with the benefits (Schirpke et al., 2019). While some services are directly available and can only be profited from within the borders of a certain area, such as the provided hiking paths in the wilderness area Sulzbachtäler, other services are also provided outside the borders. For example, the mountain panorama's aesthetic value in the case of this study. Some services, such as provided water, can even still be retrieved a long distance from the wilderness area. Particularly regulating services available in the wilderness area benefit the population globally, such as Climate Regulation. Therefore, it is important to protect the vulnerable services from indirect drivers. Furthermore, the local population as well as visitors need to be made aware of the services they benefit from through this environment's protection through a shift in perception.

5.5 Limitations and Potentials for Future Research

Several limiting factors arose throughout the research for this master's thesis. First, limitations that appeared through the process of the land cover classification are outlined. Second, the limiting aspects linked to the ecosystem services analysis are discussed. Third, shortcomings of the self-administrated questionnaire are identified and evaluated. Finally, ideas for future research are presented.

5.5.1 Limitations of the Land Cover Classification

Certain limitations became apparent during the application process of the manual land cover classification. First, the applied remote sensing data represent a snapshot in time and therefore, the current situation of the region on one specific day, season, and year. This is of relevance when glaciers, water courses, water bodies or outwash plains are mapped. During extreme weather events, periods with more or less precipitation than usual, the shape and size of these features is modified due to the rapid changes in water level. Furthermore, in the case of the applied orthophotos the data collection flights took place on two different days (28.08.2018 and 11.09.2018). In between the two flights a thin snow cover developed that made it harder to define certain land cover classes, because of small snow patches in shady areas. Second, when an aerial picture is processed into an orthophoto, image rectification is conducted. This results in distortions of certain areas, particularly in steep terrain and complicates the classification process, because of blurry land cover transitions. Third, shadow casts and hardly differentiable contrast often occur in mountain areas and therefore the data set of the case study area, entails certain chance for misinterpretation. However, the same possibilities applies to semi-automatic and automatic classifications and not only to manual classifications (Kääb et al., 2005). Still, this can be seen as a limitation when the border of two classes lies within such shadow cast. In these cases, an interpolation is necessary to determine the border. Fourth, the scale of 1:2,000 used for the mapping process is not always detailed enough to clearly distinguish between two individual classes and is therefore a limiting factor of this method. Finally, it also needs to be considered that the land cover classification relies on the observer's visual interpretation and this subjective analysis can lead to irregularities. However, the completed classification was double-checked to minimize this issue's effects.

5.5.2 Limitations of the Ecosystem Services Analysis

During the process of identifying and evaluating the ecosystem services available in the wilderness area Sulzbachtäler, a set of limiting factors appeared. As already introduced in Chapter 3.2, the most essential ecosystem services in the Sulzbach Valleys were derived from relevant literature, because the alternative approach to conduct workshops with relevant stakeholder groups and experts of the case study area exceeded this study's scope. This method, however, limited the availability of services to the those already identified in other scientific studies, so no additional services could be considered. Another limitation was that only a small number of scientific studies were conducted in regions with moderate alpine climate and none of these publications were performed with specific regard to wilderness areas. In addition, depending on the different categories of services (i.e., regulating, provisioning and cultural services) a variable number of publications was available for consideration. The least information is available for cultural services, due to their difficulty to be quantified. Furthermore, the results of these publications needed to be assumed as expert opinions. Nevertheless, a comparison of this study's outcome with similar publications revealed comparable results (see Chapter 5.2). Next, the insufficient spatial data availability for each identified ecosystem service and the knowledge about other limitations of the spatial matrices' analysis indicated to not apply this commonly performed method to evaluate the spatial availability of ecosystem services. The 3-level ranking of 'not available, 'relevant' and 'highly relevant' that was applied instead, made it possible to rank the availability of the ecosystem services based on the individual ecosystems. However, this is only a rough quantification.

5.5.3 Limitations of the Self-Administrated Questionnaire

As the majority of social science methods, the performance of this questionnaire implicated certain limiting factors. First, the respondents of this survey were not chosen randomly, but were based on a convenience sample. On two different days data were collected in the Ober- and Untersulzbach Valley on several different spots. If people were still filling in the survey and people passed by, these could not be asked to participate. Furthermore, since the participation was voluntary, not everyone asked was willing to participate. Second, the questionnaire was conducted during warm summer days at the end of the Austrian school holidays, so winter tourists and possible other target groups are not represented in the sample. Therefore, full representativity cannot be assumed. Third, the small sample size (*n = 114*) is another limitation. Nevertheless, the sample size is sufficient for a descriptive analysis and the scope of this study. According to Elliott and Woodward (2007) a normal distribution of the data is already guaranteed with a sample size greater than 50. Fourth, since visitors are normally hiking in small groups, people were not filling in the survey alone, but sometimes in pairs. This might result in attenuated responses. Finally, when topics related to climate change and sustainability are addressed, people tend to answer questions according to social desirability (Raab-Steiner & Benesch, 2021). Participants attempt to respond corresponding certain social norms. Since no universal social norms exist, but they rather differ from target group and situation, it is difficult to quantify this phenomenon (Raab-Steiner & Benesch, 2021).

5.5.4 Potential for Future Research

This master's thesis aimed to investigate the available ecosystem services in a protected mountainous area, namely the wilderness area Sulzbachtäler. In addition, the visitor's perception of these services was evaluated to see which are actively perceived and important for visiting people. Several potentials for future research were discovered throughout the process of this study.

This study's research design included an identification of the local ecosystems based on a manual land cover classification. However, this is a time-consuming process, and the results cannot be directly applied on similar research areas (e.g., other national parks in the Central Alps). Therefore, it would be interesting to develop a data set, similar to the CORINE land cover data, but on a more detailed scale. The aim would be to provide also other areas with similar data and to get some more insights about ecosystems available in other protected areas. This information again can be included in the management strategies of this region.

In the case of this project, the simplified method of a screening relevant literature was applied to identify the available ecosystem services of this region. The shortcomings of this approach were already lined out in Chapter 5.5.2. Therefore, it would be valuable for further investigations to conduct a spatial matrices analysis that relies on more diverse spatial data than solely orthophotos. With the aim to make the study more specialized to the region's preconditions. However, based on the existing data, such research cannot be performed for the entire wilderness area, because comprehensive high-resolution data do not exist for the complete region for each potential ecosystem service. This particularly applies to cultural services. Still, future technological innovations might develop a simplified approach to produce these data sets.

Furthermore, this study's results revealed that people consciously visit protected areas to experience untouched nature, fresh air, and alpine landscapes. However, the questionnaire was predominantly completed by visitors of the region. The sample hardly represents people who work in the border zone of the wilderness area and the local population. To get a more comprehensive view of people's perception of ecosystem services in the Sulzbach Valleys it would be important to also interview other stakeholders on top of visitors to receive the complete picture of perceived services. Furthermore, through an increase in sample size, the results can be further validated.

Another potential for future research can be derived from the discovery that people are more aware of cultural services and those they visually perceive. Therefore, it would be valuable to further investigate particularly those services that are not actively recognized by visitors. For example, such a study could focus on regulating services, as these have the greatest impact on climate regulation and disaster risk reduction. The final objective of this study could be to provide visitors with information to strengthen their awareness regarding these essential factors of human well-being and observe the possible behavioral change regarding the perception of ecosystem services.

Finally, even though the evaluation of ecosystem services has already been applied in various scientific publications until February 2022, less research was conducted in the field of cultural services. This is addressed in several publications and also led to uncertainties in this study, as discussed in Chapter 5.3 (Dickinson & Hobbs, 2017; Schirpke et al., 2020). Still, the provision of these services is the main reason people visit areas such as the Sulzbach Valleys. Although, these ecosystem services are harder to quantify compared to other services, they are essential to be evaluated to better understand the relationship between protected areas and human visitors.

