MONETARY VALUES OF NATURE'S CONTRIBUTIONS TO PEOPLE (NCP) IN SWITZERLAND MEASURED WITHIN VALPAR.CH

TECHNICAL REPORT WITH RESULTS

Authors:

Raushan Bokusheva (raushan.bokusheva@zhaw.ch)

Astrid Zabel

Martina Bozzola

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Participation

The following people contributed to the report:
Raushan Bokusheva (ZHAW): co-author, main author for the following sections: Regulation of air quality; Regulation of climate; Formation, protection and decontamination of soils (jointly with A. Zabel); Regulation of organisms detrimental to humans; and Food and feed.
Astrid Zabel (ZHAW): co-author, main author for the following sections: Habitat creation and maintenance (jointly with M. Bozzola), Regulation of freshwater quantity, location and timing; Regulation of freshwater quality; Formation, protection and decontamination of soils (jointly with R. Bokusheva); Regulation of hazards and extreme events; Energy; Material and assistance; Medicinal, biochemical and genetic resources (jointly with M. Bozzola), and Learning and inspiration.
Martina Bozzola (ZHAW): co-author, main author for the following sections: Habitat creation and maintenance (jointly with A. Zabel); Pollination and dispersal of seeds; Medicinal, biochemical and genetic resources (jointly with A. Zabel); and Physical and psychological experiences.
Contact: Raushan Bokusheva (ZHAW), raushan.bokusheva@zhaw.ch

Bernard Lehmann (FOEN Support Group), Johann Dupuis (FOEN): supporting the conceptualization of the first version, detailed commenting of the first and second versions.
Roger Keller (UZH), *Adrienne Grêt-Regamey (ETHZ)*, Emmanuel *Reynard (UNIL)*, *Marina Cracco (UNIL)*, *Iago Otero (UNIL)*, *Nathan Külling (UNIGE)*: detailed commenting/editing of the first and second versions.
Jodok Guntern (FOEN Support Group, Biodiversity Forum), *Andreas Hauser (FOEN)*, *Jean-Laurent Pfund (FOEN)*, *Simone Remund (FOEN)*: detailed commenting of the first and second versions.
Anthony Lehmann (UNIGE) & *Gretchen Walters (UNIL)*: commenting on the first version.
Norman Backhaus (UZH), *Sven-Erik Rabe (ETHZ)*, *Benjamin Black (ETHZ)*: commenting on the second version.
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Abstract

Nature's Contributions to People (NCPs) are all the contributions, both positive and negative, of living nature including diversity of organisms, ecosystems, and their associated ecological and evolutionary processes to the quality of life for people (IPBES 2019). This document presents the conceptual framework and the methodological procedure used for deriving monetary values within the ValPar.CH project, a research project implemented on behalf of the Swiss Federal Office for the Environment. It also reports NCPs' monetary values derived for 15 NCPs' economic benefit indicators selected in the project to study benefits and added value of ecological infrastructure in Switzerland. Following the ValPar.CH project approach, the scope of the economic valuation of NCPs is limited to the assessment of their values from an anthropocentric perspective and, consequently, does not consider intrinsic values of ecosystems. Furthermore, the economic valuation focused exclusively on NCPs' positive contributions. To measure NCPs' economic benefits, we applied the exchange value approach adopted for the valuation of ecosystem services in the United Nations System of Environmental Economic Accounting (SEEA). The contribution of this report is three-fold. Firstly, we argue for the inclusion in an economic valuation of the institutional resource regime that governs an NCP and the ecosystem asset from which it originates. This is important to develop an understanding of the extent to which the resulting monetary value depends on public policies and property rights rather than just market forces. Secondly, it lays out the detailed descriptions of the methodologies and data sources that are used for valuing each of the 15 selected NCPs. Third, it reports the estimates of the monetary values derived for these 15 NCPs.

Content

Part A: Methodological Framework

1. Introduction

According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Nature´s Contributions to People (NCPs) are all the contributions, both positive and negative, of living nature including diversity of organisms, ecosystems, and their associated ecological and evolutionary processes to the quality of life for people (IPBES 2019). This section presents a conceptual and methodological framework for deriving marginal monetary values[1] of NCPs. We further present the economic valuation methods applied to value each of the 15 NCPs´ benefit indicators selected in the ValPar.CH project to study benefits and value-added of ecological infrastructure (EI) in Switzerland. The list of the selected NCPs consists of all regulating NCPs applicable in the Swiss context, all the material NCPs and two of three non-material NCPs.

The methodology applied to value the selected NCPs´ benefit indicators follows the ValPar.CH project approach and focuses exclusively on NCPs' *positive* contributions. In addition, the scope of the economic valuation of NCPs is limited to the assessment of NCPs´ values from an anthropocentric perspective and, consequently, does not consider intrinsic values of ecosystems[2]. Hence, it is important to note that the monetary values derived in our analysis do not provide a complete assessment of the entire relationship between nature and people, as a range of benefits are not captured.

To enable their joint, broad application, NCPs' monetary values were derived using the exchange value approach, which is used for the valuation of ecosystem services (ESs) in the UN System of Environmental Economic Accounting (SEEA) Ecosystem Accounting (EA). The exchange value approach has an important advantage compared to other economic valuation approaches. Firstly, by applying the same value concept, it allows for a consistent aggregation of estimates for a wide variety of ESs/NCPs; secondly, it enables the inclusion of NCPs into the System of National Accounts (SNA) and thereby facilitates accounting for ESs/NCPs to economic growth and well-being.