6 Conclusion

Ecosystems in their natural state provide humans with essential services, maintain their biodiversity, and enable the functioning of important biogeochemical cycles. Scientific publications have confirmed that anthropogenic interferences in the form of land cover and land use change are among the main drivers for human induced climate change. Until today, little research has been conducted with a focus on ecosystems services in mountain regions, particularly in protected areas.

The wilderness area Sulzbachtäler provided an interesting case study area because of its remote location in the Austrian Alps in an otherwise densely populated region, while at the same time representing a popular tourist destination. By applying the developed research design on the wilderness area Sulzbachtäler, it was possible to answer the two research questions proposed in the introduction of this master's thesis.

1. Which ecosystem services can be identified in the wilderness area Sulzbachtäler based on a remote sensing data analysis?
2. Which available ecosystem services are perceived by visitors of the Sulzbach Valleys?

The first research question can be answered as follows: Twelve ecosystems were identified as a result of the manual land cover classification, based on remote sensing data. Furthermore, five regulating, one provisioning and three cultural ecosystem services were defined as the most essential services in the wilderness area Sulzbachtäler. Due to the high elevation gradient in the wilderness area (1,389 meters a.s.l. to 3,657 meters a.s.l.), the ecosystems are arranged along "elevation belts". A higher diversity of ecosystems is located below the tree line and the variety decreases extremely above 2,500 meters a.s.l. The number of services provided by individual ecosystems cannot be related to their size, but rather to their diversity. Therefore, a greater variety of services is available at lower elevations of the wilderness area. They are particularly provided by ecosystems that feature a predominant vegetation cover. Regardless their diverse offer of services, vegetation-covered ecosystems only make up a small share of the total area (9.6%), while more than 85% are covered with *Rocks* or *Glaciers and Perpetual Snow*.

The main results regarding the second research question are summarized as follows: The output of the questionnaire revealed that the local ecosystem services were only perceived by visitors to a certain extent. In conclusion, visitors mainly named services they could visually recognize (e.g., Water Provision) or directly experience (e.g., Recreation in Nature). The "objective" availability of cultural services agrees with the visitors' perception of these and can be ranked as the most important for visitors of the Sulzbach Valleys, in particular Recreation in Nature. This aligns with the reason why people visit the case study area's border region. Precisely to practice sports or perform other recreational activities. Besides cultural services, Water Provision and Water Regulation were consciously perceived. The questionnaire's respondents referred more indirectly to the other regulating services. Even though, these services have a greater broad-scale impact, such as the numerous aspects of Climate Regulation (e.g., regulation of surface temperature, atmospheric conditions, carbon sequestration, filtering of pollutants).

To conclude, people visit protected areas to experience wilderness and nature as well as to benefit from other cultural services provided by the local ecosystems. However, a shift in awareness would be necessary to reach an active perception of regulating services that support human well-being by climate regulation, natural hazard reduction and biodiversity conservation, since also protected mountain ecosystems are influenced by the indirect drivers of human-induced climate change. This shift is also relevant for the coming up future, as wilderness areas should still be able to provide the favored cultural services and to meet the standards of their IUCN classification. Namely, current, and future generations should be able to experience nature, where the natural character of a region is maintained without modification. At the same time, this would ensure the presence and the functioning of regulating and provisioning services.

References

Aigner, S. (2020). *Vegetationsökologisches Monitoring auf der Aschamalm im Untersulzbachtal im Jahr 2020*. Köttmannsdorf, Austria. Ökologiebüro Aigner e. U.

Albertz, J. (2007). *Einführung in die Fernerkundung: Grundlagen der Interpretation von Luft- und Satellitenbildern*. Wiss. Buchges.

ALPARC. (2019). *Protected Area Categories*. https://alparc.org/categories-of-apa

AlpES. (2018). *AlpES: Alpine Ecosystem Services - mapping, maintenance, management.* Interrreg ALpine Space. https://www.alpine-space.org/projects/alpes/en/home

Bastian, O. (2013). The role of biodiversity in supporting ecosystem services in Natura 2000 sites. *Ecological Indicators*, *24*, 12–22. https://doi.org/10.1016/j.ecolind.2012.05.016

Becile, A. (2020). *Wild – Unerschlossen - Eindrucksvoll Wildnisgebiet Sulzbachtäler.* Nationalpark Hohe Tauern. https://hohetauern.at/de/np-blog/nationalpark-blog/29-wandern/1417-wild-unerschlossen-eindrucksvoll.html

Betts, M. G., Wolf, C., Ripple, W. J., Phalan, B., Millers, K. A., Duarte, A., Butchart, S. H. M., & Levi, T. (2017). Global forest loss disproportionately erodes biodiversity in intact landscapes. *Nature*, *547*(7664), 441–444. https://doi.org/10.1038/nature23285

Blattert, C., Lemm, R., Thees, O., Lexer, M. J., & Hanewinkel, M. (2017). Management of ecosystem services in mountain forests: Review of indicators and value functions for model based multi-criteria decision analysis. *Ecological Indicators*, *79*, 391–409. https://doi.org/10.1016/j.ecolind.2017.04.025

Braat, L. C., & Groot, R. de (2012). The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. *Ecosystem Services*, *1*(1), 4–15. https://doi.org/10.1016/j.ecoser.2012.07.011

Brudermann, T., Zaman, R., & Posch, A. (2019). Not in my hiking trail? Acceptance of wind farms in the Austrian Alps. *Clean Technologies and Environmental Policy*, *21*(8), 1603–1616. https://doi.org/10.1007/s10098-019-01734-9

Bundesamt für Eich- und Vermessungswesen (Ed.). (2014). *EPSG-Übersicht: Geodätisches Datum und Projektionen in Österreich*. BEV. http://isticktoit.net/wp-content/uploads/2014/03/PROJEKTIONEN_TRANSF.pdf

Bürgi, M., Silbernagel, J., Wu, J., & Kienast, F. (2015). Linking ecosystem services with landscape history. *Landscape Ecology*, *30*(1), 11–20. https://doi.org/10.1007/s10980-014-0102-3

Burkhard, B., Kroll, F., Müller, F., & Windhorst, W. (2009). Landscapes' capacities to provide ecosystem services - A concept for land-cover based assessments. *Landscape Online*, *15*, 1–22. https://doi.org/10.3097/LO.200915

Burkhard, B., Kroll, F., Nedkov, S., & Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. *Ecological Indicators*, *21*, 17–29. https://doi.org/10.1016/j.ecolind.2011.06.019

Burkhard, B., & Maes, J. (Eds.). (2017). *Mapping Ecosystem Services.* Pensoft Publishers.

Carver, S., Comber, A., McMorran, R., & Nutter, S. (2012). A GIS model for mapping spatial patterns and distribution of wild land in Scotland. *Landscape and Urban Planning*, *104*(3-4), 395–409. https://doi.org/10.1016/j.landurbplan.2011.11.016

Carver, S., Evans, A., & Fritz, S. (2002). Wilderness attribute mapping in the United Kingdom. *International Journal of Wilderness*, *8*.

Carver, S., Tricker, J., & Landres, P. (2013). Keeping it wild: Mapping wilderness character in the United States. *Journal of Environmental Management*, *131*, 239–255. https://doi.org/10.1016/j.jenvman.2013.08.046

Cazalis, V., Loreau, M., & Henderson, K. (2018). Do we have to choose between feeding the human population and conserving nature? Modelling the global dependence of people on ecosystem services. *The Science of the Total Environment*, *634*, 1463–1474. https://doi.org/10.1016/j.scitotenv.2018.03.360

Cerretelli, S., Poggio, L., Gimona, A., Yakob, G., Boke, S., Habte, M., Coull, M., Peressotti, A., & Black, H. (2018). Spatial assessment of land degradation through key ecosystem services: The role of globally available data. *The Science of the Total Environment*, *628-629*, 539–555. https://doi.org/10.1016/j.scitotenv.2018.02.085

Comber, A., Carver, S., Fritz, S., McMorran, R., Washtell, J., & Fisher, P. (2010). Different methods, different wilds: Evaluating alternative mappings of wildness using fuzzy MCE and Dempster-Shafer MCE. *Computers, Environment and Urban Systems*, *34*(2), 142–152. https://doi.org/10.1016/j.compenvurbsys.2009.10.006

Constanza, R., d’Arge, R., Groot, R. de, Farberk, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O’Neill, R. V., Paruelo, J., Raskin, R. G., & Suttonkk, Paul & Marjan van den Belt (1997). The value of the world’s ecosystem services and natural capital. *Nature*, *387*, 253–260.

Copernicus. (2019). *OBSERVER: A new way of mapping Land Cover on a global scale*. https://www.copernicus.eu/en/observer-new-way-global-land-cover-mapping

Copernicus. (2021). *CORINE Land Cover*. https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2012-2018?tab=metadata

Cramer, W [W.] (2008). Global Change Impacts on the Biosphere. *Encyclopedia of Ecology*, 1736–1741. https://doi.org/10.1016/B978-008045405-4.00736-9

D'agata, S., Mouillot, D., Wantiez, L., Friedlander, A. M., Kulbicki, M., & Vigliola, L. (2016). Marine reserves lag behind wilderness in the conservation of key functional roles. *Nature Communications*, *7*, 12000. https://doi.org/10.1038/ncomms12000

DeFries, R., Foley, J. A., & Asner, G. P. (2004). Land-Use Choices: Balancing Human Needs and Ecosystem Function. *Frontiers in Ecology and the Environment*, *2*(5), 249. https://doi.org/10.2307/3868265

DeFries, R., & Nagendra, H. (2017). Ecosystem management as a wicked problem. *Science (New York, N.Y.)*, *356*(6335), 265–270. https://doi.org/10.1126/science.aal1950

Dickinson, D. C., & Hobbs, R. J. (2017). Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. *Ecosystem Services*, *25*, 179–194. https://doi.org/10.1016/j.ecoser.2017.04.014

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., Hahn, N., Palminteri, S., Hedao, P., Noss, R., Hansen, M., Locke, H., Ellis, E. C., Jones, B., Barber, C. V., Hayes, R., Kormos, C [Cyril], Martin, V., Crist, E., . . . Saleem, M. (2017). An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. *BioScience*, *67*(6), 534–545. https://doi.org/10.1093/biosci/bix014

Dudley, N. (Ed.). (2013). *Best practice protected area guidelines series: Vol. 21. Guidelines for applying protected area management categories including IUCN WCPA best practice guidance on recognising protected areas and assigning management categories and governance types*. IUCN.

D'Urban Jackson, T., Williams, G. J., Walker-Springett, G., & Davies, A. J. (2020). Three-dimensional digital mapping of ecosystems: A new era in spatial ecology. *Proceedings. Biological Sciences*, *287*(1920), 20192383. https://doi.org/10.1098/rspb.2019.2383

Egan, P. A., & Price, M. F. (Eds.). (2017). *Mountain Ecosystem Services and Climate Change: A Global Overview of Potential Threats and Strategies for Adaptation*. https://unesdoc.unesco.org/ark:/48223/pf0000248768

Egarter Vigl, L., Marsoner, T., Schirpke, U., Tscholl, S., Candiago, S., & Depellegrin, D. (2021). A multi-pressure analysis of ecosystem services for conservation planning in the Alps. *Ecosystem Services*, *47*, 101230. https://doi.org/10.1016/j.ecoser.2020.101230

Elliott, A., & Woodward, W. (2007). *Statistical Analysis Quick Reference Guidebook*. SAGE Publications, Inc. https://doi.org/10.4135/9781412985949

Ellis, E. C., Pascual, U., & Mertz, O. (2019). Ecosystem services and nature's contribution to people: negotiating diverse values and trade-offs in land systems. *Current Opinion in Environmental Sustainability*, *38*, 86–94. https://doi.org/10.1016/j.cosust.2019.05.001

European Commission. (2013). *Guidelines on Wilderness in Natura 2000: Management of terrestrial wilderness and wild areas within the Natura 2000 Network.* European Commission.

European Environment Agency. (2021). *CICES: Towards a common classification of ecosystem services*. https://cices.eu/

European Wilderness Society. (2021). *The European Wilderness Society.* European Wilderness Society. https://wilderness-society.org/the-european-wilderness-society/

Felipe-Lucia, M. R., Soliveres, S., Penone, C., Manning, P., van der Plas, F., Boch, S., Prati, D., Ammer, C., Schall, P., Gossner, M. M., Bauhus, J., Buscot, F., Blaser, S., Blüthgen, N., Frutos, A. de, Ehbrecht, M., Frank, K., Goldmann, K., Hänsel, F., . . . Allan, E. (2018). Multiple forest attributes underpin the supply of multiple ecosystem services. *Nature Communications*, *9*(1), 4839. https://doi.org/10.1038/s41467-018-07082-4

Feuerwehr Neukirchen a. Grv. (2021, August 15). Murenabgang & behördliche Sperre Obersulzbachtal. https://www.feuerwehr-neukirchen.at/2021/08/murenabgang-behoerdliche-sperre-obersulzbachtal/

Glushkova, M., Zhiyanski, M., Nedkov, S., Yaneva, R., & Stoeva, L. (2020). Ecosystem services from mountain forest ecosystems: conceptual framework, approach and challenges. *Silva Balcanica*, *21*(1), 47–68. https://doi.org/10.3897/silvabalcanica.21.e54628

Gornitz, V. (2009). *Encyclopedia of paleoclimatology and ancient environments*. *The encyclopedia of earth sciences series*. Springer. https://doi.org/10.1007/978-1-4020-4411-3

Gratzer, G., & Keeton, W. S. (2017). Mountain Forests and Sustainable Development: The Potential for Achieving the United Nations' 2030 Agenda. *Mountain Research and Development*, *37*(3), 246–253. https://doi.org/10.1659/MRD-JOURNAL-D-17-00093.1

Grêt-Regamey, A., Brunner, S. H., & Kienast, F. (2012). Mountain Ecosystem Services: Who Cares? *Mountain Research and Development*, *32*(S1), S23-S34. https://doi.org/10.1659/MRD-JOURNAL-D-10-00115.S1

Grêt-Regamey, A., Huber, S. H., & Huber, R. (2019). Actors' diversity and the resilience of social-ecological systems to global change. *Nature Sustainability*, *2*(4), 290–297. https://doi.org/10.1038/s41893-019-0236-z

Grêt-Regamey, A., & Weibel, B. (2020). Global assessment of mountain ecosystem services using earth observation data. *Ecosystem Services*, *46*, 101213. https://doi.org/10.1016/j.ecoser.2020.101213

Haines-Young, R [R.], & Potschin, M. B. (2018). *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure.* www.cices.eu

Halpern, B. S., Frazier, M., Potapenko, J., Casey, K. S., Koenig, K., Longo, C., Lowndes, J. S., Rockwood, R. C., Selig, E. R., Selkoe, K. A., & Walbridge, S. (2015). Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications*, *6*, 7615. https://doi.org/10.1038/ncomms8615

Hannah, L., Lohse, D., Hutchinson, C., Carr, J. L., & Lankerani, A. (1994). A preliminary inventory of human disturbance of world ecosystems. *Biological Conservation*, *23*(4), 246–250.