The estimates of NCPs' monetary values obtained in task B.2.1 presented in this report can also be used for aggregating ES/NCP physical flows. This requires ES or NCP physical flows measured according to the ES definitions by the UN SEEA EA, in particular, as "The contribution of ecosystems to the benefits that are used in economic and other human activity" (United Nations et al. 2021). This definition is also consistent with Constanza et al. (1997) who put forward that ecosystem services "only exist if they contribute to human wellbeing and cannot be defined independently", and (Horlings et al. 2020) who define the objectives and concepts of monetary valuation as follows: "the valuation of ecosystem services is meant to provide an estimate of the value of the contribution of ecosystems to economic production and consumption".

In the current report, we present estimates of the monetary value per NCP unit (i.e. like price tags for marketed goods and services) as well as aggregated monetary values/flows of NCPs at the national level. We derived the latter by multiplying the NCP unit estimates by estimates of NCP consumption in Switzerland.

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[1] The incremental monetary value of an additional unit of an NCP benefit.

[2] According to the Millenium Ecosystem Assessment an intrinsic value is the value of something in and for itself, irrespective of its utility for someone else. From the perspective of many ethical, religious, and cultural points of view, ecosystems may have intrinsic value, independent of their contribution to human well-being (Bennett and Hassan 2003).

The modes of managing ecosystems, generating benefits from NCPs, and distributing them among beneficiaries are shaped by institutions. Accordingly, an economic valuation of benefits provided by NCPs requires a good understanding of these institutions, especially in highly regulated economies like Switzerland. To take this into account, we extend the United Nations System of Environmental Economic Accounting (SEEA) framework as applied by (Horlings et al. 2020) by the Institutional Resource Regime (Gerber et al. 2009). This extended framework marks a first step toward dealing with distortion caused by policy interventions in monetary valuation. It is, however, beyond the scope of ValPar.CH to assess how changes in institutional resource regimes of NCPs may influence their monetary values[3].

2. Economic valuation approaches and methods

2.1. Valuation approaches

To measure NCPs´ economic benefits, we apply the exchange value approach, which is used for the valuation of ecosystem services in the United Nations System of Environmental Economic Accounting (SEEA). "*Exchange values reflect the price at which ecosystem services and ecosystem assets would be exchanged between buyer and seller if a market existed*" (UN DESA 2019). Exchange values are the preferred choice when ecosystem assets or NCPs shall be integrated in national accounts since they are consistent and comparable with national accounting values. It is important to note that only certain valuation methods can be used for the estimation of exchange values. These methods are presented and discussed in Section 2.2, with a focus on the methods that were applied to derive marginal monetary values for the 15 selected NCPs. Recent applications of the exchange value approach have been published for the Netherlands (Horlings et al. 2020), Scotland (Scottish government 2020) and numerous other global applications (Hein et al. 2020). Some considerations along these lines have been done for France (Abildtrup and Garcia 2020). Two further monetary valuation approaches can be found in the literature: the welfare approach and the Gross Value Added (GVA) approach. All three approaches assess instrumental values of NCPs[4], but they each serve different purposes.

The welfare approach often relates to case studies and expresses – in monetary terms – welfare changes that arise when changes in institutions, governance modes or other (direct or indirect) drivers alter flows of NCPs´ benefits and/or their distribution among stakeholders. The welfare approach is useful for comparisons of different scenarios and is often applied in cost-benefit analyses. Notably, it allows considering welfare changes for specific groups of stakeholders under specific scenarios. A broad set of valuation methods has been applied to measure welfare changes in the literature[5].

The GVA approach measures value added generated by economic activities that directly depend on the provision of ecosystem services, i.e. it does not measure contributions of ecosystem services exclusively, but also incorporates returns obtained on labor and produced capital in

[3] The monetary values obtained with the methodologies described in this report will feed into further computations within the ValPar.CH project. In particular, they will be multiplied by estimates of the NCPs' physical flows. The resulting products can then be summed per unit of land. To ensure that this further processing of the data is possible, we have used the same NCP indicators for the monetary valuation that are also used for the modelling of physical flows in ValPar.CH.

[4] Pascual et al. 2017 define an instrumental value as "the value attributed to something as a means to achieve a particular end".

5 Typically, valuation methods that include consumer surplus (stated preference methods, e.g. choice experiments or travel cost method) are used, but some studies also use mixed-methods.

respective sectors of the economy. The GVA approach provides a broader perspective on the economic significance of NCPs and is useful to understand how much value added in an economy depends on the provision of ecosystem services. This approach will be applied in ValPar.CH to construct environmental input-output tables and, based on that, to evaluate how much value added and employment in Switzerland depends on the provision of selected NCPs in different groups of economic sectors.

The exchange value approach has two important advantages over the welfare approach and the GVA approach: (i) by applying the same value concept, it allows for a consistent aggregation of estimates for a wide variety of NCPs; (ii) it allows for the inclusion of NCPs into the System of National Accounts (SNA) and thereby enables accounting for NCPs' contribution to economic growth and well-being. However, the use of exchange values does not provide a broader monetary value that incorporates the direct and indirect benefits received from ecosystems including their non-use values. In this respect, estimates obtained using this approach do not provide a *comprehensive* monetary value of well-being (SEEA 2021).

2.2. Valuation methods

The SEEA (2021) guidelines propose to use market prices for monetary valuation whenever possible[6]. However, often market prices are not observable for ecosystem services and therefore need to be estimated. In this context, the SEEA (2021) refers to so-called exchange value estimates. The concept of exchange values refers to the theoretical notion of an exchange happening for an ecosystem service between an ecosystem asset and an economic agent. Given that ecosystem assets do not actually participate in market transactions, methods that produce proxies for this exchange are required (UN DESA 2019). Exchange values can be defined as valuations of ecosystem services and assets that are consistent with values that would have been obtained if a market for the ecosystem services or assets had existed (SEEA 2021). This procedure is similar to measuring monetary values for certain services provided by governments such as health, education and defence services that are included in the SNA. These services cannot be valued using directly observed market transactions and therefore are valued using alternative methods approximating their exchange values SEEA (2021).

The SEEA guidelines provide a list of methods that are suitable for the computation of exchange values. These selected methods are conceptually consistent because they all exclude consumer surplus which is the additional benefit obtained by consumers from purchasing a good or service at the equilibrium market price when their actual willingness to pay is higher than the market price (Figure 1). Accordingly, monetary values derived using these methods can be aggregated.

[6] SEEA (2021) guidelines refer to ecosystem services, whereas in ValPar.CH we apply these methods to NCPs.

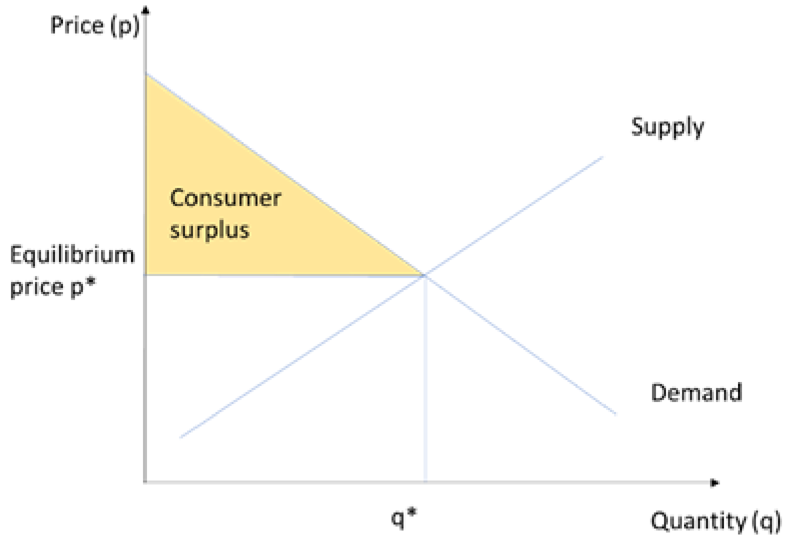

Figure 1: Consumer Surplus.
Source: authors´ representation.

Willingness-to-pay (WTP) and willingness to accept (WTA) estimates obtained using stated preference techniques such as contingent valuation and choice experiments contain consumer surplus. For this reason, these methods are in general not compatible with the exchange value approach. However, as it has been shown by Caparrós et al. (2015) and Hein et al. (2016), the method of Simulated Exchange Values can be applied to derive monetary values consistent with the exchange value approach using empirical distributions of WTP and WTA estimates.

2.3. Valuation methods used in ValPar.CH

For the monetary valuation of NCPs, we use only methods that the SEEA EA guidelines list as suitable for deriving exchange values of ecosystem services. In the following, we briefly describe the different methods that we use for deriving NCPs' monetary values.

- **Observed market prices and Payments for Ecosystem Services (PES).** The ecosystem services, for which observed market prices exist, are valued using their market prices. PES from the public sector (e.g. federal and cantonal authorities) to landowners and land managers provide a direct measure of the value of a NCP when the scheme in question specifically targets the NCP (compared to PES implemented to support broader public policies' objectives) (SEEA, 2021: 194).
- **Replacement cost.** This method estimates the cost of substituting for a NCP, e.g. by an engineered solution, that provides the same contribution to benefits. The exchange value of the NCP is estimated as the observed market price of its substitute (SEEA, 2021: 198).
- **Avoided damage costs.** This method uses the costs of the damages that would occur due to the loss of the NCP. In cases in which it is possible to compute the avoided damage cost and the replacement cost, preference is to be given to the one that produces lower monetary values, which is usually the value derived by the replacement cost method.
- **Residual value method.** The residual value method estimates a value for an ecosystem service by taking the price of the final marketed good or service, to which the ecosystem service provides an input, and then deducting the cost of all other inputs, including labor, produced assets and intermediate inputs. Depending on the scope of the data (e.g. pertaining to a specific location or to the activities of an industry as a whole), the estimated residual value

provides a direct value that can be recorded in national accounts or may be applied to derive a price in other contexts.

Some possible issues of this method are: in some cases, distinguishing the NCP contribution from other non-paid and indirect inputs may be difficult. Second, the estimate is subject to errors in calculating the value of all the paid inputs. Third, and most importantly, the size of the residual will be directly affected by the institutional arrangements surrounding the use of the ecosystem (SEEA 2021: 196).

- **Rental price method.** The rental price method can be used when a NCP contributes to the production of some final marketed goods and services and is determined in a market with a fixed supply and a competitive demand. Rent is the income that the owner of a natural resource receives or could receive when placing it at the disposal to another economic agent who uses it for producing a good or service. Examples for rental prices are agricultural land rents, stumpage values in forestry or concessions paid for the use of water resources. In the absence of observed rental prices or competitive market for resource under consideration, they can be approximated using the residual value method or production function method.
- **Production function method (also called productivity change method).** In this method, the NCP is considered an input in the production function of a marketed good. Thus, changes in the NCP will lead to changes in the output of the marketed good, holding other things equal. The price is derived in two stages. First, the marginal product of the NCP (or the ecosystem service in the SEEA´s jargon) is estimated as the change in the value of production consequent upon a marginal change in the supply of the ecosystem service. Second, the marginal product is multiplied by the price of the marketed good. The relationships should be estimated for a single accounting period recognizing that they may change over time (SEEA 2021: 196). However, in agriculture, it may be more appropriate to use data for several production periods to control for interannual weather variation.
- **Consumption expenditure approach.** This approach consists of adding up consumption expenditures incurred by individuals to reach and enjoy a recreational site. This method builds upon the travel cost method (Hotelling 1949) but differently than the travel cost method it does not take into account the opportunity cost of time for visitors to travel and visit the observed location. This adjustment allows deriving values that are consistent with the exchange value approach.