Harrison, P. A., Dunford, R., Barton, D. N., Kelemen, E., Martín-López, B., Norton, L., Termansen, M., Saarikoski, H., Hendriks, K., Gómez-Baggethun, E., Czúcz, B., García-Llorente, M., Howard, D., Jacobs, S., Karlsen, M., Kopperoinen, L., Madsen, A., Rusch, G., van Eupen, M., . . . Zulian, G. (2018). Selecting methods for ecosystem service assessment: A decision tree approach. *Ecosystem Services*, *29*, 481–498. https://doi.org/10.1016/j.ecoser.2017.09.016

Hock, R., Rasul, G., Adler, C., Cáceres, B., Gruber, S., Hirabayashi, Y., Jackson, M., Kääb, A., Kang, S [S.], Kutuzov, S., Milner, A., Molau, U., Morin, S., & Orlove, B. and Steltzer, H. (2019). High Mountain Areas. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/06_SROCC_Ch02_FINAL.pdf

Holdgate, M. (1999). *The Green Web: A Union for World Conservation*. Earthscan. http://gbv.eblib.com/patron/FullRecord.aspx?p=1666859

Huber, R., Rigling, A., Bebi, P., Brand, F. S., Briner Simon, Buttler, A., Elkin, C., Gillet Francois, Grêt-Regamey, A., Hirschi, C., Litsche, H., Stolz, R. W., Seidl, R [Roman], Spiegelberger, T., Walz, A., Zimmermann, W., & Bugmann, H. (2013). Sustainable Land Use in Mountain Regions Under Global Change: Synthesis Across Scales and Disciplines. *Ecology and Society*, *18*(3), 1–36. https://doi.org/10.5751/ES-05499-18033

IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* IPBES secretariat.

IUCN. (1978). *Categories, Objectives and Criteria: Final Report of the Committee and Criteria of the CNPPA/IUCN.* IUCN.

Jenkins, M., & Schaap, B. (2018). *Background Analytical Study 1: Forest Ecosystem Services: Background study prepared for the thirteenth session of the United Nations Forum on Forests*. https://www.un.org/esa/forests/wp-content/uploads/2018/05/UNFF13_BkgdStudy_ForestsEcoServices.pdf

Jiang, H., Wu, W., Wang, J., Yang, W., Gao, Y., Duan, Y., Ma, G., Wu, C., & Shao, J. (2021). Mapping global value of terrestrial ecosystem services by countries. *Ecosystem Services*, *52*, 101361. https://doi.org/10.1016/j.ecoser.2021.101361

Jones, K. R., Klein, C. J., Halpern, B. S., Venter, O., Grantham, H., Kuempel, C. D., Shumway, N., Friedlander, A. M., Possingham, H. P., & Watson, J. E. M. (2018). The Location and Protection Status of Earth's Diminishing Marine Wilderness. *Current Biology : CB*, *28*(15), 2506-2512.e3. https://doi.org/10.1016/j.cub.2018.06.010

Kääb, A., Huggel, C., Fischer, L., Guex, S., Paul, F., Roer, I., Salzmann, N., Schlaefli, S., & Schmutz, K. (2005). Remote sensing of glacier- and permafrost-related hazards in high mountains: an overview. *Natural Hazards and Earth System Sciences*, *5*, 527–554.

Kapoor, V., Tripathi, S., Devi, R. S., Srivastava, P., & Bhadouria, R. (2020). *Urban Ecology. Emerging Patterns and Social-Ecological Systems: Chapter 6 - Ecological economics of an urban settlement: an overview.* https://doi.org/10.1016/B978-0-12-820730-7.00006-9

Kienast, F., Bolliger, J., Potschin, M [Marion], Groot, R. S. de, Verburg, P. H., Heller, I., Wascher, D., & Haines-Young, R [Roy] (2009). Assessing landscape functions with broad-scale environmental data: Insights gained from a prototype development for Europe. *Environmental Management*, *44*(6), 1099–1120. https://doi.org/10.1007/s00267-009-9384-7

Klein, J. A., Tucker, C. M., Nolin, A. W., Hopping, K. A., Reid, R. S., Steger, C., Grêt-Regamey, A., Lavorel, S [S.], Müller, B., Yeh, E. T., Boone, R. B., Bourgeron, P., Butsic, V., Castellanos, E., Chen, X., Dong, S. K., Greenwood, G., Keiler, M., Marchant, R., . . . Yager, K. (2019). Catalyzing

Transformations to Sustainability in the World's Mountains. *Earth's Future*, *7*(5), 547–557. https://doi.org/10.1029/2018EF001024

Kohler, B., Zika, M., & Vancura, V. (2014). *The potential wilderness area Grossvenediger*. WWF Österreich.

Kormos, C. F., Casson, S. A., Mittermeier, R. A., & Filardi, C. E. (2018). Wilderness and Intact Ecosystems. *Encyclopedia of the Anthropocene*, *3*, 31–36. https://doi.org/10.1016/B978-0-12-809665-9.09781-0

Kosztra, B., Büttner, G., Hazeu, G., & Arnold, S. (2019). *Updated CLC Illustrated Nomenclature Guidelines.* Environment Agency Austria.

Lamarque, P., Tappeiner, U., Turner, C., Steinbacher, M., Bardgett, R. D., Szukics, U., Schermer, M., & Lavorel, S [Sandra] (2011). Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. *Regional Environmental Change*, *11*(4), 791–804. https://doi.org/10.1007/s10113-011-0214-0

Land Tirol - data.tirol.gv.at. (2013). *Außengrenze des Nationalparks Hohe Tauern (ohne Rechtsverbindlichkeit)*. Land Tirol - data.tirol.gv.at. https://www.data.gv.at/katalog/dataset/land-tirol_auengrenzenationalparkhohetauern

Lesslie, R. G., & Taylor, S. G. (1985). *The wilderness continuum concept and its implications for Australian wilderness preservation policy* (Vol. 32). https://doi.org/10.1016/0006-3207(85)90021-7

Matzdorf, B., & Meyer, C. (2014). The relevance of the ecosystem services framework for developed countries' environmental policies: A comparative case study of the US and EU. *Land Use Policy*, *38*, 509–521. https://doi.org/10.1016/j.landusepol.2013.12.011

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis.* Island Press.

Minichberger, M. (2021). Heftige Debatten um Kraftwerkspläne am Eingang zum Nationalpark in Neukirchen. *Salzburger Nachrichten*. https://www.sn.at/salzburg/wirtschaft/heftige-debatten-um-kraftwerksplaene-am-eingang-zum-nationalpark-in-neukirchen-107198266

Mittermeier, R. A., Mittermeier, C. G., Brooks, T. M., Pilgrim, J. D., Konstant, W. R., Da Fonseca, G. A. B., & Kormos, C. (2003). Wilderness and biodiversity conservation. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(18), 10309–10313. https://doi.org/10.1073/pnas.1732458100

Mori, A. S., Furukawa, T., & Sasaki, T. (2013). Response diversity determines the resilience of ecosystems to environmental change. *Biological Reviews of the Cambridge Philosophical Society*, *88*(2), 349–364. https://doi.org/10.1111/brv.12004

Morimoto, J., & Negishi, J. (2019). Ecological resilience of ecosystems to human impacts: resilience of plants and animals. *Landscape and Ecological Engineering*, *15*(2), 131–132. https://doi.org/10.1007/s11355-019-00376-9

Moser, L. (2008). *Fernerkundungsmethoden zum Gletschermonitoring - Einsatz ausgewählter Luftbilder und Orthophotos* [PhD Thesis]. Karl-Franzesens-Universität Graz, Graz.