The estimates of NCP monetary values produced with these methods do not include non-use values. Although non-use values present an important and often large part of the total economic values of NCPs, the exchange value approach values only those NCPs (their benefits) that are of *direct* use for society.

2.4. Considerations on dealing with negative estimates of NCP benefits

In the presence of considerable market failures, market prices for a good or a service may lie below costs of inputs used for producing this good or service such as labor, produced assets (capital) and intermediate inputs. Under such circumstances, the derivation of residual values for corresponding NCPs may result in negative values.

There are three options for measuring NCPs´ monetary values under these circumstances. First, alternative valuation methods should be considered to derive a monetary value for the NCP under consideration, for example a market-based method such as the user-cost method or the rental price method. Second, considering that governments often introduce some countermeasures such as e.g. subsidies, trade restrictions and tariffs, addressing negative implications of market failures on economic actors´ decisions, corresponding residual value estimates can and should be adjusted for the value of relevant public spending per unit of resource under consideration. For example, in the presence of public subsidies addressing negative externalities, the corresponding good's market price can be adjusted for subsidies paid to its producers before deducting costs of conventional economic inputs. Third, if neither of the two options are feasible, some authors use the gross value added of the corresponding good, i.e. do not subtract from the good's market price the costs of labor and produced assets borne by its producers (Horlings et al. 2020).

3. ValPar.CH approach to economic valuation of NCPs

To exemplify the institutional context of relevance for specific NCPs, we structure the discussion for each NCP using the framework presented in Figure 2, which is an augmented representation of the SEEA ecosystem accounting (EA) framework. The starting point of this conceptual framework are the ecosystem assets that generate NCPs (the upper right-side box in Figure 2). NCPs encompass a broad range of services provided by ecosystems to economic agents/units referred to in the SEEA, in particular, businesses, households and governments. Corresponding to the IPBES NCP framework, the SEEA EA framework shows that ecosystem assets, in the sense of Nature, generate NCPs. At the point when these NCPs start to benefit society including the economy, they can be valued using economic valuation methods.

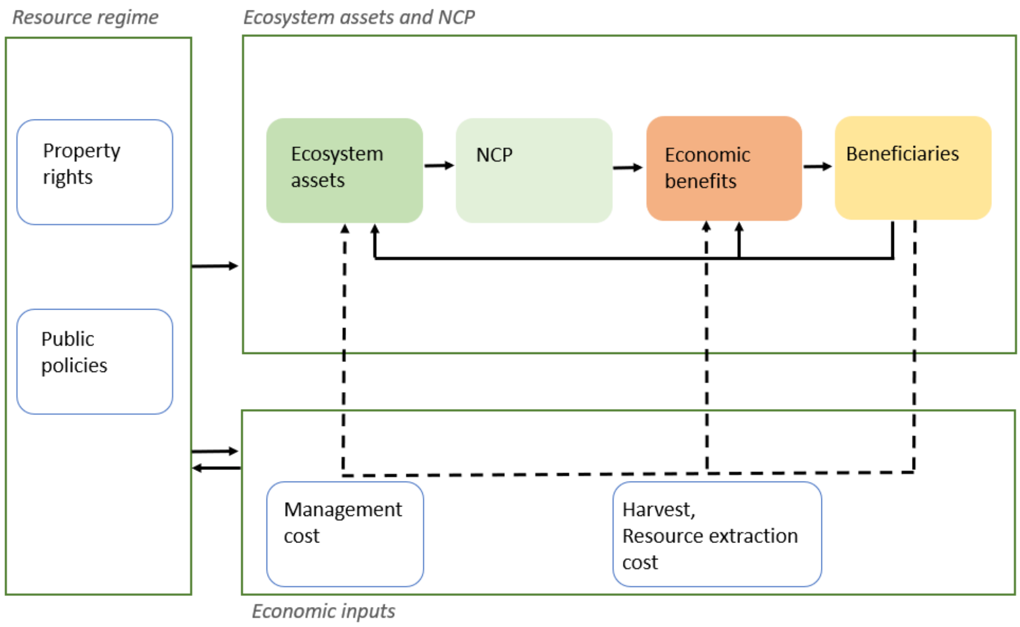

Figure 2. NCP economic valuation framework.
Source: authors´ presentation based on UN DESA (2019), Horlings et al. (2020), Gerber et al. (2009) and Lieberherr et al. (2019).

Economic inputs may be required for both managing ecosystem assets as well as generating economic benefits from NCPs. Economic inputs, e.g. some forms of human or material capital, are often used to manage ecosystem assets. In these cases, economic inputs are applied to retain ecosystem specific processes and characteristics which ensure the functioning of the ecosystem and the provision of NCPs (SEEA 2021). Economic inputs are also often required to capture and use the NCP flows for producing economic goods and services. Examples are the equipment needed for harvesting in forestry and fishery, or the production factors needed to produce food and fiber in agriculture. In Figure 2, these relationships are represented by the dashed lines that connect the box titled 'Economic inputs' with the box 'Ecosystem assets and NCPs'. However, there can be feedback loops from economic units to ecosystem assets as well as economic benefits that do not require using economic inputs. Examples are inaction or negative externalities. Such relationships are represented by the solid line connecting the box titled 'Beneficiaries' with the boxes 'Ecosystem assets' and 'Economic benefits'.

The modes of managing ecosystems, generating economic benefits from NCPs and distributing benefits among beneficiaries are often shaped by formal institutions and property rights which form institutional resource regimes (the left side box in Figure 2). In Switzerland, markets for economic benefits derived from NCPs very often are subject to regulation. However, considering that many economic benefits are not exchanged in markets, it is crucial to understand and to take into account institutional arrangements governing the access to and the use of these benefits. The consideration of property rights and public policies form the Institutional Resource Regime (IRR), which itself is an established framework for the description and exploration of resource management practices (Gerber et al. 2009; Lieberherr et al. 2019).

Subject to their location and utilization, the same ecosystem assets may provide different NCPs and therefore economic benefits to society. In addition, while in some cases an ecosystem asset provides several NCPs simultaneously, there could be also cases when the provision of one NCP hinders the provision of another one or several other NCPs. An example for the earlier is a forest that fulfils a protective function and simultaneously is a habitat for a number of species, regulates climate, filters air, purifies water, retains sediments and is a source for learning and inspiration. An example for the latter could be a forest actively used for recreation purposes which compromises habitat conditions for local species.

A complementary task to the monetary valuation of NCPs is the modelling of current and future physical flows of NCPs provided by different types of ecosystem assets such as e.g. forests. Physical flows of various NCPs computed for particular spatial units can be aggregated by multiplying these physical NCP flows with the corresponding monetary values.

The analysis presented in this report takes into account, for each NCP, the current institutional resource regime. As already mentioned earlier, it is beyond the scope of this study to assess how changes in resource regimes of NCPs may influence their monetary values.

4. Overview of previous studies for Switzerland

Several previous studies mandated by the FOEN on the monetary valuation of ecosystem services, e.g. Von Grünigen et al. (2014) or Buser et al. (2020) follow the welfare approach. The former uses a simplified version of a travel cost method to assess recreational benefits of forests and the latter compares scenarios to compute benefits related to changes in NCP flows in different case study areas. As mentioned above, for the ValPar.CH project, we suggest to follow the exchange value approach, which enables consistent economic valuation of a number of NCPs. This advantage is particularly relevant for the ValPar.CH project, which values benefits from several NCPs, while most of the economic valuation methods conducted in Switzerland so far focused on specific NCPs only.

While the welfare and exchange value approaches differ, some valuation methods are applicable to both approaches. Hence, there are several examples of monetary valuation studies mandated by the FOEN that are consistent with the exchange value approach, although they may not have been developed for this purpose. An example is the study by Odermatt et al. (2020), which discusses the monetary valuation of carbon sequestration in Swiss forests. Similarly, a study by INFRAS and Faunatur (2022) adopts the replacement cost method to implement a monetary valuation of pollination for Switzerland. This method relates the value of pollination by wild pollinators to the costs of alternative ways of obtaining the same benefit, for example the cost of using breeded bees or manual pollination. A study by Sutter et al. (2017a) also presents monetary values for pollination in Switzerland that are consistent with the exchange value approach[7]. Notably, this study applies the FAO's Guidelines for The Economic Valuation of Pollination Services at National Scale (Gallai et al. 2009), which builds upon the production function approach.

Buser et al. (2020) valued a number of NCPs for three selected case study areas, in particular, Seeland, Bois du Jorat and Breil/Brigels. They applied the restoration cost method for approximating the value of the NCP Formation, protection and decontamination of soils. Considering that in ValPar.CH this NCP is modelled as soil erosion control (through sediment retention by vegetation), we value it as the sediment retained in the ecosystem avoiding impoundment filling at storage power plants. Furthermore, in contrast to Buser et al. (2020), who use market prices of final goods for valuing NCPs such as "Food and feed" and "Material and assistance", we propose using the production function approach for the former and the residual value method for the latter. Similar to the procedure adopted in the studies by Buser et al. (2020) and Odermatt et al. (2020), we propose using social costs of carbon (SCC) and marginal abatement costs (MAC) to value the NCP Regulation of climate[8].

5. NCPs' benefit indicators and monetary values

The list of the NCPs covered in ValPar.CH consists of all regulating NCPs applicable in the Swiss context (9 out of totally 10)[9], all the material NCPs and two of totally three non-material NCPs[10]. Considering that a number of NCPs are formulated in a very broad sense and contribute to economic activities and human well-being in numerous and diverse ways, it is important to agree on a set of benefit indicators to be applied when valuing NCPs. Table 1 presents the economic benefit indicators selected within ValPar.CH. This selection was composed using the following three criteria: 1) the economic significance of a benefit for society; 2) the existence of peer-reviewed methodological approaches for the economic valuation of specific benefits; and 3) the availability of relevant and reliable data. Another important aspect of the selection process has been the harmonization of indicators and metrics used for the valuation of NCPs within the ValPar.CH project.

Table 1 also outlines methods used for deriving monetary values for selected NCPs, spatial aggregation levels for which the valuation is undertaken, units of measurement and corresponding estimates. A detailed description of the methodologies applied for valuing individual NCPs is presented in part B of this report.

[7] The study by Sutter et al. (2017a) was mandated by the FOAG.

[8] Both the study by Buser et al. (2020) and the one by Odermatt et al. (2020) propose using four different methods for valuing the NCP Regulation of climate, in particular, CO_2 market prices, replacement costs, avoided damage costs (SCC) and MAC. However, we doubt that the current market price of CO_2 as well as prices of market instruments for CO_2 emissions´ compensation appropriately reflect the real social benefits of the NCP Regulation of climate in the Swiss context. Considering that Switzerland (as an alpine country) is particularly affected by climate change as well as high degree of the economic development of the country, costs of inaction on climate change may be particularly high for Switzerland. Accordingly, we recommend to apply a relatively high value for climate regulation services. In particular, we suggest to use an estimate of SCC obtained for Germany (by applying a relatively low social rate of time preference of 1%,) that was used by both above mentioned studies (180 Euro of 2016/t CO_2eq), and the MAC estimate derived by Ecoplan and INFRAS (2014) for Switzerland.