Nash, R. (1967). *Wilderness and the American mind*. Yale University Press.

Oliver, T. H., Heard, M. S., Isaac, N. J. B., Roy, D. B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A., Orme, C. D. L., Petchey, O. L., Proença, V., Raffaelli, D., Suttle, K. B., Mace, G. M., Martín-López, B., Woodcock, B. A., & Bullock, J. M. (2015). Biodiversity and Resilience of Ecosystem Functions. *Trends in Ecology & Evolution*, *30*(11), 673–684. https://doi.org/10.1016/j.tree.2015.08.009

Orsi, F., Geneletti, D., & Borsdorf, A. (2013). Mapping wildness for protected area management: A methodological approach and application to the Dolomites UNESCO World Heritage Site (Italy). *Landscape and Urban Planning*, *120*, 1–15. https://doi.org/10.1016/j.landurbplan.2013.07.013

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R. T., Başak Dessane, E., Islar, M., Kelemen, E., Maris, V., Quaas, M., Subramanian, S. M., Wittmer, H., Adlan, A., Ahn, S., Al-Hafedh, Y. S., Amankwah, E., Asah, S. T., . . . Yagi, N. (2017). Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability*, *26-27*, 7–16. https://doi.org/10.1016/j.cosust.2016.12.006

Pătru-Stupariu, I., Hossu, C. A., Grădinaru, S. R., Nita, A., Stupariu, M.-S., Huzui-Stoiculescu, A., & Gavrilidis, A.-A. (2020). A Review of Changes in Mountain Land Use and Ecosystem Services: From Theory to Practice. *Land*, *9*(9), 336. https://doi.org/10.3390/land9090336

Pickett, S. T. A., & White, P. S. (Eds.). (1985). *The ecology of natural disturbance and patch dynamics*. Academic Press.

Quintero, I., & Jetz, W. (2018). Global elevational diversity and diversification of birds. *Nature*, *555*(7695), 246–250. https://doi.org/10.1038/nature25794

Raab-Steiner, E., & Benesch, M. (2021). *Der Fragebogen: Von der Forschungsidee zur SPSS-Auswertung* (6., aktualisierte und überarbeitete Auflage). *UTB: Vol. 8406*. facultas Verlags- und Buchhandels AG. https://elibrary.utb.de/doi/book/10.36198/9783838587882

Rahbek, C., Borregaard, M. K., Colwell, R. K., Dalsgaard, B., Holt, B. G., Morueta-Holme, N., Nogues-Bravo, D., Whittaker, R. J., & Fjeldså, J. (2019). Humboldt's enigma: What causes global patterns of mountain biodiversity? *Science (New York, N.Y.)*, *365*(6458), 1108–1113. https://doi.org/10.1126/science.aax0149

Rahmonov, O., Abramowicz, A., Pukowiec-Kurda, K., & Fagiewicz, K. (2021). The link between a high-mountain community and ecosystem services of juniper forests in Fann Mountains (Tajikistan). *Ecosystem Services*, *48*, 101255. https://doi.org/10.1016/j.ecoser.2021.101255

Ramankutty, N., & Coomes, O. T. (2016). Land-use regime shifts: an analytical framework and agenda for future land-use research. *Ecology and Society*, *21*(2). https://doi.org/10.5751/ES-08370-210201

Ramesh, R., Paneer Selvam, A., Robin, R. S., Ganguly, D., Singh, G., & Purvaja, R. (2017). Nitrogen Assessment in Indian Coastal Systems. *The Indian Nitrogen Assessment. Sources of Reactive Nitrogen, Environmental and Climate Effects, Management Options, and Policies*, 361–379. https://doi.org/10.1016/B978-0-12-811836-8.00023-9

Salinger, M. J. (2007). Agriculture's influence on climate during the Holocene. *Agricultural and Forest Meteorology*, *142*(2-4), 96–102. https://doi.org/10.1016/j.agrformet.2006.03.024

Salzburg AG. (2019). *Wasserkraftwerk Gries.* Salzburg AG. https://www.salzburg-ag.at/ueber-die-salzburg-ag/unternehmen/erzeugung/erzeugungsanlagen/wasserkraftwerk-gries0.html

Salzburg ORF (2005, September 14). Salzburg AG prüft Kraftwerkplan. *Salzburg ORF.At*. https://sbgv1.orf.at/stories/57768

Salzburger Nationalparkfonds Hohe Tauern. (2016). *Managementplan Wildnisgebiet Sulzbachtäler 2016-2024: Nationalpark Hohe Tauern Salzburg*. Salzburger Nationalparkfonds Hohe Tauern.

Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., Wright, D., Martin, M., Butler, K., van Graafeiland, K., Touval, J., Sotomayor, L., McGowan, J., Game, E. T., & Possingham, H. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. *Global Ecology and Conservation*, *21.* https://doi.org/10.1016/j.gecco.2019.e00860

Schirpke, U., Ebner, M., Pritsch, H., Fontana, V., & Kurmayer, R. (2021b). Quantifying Ecosystem Services of High Mountain Lakes across Different Socio-Ecological Contexts. *Sustainability*, *13*(11), 6051. https://doi.org/10.3390/su13116051

Schirpke, U., Leitinger, G., Tasser, E., Schermer, M., Steinbacher, M., & Tappeiner, U. (2013). Multiple ecosystem services of a changing Alpine landscape: Past, present and future. *International Journal of*

Biodiversity Science, Ecosystem Services & Management, *9*(2), 123–135. https://doi.org/10.1080/21513732.2012.751936

Schirpke, U., Scolozzi, R., Dean, G., Haller, A., Jäger, H., Kister, J., Kovács, B., Sarmiento, F. O., Sattler, B., & Schleyer, C. (2020). Cultural ecosystem services in mountain regions: Conceptualising conflicts among users and limitations of use. *Ecosystem Services*, *46*, 101210. https://doi.org/10.1016/j.ecoser.2020.101210

Schirpke, U., Tappeiner, U., & Tasser, E. (2019). A transnational perspective of global and regional ecosystem service flows from and to mountain regions. *Scientific Reports*, *9*(1), 6678. https://doi.org/10.1038/s41598-019-43229-z

Schirpke, U., Wang, G., & Padoa-Schioppa, E. (2021a). Editorial: Mountain landscapes: Protected areas, ecosystem services, and future challenges. *Ecosystem Services*, *49*, 101302. https://doi.org/10.1016/j.ecoser.2021.101302

Schmuck, C. (2020, December 9). Kraftwerk Obersulzbachtal - Umbau der mechan. und elektr. Regelung. *Alpenverein Salzburg*. https://www.alpenverein.at/salzburg/archivberichte/Startseite/Archiv/2013/Kraftwerk-Obersulzbachtal-Umbau-der-mechan-und-ele.php

Schneider, S. (1974). *Luftbild und Luftbildinterpretation*. De Gruyter. https://doi.org/10.1515/9783110826128

Schröter, D., Cramer, W [Wolfgang], Leemans, R., Prentice, I. C., Araújo, M. B., Arnell, N. W., Bondeau, A., Bugmann, H., Carter, T. R., Gracia, C. A., La Vega-Leinert, A. C. de, Erhard, M., Ewert, F., Glendining, M., House, J. I., Kankaanpää, S., Klein, R. J. T., Lavorel, S [Sandra], Lindner, M., . . . Zierl, B. (2005). Ecosystem service supply and vulnerability to global change in Europe. *Science (New York, N.Y.)*, *310*(5752), 1333–1337. https://doi.org/10.1126/science.1115233

Schutter, M. S., Hicks, C. C., Phelps, J., & Belmont, C. (2021). Disentangling ecosystem services preferences and values. *World Development*, *146*, 105621. https://doi.org/10.1016/j.worlddev.2021.105621

Shakya, B., Uddin, K., Yi, S., Bhatta, L. D., Lodhi, M. S., Htun, N. Z., & Yang, Y. (2021). Mapping of the ecosystem services flow from three protected areas in the far-eastern Himalayan Landscape: An impetus to regional cooperation. *Ecosystem Services*, *47*, 101222. https://doi.org/10.1016/j.ecoser.2020.101222

Soulé, E. M., Mackey, B. G., Recher, H. F., Williams, J. E., Woinarski, J. C. Z., Driscoll, D., C. Dennison, W., & E. Jones, M. (2004). The role of connectivity in Australian conservation. *Pacific Conservation Biology*, *10*(4), 266. https://doi.org/10.1071/PC040266

Tampucci, D., Azzoni, R. S., Boracchi, P., Citterio, C., Compostella, C., Diolaiuti, G., Isaia, M., Marano, G., Smiraglia, C., Gobbi, M., & Caccianiga, M. (2017). Debris-covered glaciers as habitat for plant and arthropod species: Environmental framework and colonization patterns. *Ecological Complexity*, *32*, 42–52. https://doi.org/10.1016/j.ecocom.2017.09.004

Taye, F. A., Folkersen, M. V., Fleming, C. M., Buckwell, A., Mackey, B [Brendan], Diwakar, K. C., Le, D., Hasan, S., & Ange, C. S. (2021). The economic values of global forest ecosystem services: A meta-analysis. *Ecological Economics*, *189*, 107145. https://doi.org/10.1016/j.ecolecon.2021.107145

Thompson, I [I.], Mackey, B., McNulty, S., & Mosseler, A. (2009). Forest Resilience, Biodiversity, and Climate Change.: A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems, Article 43.

Tiel, M., Kohn, I., van Loon, A. F., & Stahl, K. (2020). The compensating effect of glaciers: Characterizing the relation between interannual streamflow variability and glacier cover. *Hydrological Processes*, *34*(3), 553–568. https://doi.org/10.1002/hyp.13603

Tilman, D., Reich, P. B., & Knops, J. M. H. (2006). Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature*, *441*(7093), 629–632. https://doi.org/10.1038/nature04742

Tratalos, J. A., Haines-Young, R [R.], Potschin, M., Fish, R., & Church, A. (2016). Cultural ecosystem services in the UK: Lessons on designing indicators to inform management and policy. *Ecological Indicators*, *61*, 63–73. https://doi.org/10.1016/j.ecolind.2015.03.040

UNESCO. (2021). *World Heritage Centre*. https://en.unesco.org/

United Nations. (1992). *Convention on Biological Biodiversity.*

United Nations. (2020a). *Sustainable Development Goal 15.: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.* https://sustainabledevelopment.un.org/sdg15

United Nations. (2020b). *Sustainable Development Goals*. https://sustainabledevelopment.un.org/sdgs

Verburg, P. H., Crossman, N., Ellis, E. C., Heinimann, A., Hostert, P., Mertz, O., Nagendra, H., Sikor, T., Erb, K.-H., Golubiewski, N., Grau, R., Grove, M., Konaté, S., Meyfroidt, P., Parker, D. C., Chowdhury, R. R., Shibata, H., Thomson, A., & Zhen, L. (2015). Land system science and sustainable development of the earth system: A global land project perspective. *Anthropocene*, *12*, 29–41. https://doi.org/10.1016/j.ancene.2015.09.004

Viviroli, D., Kummu, M., Meybeck, M., Kallio, M., & Wada, Y. (2020). Increasing dependence of lowland populations on mountain water resources. *Nature Sustainability*, *3*(11), 917–928. https://doi.org/10.1038/s41893-020-0559-9

Watson, J. E. M., Evans, T., Venter, O., Williams, B., Tulloch, A., Stewart, C., Thompson, I [Ian], Ray, J. C., Murray, K., Salazar, A., McAlpine, C., Potapov, P., Walston, J., Robinson, J. G., Painter, M., Wilkie, D., Filardi, C., Laurance, W. F., Houghton, R. A., . . . Lindenmayer, D. (2018). The exceptional value of intact forest ecosystems. *Nature Ecology & Evolution*, *2*(4), 599–610. https://doi.org/10.1038/s41559-018-0490-x

Watson, J. E. M., Shanahan, D. F., Di Marco, M., Allan, J., Laurance, W. F., Sanderson, E. W., Mackey, B [Brendan], & Venter, O. (2016). Catastrophic Declines in Wilderness Areas Undermine Global Environment Targets. *Current Biology : CB*, *26*(21), 2929–2934. https://doi.org/10.1016/j.cub.2016.08.049

Watson, J. E. M., Venter, O., Lee, J., Jones, K. R., Robinson, J. G., Possingham, H. P., & Allan, J. R. (2018). Protect the last of the wild. *Nature*, *563*(7729), 27–30. https://doi.org/10.1038/d41586-018-07183-6

Wild Europe. (2020, July 20). *A Working Definition of European Wilderness and Wild Areas.* Wild Europe.

Wildnisgebiet. (2021). *Wildnisgebiet Dürrenstein - Geschichte*. https://www.wildnisgebiet.at/en/wildnisgebiet/geschichte/

Wilson, E. O. (2016). *Half-earth: our planet's fight for life*. Liveright Publishing Corporation. https://doi.org/10.1080/09644016.2016.1216793

WWF Österreich. (2016). *Buch der Wildnis: Wildnispotentiale in Österreich.*

Zhang, Y., Gao, T., Kang, S [Shichang], Shangguan, D., & Luo, X. (2021). Albedo reduction as an important driver for glacier melting in Tibetan Plateau and its surrounding areas. *Earth-Science Reviews*, *220*, 103735. https://doi.org/10.1016/j.earscirev.2021.103735

Zhao, Y., Liu, Z., & Wu, J. (2020). Grassland ecosystem services: A systematic review of research advances and future directions. *Landscape Ecology*, *35*(4), 793–814. https://doi.org/10.1007/s10980-020-00980-3

Appendix A: Self-Administrated Questionnaire

The self-administrated questionnaire was provided in German and English language on a double sided A4 piece of paper. In this section of the thesis, the empty forms in both languages are attached.