[9] i.e. we do not value the NCP Regulation of ocean acidification.

[10] Following the IPBES conceptual framework, there three major NCPs categories: regulating, material and non-material NCPs (IPBES 2019).

To cope with substantial differences in the availability of relevant data at different levels of spatial aggregation, a sequential approach is applied. In the first step, a comprehensive set of approaches/functions is developed using rich datasets available at the national level (Tier 1). In the second step, given relevant data availability, these approaches/functions are applied to obtain corresponding economic values at lower aggregation levels such as cantons and parks (Tier 2).

An economic appraisal requires choosing a reference period for the analysis. We set the reference year to 2019. The two main reasons for that are: (i) some statistics may not yet be available for more recent years; (ii) due to the Covid-19 pandemic, at least for some monetary and other indicators the values for 2020 may deviate from those for the period before the outbreak of the pandemic and therefore may not well represent long-term trends.

Table 1: NCPs' benefit indicators and monetary value estimates

NCP	IPBES reference	Method applied	Spatial aggregation level (Tier 1: national; Tier 2: park)	Benefit(s) and units	Economic value estimates[1)], average estimate and/or estimates' range
Regulating NCPs					
Habitat creation and maintenance	C2.1	Payments for ecosystem services (PES)	Tier 1; Tier 2	Public expenditures on biodiversity conservation per ha of the country territory (incl. expenditures on fundamental research and direct payments as two main expenditure positions)	2892.4
Pollination and dispersal of seeds	C2.2	Production function approach[11] (dependency ratios derived therefrom)	Tier 1	Monetary value of pollination contribution to crop production, CHF per ha of selected pollination-dependent crops	8304.6 (5200.2; 11409.7)
		Replacement cost approach	Tier 1	Replacement cost of wild pollinators services, CHF per ha of pollination-dependent crops	8240.4 (3433.5; 12131.8) (manual pollination); 196.6 (77.7; 315.6) (use of domesticated pollinators)
Regulation of air quality	C2.3	Avoided damage cost	Tier 1	Average avoided morbidity and mortality costs per 1 μg/m³ of excessive PM10 at the national level (averaged over the populated territory of the country).	3304.2 (2198.0; 4340.2)

[11] SEEA also refers to this as the 'productivity change method'.

Regulation of climate	C2.4	Replacement costs (MAC); Avoided damage cost (SCC)	Tier 1; Tier 2	Marginal abatement cost (MAC) estimate per 1 ton of carbon (used as reference); Social cost of carbon (SCC) estimate per 1 ton of carbon	669.1 (MAC); 1106.1 (SCC)
Regulation of freshwater quantity, location and timing	C2.6	Rental prices	Tier 1; Tier 2	Median price per m^3 of surface water (range by Canton)	0.011 (0.001 – 0.5)
Regulation of freshwater quality	C2.7	Replacement cost	Tier 1; Tier 2	Costs of engineering solutions per extracted unit of nitrate and phosphate (not retained by vegetation), CHF/kg of removal	10.15 (nitrate); 7.01 (phosphate)
Formation, protection and decontamination of soils	C2.8	Avoided damage cost	Tier 1; Tier 2	Sediment retained in the ecosystem at storage power plants avoiding impoundment filling, CHF per m^3 of sediment	0.04 (0.01; 0.136)
Regulation of hazards and extreme events	C2.9	Replacement cost, Avoided damage cost	Tier 1; Tier 2	CHF per ha of protection forest (as asset); CHF per ha of protection forest (replacement cost) CHF per ha of wetland	97378 (protection forest as asset); 405 (protection forest); 6222.2 (wetland)
Regulation of organisms detrimental to humans	C2.10	Avoided damage cost	Tier 1; Tier 2	Avoided damage to crop production due to biocontrol of common vole populations by raptor species, CHF per ha of arable land; s.t. probabilities of common vole outbreaks: 0.20; 0.25 and 0.33, respectively	93.3; 119.7; 163.8
Material NCPs					
Energy	C3.11	Residual value method	Tier 1; Tier 2	Monetary value of water for hydropower in CHF per m^3; Computed stumpage price for energy wood assortments per m^3	0.02 (0.0001; 0.4122) 48 (9.04; 108.14)
Food and feed	C3.12	Production function approach	Tier 1; Tier 2	Monetary value of agricultural land contribution to the value of food and feed production (incl. environmental and hill slope direct payments), CHF per ha of land	6314.4 (4063.2, 8565.6); 4781.1 (3041.8, 6520.4);

				(crop land in plain zone; and grassland in plain, hill and mountain zones, respectively)	2557.8 (1152.1, 3963.4); 2841.3 (2355.2, 3327.4)
Materials and assistance	C3.13	Residual value method	Tier 1; Tier 2	Computed stumpage price for non-energy wood assortments per m^3	35.01 (2.49; 81.32)
Medicinal, biochemical and genetic resources	C3.14	Residual value method	Tier 1	Monetary value of selected officinal and edible medicinal plants, CHF per kg	0.81 - 12.74
Non-material NCPs					
Learning and inspiration	C4.15	Observable prices from a similar market	Tier 2	Annual monetary value of photos taken in the parks and uploaded to a sharing platform	21.91 – 201.57
Physical and psychological experiences	C4.16	Consumption expenditure	Tier 2	Annual travel expenditure to the parks per km of hiking trails CHF	11.91 - 788.21

Notes: For several NCPs, monetary value estimates vary subject to assumptions used and confidence intervals obtained for corresponding mean estimates. In these cases, ranges of corresponding estimates are reported. We use the following notation: average values (min; max) or range lowest values – highest value.