Nationalpark Hohe Tauern

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UNI GRAZ

Wildnisgebiet Sulzbachtäler – die Besonderheiten der geschützten Natur

Im Zuge meiner Masterarbeit (Masterstudium Nachhaltige Entwicklung an der Universität Graz) beschäftige ich mich mit den Ökosystemdienstleistungen im Wildnisgebiet Sulzbachtäler. Kurz: Welche Güter und Dienstleistungen werden den Menschen, in einem Gebiet mit besonders hohem Umweltschutzfaktor, von der Natur zu Verfügung gestellt? Da Sie sich gerade nahe der Grenze des Wildnisgebietes aufhalten, bitte ich Sie im Rahmen dieser Studie diesen Fragebogen auszufüllen. Alle Angaben erfolgen anonym und dienen rein wissenschaftlichen Zwecken. Das Ausfüllen des Fragebogens dauert etwa zehn Minuten. **Vielen Dank, für Ihre Mithilfe!**

1. Wie oft besuchen Sie die Sulzbachtäler?	☐ heute zum ersten Mal	☐ 1-2x pro Jahr	☐ einige Male pro Jahr (3-12x)	☐ mehr als 12x pro Jahr	☐ keine Angabe
2. Was ist der Grund für Ihren Aufenthalt? (Mehrfachantworten möglich)	☐ sportliche Aktivitäten	☐ Erholung	☐ kulinarische Gründe	☐ Interesse an lokaler Fauna und Flora	☐ andere Gründe: ________
3. Wie lange brauchen Sie, um hierher zu kommen? (von der Haustüre zum Parkplatz Hopffeldboden)	☐ unter einer Stunde	☐ 1 bis 2 Stunden	☐ mehr als 2 bis 4 Stunden	☐ über 4 Stunden	☐ keine Angabe
4. Haben Sie vor dieser Umfrage schon von diesem Wildnisgebiet gehört?	☐ nein	☐ ja	**Wenn ja,** bitte beantworten Sie auch die folgende Frage 4.1.		
4.1 Wie haben Sie vom Wildnisgebiet erfahren?	☐ Internet	☐ Zeitung	☐ Infocenter NP Hohe Tauern	☐ Freunde/ Bekannte	☐ andere: ________
5. Besuchen Sie bewusst Regionen, die unter Naturschutz stehen?	☐ nein	☐ ja	**Wenn ja,** bitte nennen Sie Regionen, die Sie schon besucht haben: ________		

6. Wie stehen Sie zu den folgenden Aussagen? *Anhand des Schulnotensystems kreuzen Sie ganz links an, wenn Sie völlig zustimmen (1), und ganz rechts, wenn Sie nicht zustimmen (5).*	stimme völlig zu (1)	(2)	(3)	(4)	stimme nicht zu (5)	keine Angabe
Ich kann die Natur in einem geschützten Gebiet mehr genießen als in einer Region ohne Naturschutz.	☐	☐	☐	☐	☐	☐
Ich finde es gut, dass Teile der Landschaft/Umwelt geschützt werden.	☐	☐	☐	☐	☐	☐
Ich würde das Gebiet mehr genießen, wenn ich es mit meinem eigenen Auto besichtigen dürfte.	☐	☐	☐	☐	☐	☐
Ich finde es wichtig, dass seltene Arten geschützt und ihr natürlicher Lebensraum erhalten werden.	☐	☐	☐	☐	☐	☐
Es gibt einen durch den Menschen verursachten Klimawandel.	☐	☐	☐	☐	☐	☐
Ich fühle mich gut über den Klimawandel informiert.	☐	☐	☐	☐	☐	☐

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	stimme völlig zu (1)	(2)	(3)	(4)	stimme nicht zu (5)	keine Angabe
Ich konsumiere bewusst überwiegend regionale Produkte.	☐	☐	☐	☐	☐	☐
Der Konsum regionaler Produkte ist ein guter Ansatz, um die Auswirkungen des Klimawandels zu verringern.	☐	☐	☐	☐	☐	☐
Die Bevölkerung profitiert von der Natur und natürlichen Produkten.	☐	☐	☐	☐	☐	☐
Geschützte Räume, wie Nationalparks und Wildnisgebiete, kommen der Bevölkerung zu Gute.	☐	☐	☐	☐	☐	☐
Welche natürlichen Ressourcen erwarten Sie in den Sulzbachtälern vorzufinden? Bitte nennen Sie diese.	______________________					
Welche Naturmerkmale sind in diesem Gebiet für Sie von besonderer Bedeutung? Bitte nennen Sie diese.	______________________					

7. Wie stehen Sie zu den folgenden Aussagen?
Anhand des Schulnotensystems kreuzen Sie ganz links an, wenn Sie völlig zustimmen (1), und ganz rechts, wenn Sie nicht zustimmen (5).

	stimme völlig zu (1)	(2)	(3)	(4)	stimme nicht zu (5)	habe ich noch nie bedacht
Ich empfinde die Wasserqualität in diesem Gebiet als besonders gut.	☐	☐	☐	☐	☐	☐
Die Vegetation in diesem Gebiet stellt einen guten Schutz vor Steinschlag, Hangrutschungen und Bodenerosion dar.	☐	☐	☐	☐	☐	☐
Die Vegetation in diesem Gebiet ist wichtig für das Gleichgewicht des Klimas.	☐	☐	☐	☐	☐	☐
Gletscher stellen in diesem Gebiet eine wichtige Wasserressource dar.	☐	☐	☐	☐	☐	☐
Aufgrund der vielen Quellen gibt es ein großes Potential Wasser für den menschlichen Gebrauch zu verwenden (z.B. für Stromerzeugung oder Trinkwasser).	☐	☐	☐	☐	☐	☐
Lokale Pflanzen lassen sich zu medizinischen Produkten verarbeiten.	☐	☐	☐	☐	☐	☐
In diesem Gebiet gibt es viele Möglichkeiten etwas Neues zu lernen (z.B. durch Wildtierbeobachtung).	☐	☐	☐	☐	☐	☐
In diesem Gebiet kann ich mich gut erholen.	☐	☐	☐	☐	☐	☐
Dieses Gebiet hat für mich einen spirituellen Wert.	☐	☐	☐	☐	☐	☐
Dieses Gebiet ist wertvoll für meine Gesundheit.	☐	☐	☐	☐	☐	☐
In diesem Gebiet kann ich mich gut sportlich betätigen.	☐	☐	☐	☐	☐	☐

8. Bitte beantworten Sie abschließend die folgenden Fragen.

Alter: _____

Geschlecht:
☐ weiblich ☐ divers
☐ männlich ☐ keine Angabe

Höchste absolvierte Ausbildung:
☐ Pflichtschule ☐ Lehre/ Fachschule
☐ Matura ☐ Universität/ FH

Hier können Sie gerne noch einen Kommentar zur Studie oder dem Fragebogen hinterlassen:

Nationalpark Hohe Tauern

Institute of Systems Sciences, Innovation and Sustainability Research
University of Graz, 8010 Graz
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UNI GRAZ

Wilderness Area Sulzbachtäler – the Characteristics of Protected Nature

In the course of my master thesis (Joint International Master Program in Sustainable Development at the University of Graz, Austria) I am studying the ecosystem services in the wilderness area Sulzbachtäler. In short: Which resources and goods are provided by nature in an area with a high level of environmental protection, even higher than in a national park. As you are currently close to the border of the wilderness area, I would ask you kindly to fill in the following survey. The information is collected anonymously and solely used for scientific purposes. To fill in the survey takes approx. 10 minutes. **Thank you very much for your support!**

1. How often do you visit the Sulzbachtäler?	☐ today is my first visit	☐ 1-2x per year	☐ several times per year (3-12x)	☐ more than 12x per year	☐ no answer
2. What is the reason for your stay? (Multiple answers possible)	☐ sports activities	☐ recreation	☐ culinary reasons	☐ interest in local flora and fauna	☐ other reasons: ______
3. How long do you take to get here? (From your home to the parking Hopffeldboden)	☐ less than an hour	☐ one to two hours	☐ more than 2 to 4 hours	☐ more than 4 hours	☐ no answer
4. Have you ever heard of the wilderness area before this survey?	☐ no	☐ yes	**If yes,** please also answer question 4.1 below.		
4.1 How did you get to know about the wilderness area?	☐ online	☐ news-paper	☐ infocenter NP Hohe Tauern	☐ friends	☐ other: ______
5. Do you consciously visit areas with environmental protection?	☐ no	☐ yes	**If yes,** please name the regions you have already visited: ______		

6. How do you feel about the following statements?

Please indicate how much you agree (1) or do not agree (5) with the following statements.

	totally agree (1)	(2)	(3)	(4)	don't agree at all (5)	no answer
I can enjoy nature more in areas with environmental protection than in regions without.	☐	☐	☐	☐	☐	☐
I think it is good that parts of the landscape/environment are protected.	☐	☐	☐	☐	☐	☐
I would enjoy this region more if I could visit it with my personal car.	☐	☐	☐	☐	☐	☐
I think it is important to protect rare species and preserve their natural habitat.	☐	☐	☐	☐	☐	☐
There exists climate change caused by humans.	☐	☐	☐	☐	☐	☐
I feel well informed about climate change.	☐	☐	☐	☐	☐	☐

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	totally agree (1)	(2)	(3)	don't agree at all (4)	(5)	no answer
I am aware that I consume predominantly regional products.	☐	☐	☐	☐	☐	☐
The consumption of regional products is a good measure to reduce the impact of climate change.	☐	☐	☐	☐	☐	☐
The population benefits from nature and natural products.	☐	☐	☐	☐	☐	☐
Protected areas, such as national parks and wilderness areas, benefit the population.	☐	☐	☐	☐	☐	☐
What natural resources do you expect to find in the Sulzbachtäler? Please name them.	____________________					
Which natural features are of special importance to you in this area? Please name them.	____________________					

7. How do you feel about the following statements?
Please indicate how much you agree (1) or do not agree (5) with the following statements.

	totally agree (1)	(2)	(3)	don't agree at all (4)	(5)	never thought of this before
I perceive the water quality in this region as very well.	☐	☐	☐	☐	☐	☐
The vegetation in this area provides good protection against rockfalls, landslides and soil erosion.	☐	☐	☐	☐	☐	☐
The vegetation in this area is important for the climate's balance.	☐	☐	☐	☐	☐	☐
In this area the glacier is an important water resource.	☐	☐	☐	☐	☐	☐
Because of the numerous local springs, there is a great potential to use water for human usage (e.g. for power generation or drinking water).	☐	☐	☐	☐	☐	☐
In this area, the local plants can be used to produce medical products.	☐	☐	☐	☐	☐	☐
In this area, you get many opportunities to learn something new (e.g. wildlife observation).	☐	☐	☐	☐	☐	☐
For me this area has a high potential to use it for recreational purposes.	☐	☐	☐	☐	☐	☐
This area is of spiritual value for me.	☐	☐	☐	☐	☐	☐
This area is of value for my physical and mental health.	☐	☐	☐	☐	☐	☐
For me this area has a high potential to use it for sports activities.	☐	☐	☐	☐	☐	☐

8. Finally, please answer the following questions.

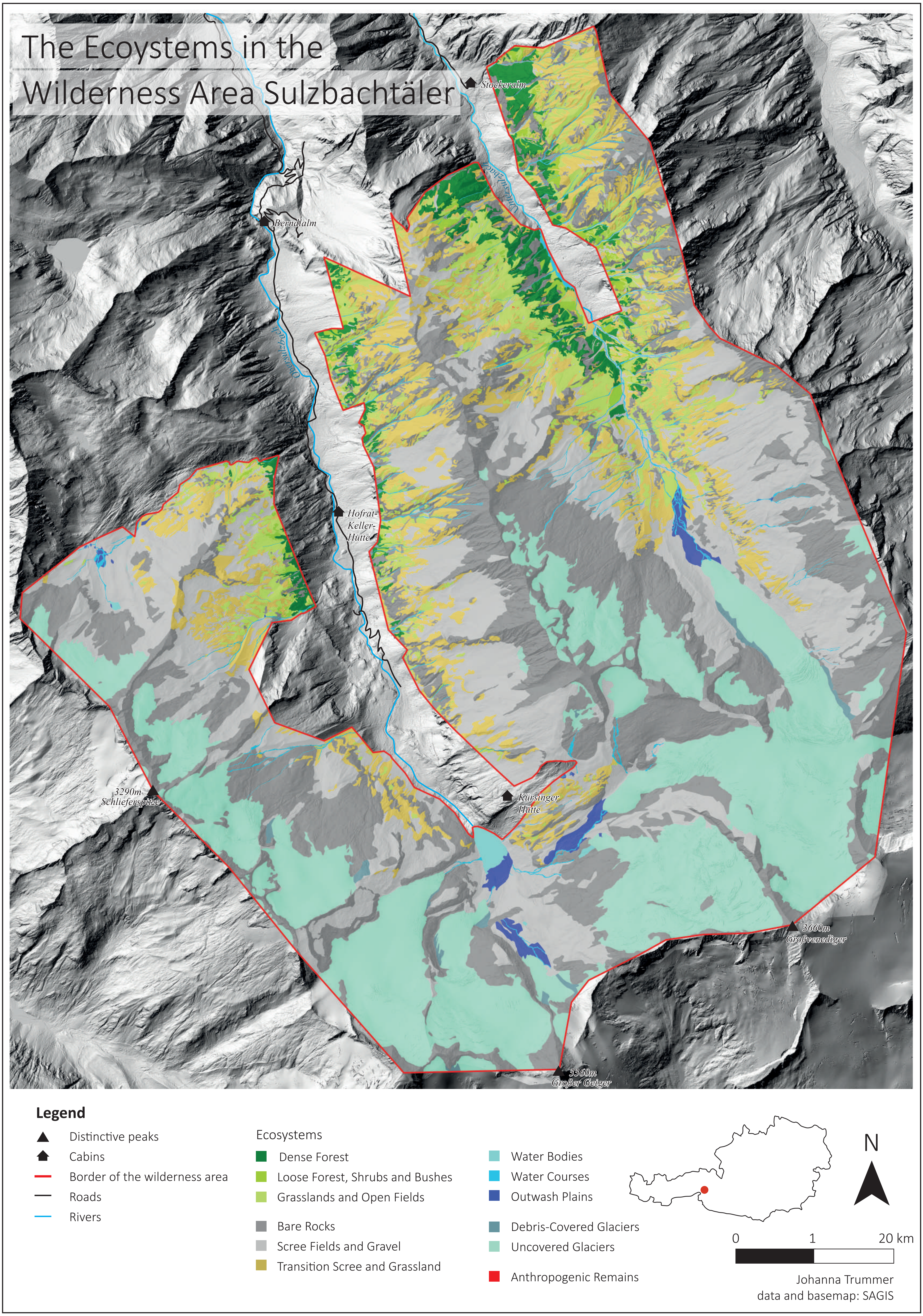
Age: _____

Gender:
☐ female ☐ diverse
☐ male ☐ no answer

Highest completed education:
☐ mandatory school ☐ apprenticeship
☐ high school ☐ university

Here is some space to leave comments related to the survey or this scientific study:

Appendix B: Overview Map of the Ecosystems in the Wilderness Area



The Ecoystems in the
Wilderness Area Sulzbachtäler
Stockeralm
Berndlalm
Hofrat-Keller-Hütte
Kürsinger Hütte
3290m Schlieferspitze
3660m Großvenediger
3360m Großer Geiger
Legend
Distinctive peaks
Cabins
Border of the wilderness area
Roads
Rivers
Ecosystems
Dense Forest
Loose Forest, Shrubs and Bushes
Grasslands and Open Fields
Bare Rocks
Scree Fields and Gravel
Transition Scree and Grassland
Water Bodies
Water Courses
Outwash Plains
Debris-Covered Glaciers
Uncovered Glaciers
Anthropogenic Remains
N
0
1
20 km
Johanna Trummer
data and basemap: SAGIS