Source: authors´ representation and estimates

6. Summary of NCPs' monetary values by sector

Our results show that many economic actors and in general sectors of the economy greatly benefit from NCPs. Below, we summarize the NCP benefits for a selection of sectors. All prices are in CHF of 2019. As the monetary valuation of the NCPs is based on individual selected indicators of NCP benefits, economic value estimates are only to be understood as examples and partial aspects and do not represent all benefits of the NCPs. Accordingly, there should be no competition for the highest economic value.

6.1. Agriculture

In agriculture, contributions of soil ecosystem processes supplied by 1 hectare of agricultural land to food and feed production constitute according to our production function estimates of land shadow prices, on average, 6314 CHF for crop farms and 2558 to 4781 CHF for dairy farms subject to the agricultural production zone in which the latter are located.

Swiss farms also benefit of biocontrol provided by species such as avian and other raptors. For example, species like common buzzards and common kestrels spare the use of rodenticides to control common vole populations, thus helping farmers avoid damages to agricultural production for an amount of up to 164 CHF/ha of arable land. In addition, farms specialized in horticulture benefit from services provided by pollinators. Subject to the valuation approach and assumptions regarding substitution options, the contribution of this NCP per ha of pollination-dependent crops is assessed to be 197 (replacing wild pollinators to 50% by domesticated pollinators), 8240 (replacing wild pollinators to 50% by manual pollination) and 8305 CHF (production function estimate based on absolute contributions of pollination to selected crop outputs). Additionally, surface water that can be used for irrigation purposes in agriculture contributes between 0.001–0-5 CHF/m3.

6.2. Forestry

Forestry enterprises benefit from the provision of wood as material in forest ecosystems. Coniferous trees that can be processed to longwood contribute between 18 CHF/m3 and 45 CHF/m3 depending on the region of the country. Hardwood that is used as longwood contributed between 23 CHF/m3 and 81 CHF/m3. These values are for the year 2020. However, the values can fluctuate a lot between years depending on wood prices in international markets.

Society, including public and private forest owners, benefit from the capabilities of protection forests to mitigate hazards and extreme events, such as avalanches or mud slides. At a broad-brushed level, the protective value of protection forests is worth 97378 CHF/ha. More fine-grained analyses are necessary though to assess the benefit provided by a specific protection forest.

6.3. Energy

Renewable energy production critically depends on NCPs. Around half of the primary domestic energy production comes from hydropower. According to our estimates, 1 cubic meter of surface water used for hydropower production on average generates value of 0.03 CHF. Storage power plants take advantage of the ability to retain large amounts of water and to produce energy when demand is high. Sediments can result in impoundment filling, which reduces a storage power plant's comparative advantage. The retention of sediment in a catchment basin above a storage power plant avoids impoundment filling. Sediment retention contributes on average 0.04 CHF/m3 of sediment. Apart from hydropower production, biomass -in particular fuel wood- contributes to energy production. Wood for energy production contributes on average 48 CHF/m^3 of fuel wood.

6.4. Tourism

Several NCPs are relevant to the tourism sector. For example, the possibility to do recreation activities in the Swiss landscapes and nature drives the country's tourism industry. The Swiss natural environment offers opportunities to perform several outdoor recreational activities that attract tourists. Our estimates for the NCP Physical and psychological experiences show that to travel to ValPar.CH study parks – Beverin, Gruyère Pays-d'Enhaut, Jurapark and Pfyn-Finges – Swiss households spend approximately 720,773 CHF annually. This corresponds to a range between 11.91 CHF/km to 788.21 CHF/km of hiking trails, depending on the study park. The learning and inspiration aspect of nature can also be a relevant contribution to tourism. As indicator for this NCP, we use pictures taken in parks. Their estimated contribution ranges from 21.91CHF/picture to 201.57CHF/picture.

6.5. Health

Our estimates also emphasise high relevance of NCPs for the population's health. By reducing PM10 concentration in the air, trees and forest reduce morbidity and mortality costs due to excessive PM10 pollution, by 3304 CHF per µg/m3, on average per 1 hectare of populated country territory. The beneficiaries of this service are the Swiss population, and the private and public sectors, who bear the costs of reduced productivity in case of employees´ sickness and premature death.

By reducing concentrations of CO2 in the atmosphere, soils, forests, and other wooded areas regulate the local and global climate. They also store enormous amounts of carbon. This service directly contributes to human health and well-being and reduces health care costs. We propose to value climate regulation services using an estimate of MAC for the Swiss economy of 182 CHF/t CO2. Considering the high degree of the economic development of the country and that, as an alpine country, it is particularly affected by climate change (BAFU et.al. 2020), costs of inaction on climate change may be particularly high in Switzerland. Therefore, we recommend using in addition to the MAC estimate a SCC estimate of 301 CHF/t CO2.[12]

Recreation activities in nature positively impact physical and mental health. Our estimates for the NCPs Physical and psychological experiences show that to visit ValPar.CH study parks – Beverin, Gruyère Pays-d'Enhaut, Jurapark and Pfyn-Finges – Swiss households spend at least 720,773 CHF CHF annually only in these 4 parks. This corresponds to a range between 11.91 CHF/km to 788.21 CHF/km of hiking trails, depending on the study park. Note that through the positive impact of physical and mental health this NCP generates also economic benefits in the form of reduced healthcare costs. The reduction of healthcare costs of various recreational activities are difficult to quantify, and are not considered in this study.

Natural Medicinal Products (NMPs) constitute one of the most common human uses of biodiversity (species and related habitats) that contribute significantly to human well-being (Brauman et al. 2019). Examples of medicinal plants' monetary contributions to the pharmaceutical sector include 12.74 CHF/kg of flowering nettle, 12.21 CHF/kg of black elderflower, or 0.81 CHF/kg of horse chestnut.

Switzerland is well known for its rich water resources and high quality of freshwater. Water is safe to drink from both taps and numerous public fountains. According to our estimates, the contribution of the ecosystem to retaining plant nutrients rather than releasing them into the water has a value of 10.15 CHF/kg of nitrate retained, and 7.01 CHF/kg of phosphate retained (which corresponds to the avoided

[12] The latter was derived using the SCC estimate of 180 Euro of 2016/t CO2eq of the German Environmental Agency and is close to the CO2 price referred to in the 5th IPCC Assessment Report, i.e. 173.5 Euro 2016/t CO2eq.[12] Both estimates of the CO2 price derived here are substantially higher than 120 CHF/t CO2eq – the current level of the CO2 levy in Switzerland and correspond to a carbon price of 690 CHF/t of carbon and 1106 CHF/t of carbon, respectively.

damage cost of removing these nutrients from the water). Note that we do not consider the removal of other substances such as pesticides or microplastics.

6.6. Habitat creation and maintenance

Maintaining and creating habitats may reduce the risk of biodiversity collapse and therefore constitutes an essential contribution to societies, because biodiversity loss threatens provisions of NCPs essential for human wellbeing. As in most OECD countries, biodiversity in Switzerland has been declining continuously for decades – a trend that has not yet been halted (Gubler et al. 2020). Expert assessments indicate that about half of the approximately 235 Swiss habitat types (Delarze et al. 2015) are classified as endangered (FOEN 2017; OECD 2017). Habitat creation and maintenance often precludes the use of land for various profitable economic activities or requires restrictions on such activities. Therefore, to incentivize economic actors to comply with regulations aimed at habitats' creation and restoration the Swiss government provides a number of direct payments and other policy support instruments. These payments reimburse economic actors for the net benefits foregone due to compliance with relevant policies/regulations. According to the Swiss Federal Finance Administration, public expenditures on habitat creation and maintenance constituted 2892 CHF/ha of the country's territory in 2020 (on average 2821 CHF/ha for the period 2016-2020). A large share of this expenditure is dedicated to research on biodiversity. In the agricultural sector, direct payments for biodiversity promotion range from 300CHF/ha (prices of 2023) for wide sowing of winter cereal to 4000CHF/ha (prices of 2023) for beneficial insect strips in permanent crops in the valley and hill zones (see Table 5 for more details). Although these expenditures may be insufficient to avoid future economic damages due to biodiversity loss, they can be considered as proxies for how much it is worth to society today to avoid potential future damages due to biodiversity loss.

7. Computation of monetary flows of NCPs

In this section, we demonstrate how the estimates of NCPs' monetary values can be used to derive aggregate contributions of selected ecosystem services at the national level using the data on the current NCP's physical flows and other indicators. As mentioned previously, for each NCP we focus only on one or a few selected indicators. Accordingly, the estimates presented in Table 2 refer only to contributions of nature captured by these indicators. We selected the indicators based on relevance and data availability, but they cannot claim to comprehensively represent the entirety of an NCP. There is much scope to refine these indicators and investigate additional or alternative indicators in future research.

Table 2: NCPs' monetary flows' estimates, in CHF of 2019

NCP	Indicator / explanation	Value estimate (mill. CHF)	Range (mill. CHF) Min	Max
Regulating NCPs				
Habitat creation and maintenance	Biodiversity expenditure 2013-2020 in CHF of 2019 (incl. expenditures on fundamental research (41.1%) and direct payments (24.4%)	11,359		
Pollination and dispersal of seeds	Value of pollination based on 3 different valuation methods: domesticated pollinator use; manual pollination; production function approach, respectively	9; 360; 363	5; 150; 227	13; 530; 498
Regulation of air quality	Avoided mortality and morbidity costs associated with PM10 pollution due to vegetation: values excl. and incl. immaterial costs of value of life year lost (VLYL), respectively	8; 106	5; 71	10; 140
Regulation of climate	Value of carbon stored based Marginal Abatement Cost (MAC) and Social Cost of Carbon (SCC) estimates, respectively	244,107; 403,537		
	Value of carbon sequestered annually in LULUCF based on SCC and MAC estimates	317; 524		
Regulation of freshwater quantity, location and timing	Value of consumed irrigation water	0.2		
Regulation of freshwater quality	Value of avoided export of N per year	4130		
Formation, protection and decontamination of soils	Value of retained sediments from a hydropower perspective	113		
Regulation of hazards and extreme events	Value of protection by protection forests in Switzerland	214		
	Value of protection by flood plains in Switzerland	177		
Regulation of organisms detrimental to humans	Value of avoided damage to crop production due to biocontrol of common vole populations by raptor species; s.t. probabilities of common vole outbreaks of 0.20; 0.25 and 0.33, respectively	26; 33; 45		
Material NCPs				
Energy	Value of harvested energy wood (average 2013-2018)	120		
	Value of water used for hydropower production	11,000		

Food and feed	Soils ecosystem services to food and feed production (captured by agricultural land)	3,640	2,148	5,132
Materials and assistance	Value of harvested material wood (average 2013-2018)	246		
Medicinal, biochemical and genetic resources	Lack of data on quantities of medicinal plants harvested in the wild in Switzerland	na		
Non-material NCPs				
Learning and inspiration	Value of pictures posted on a picture platform (gettyimages.ch) found when searching for "Natur Schweiz"		3	24
Physical and psychological experiences	Value added of nature-related tourism	5,363		

Regulating NCPs

- Habitat creation and maintenance

We report the total biodiversity expenditure data as reported by the Federal Finance Administration (Eidg. Finanzverwaltung). This indicator refers to biodiversity expenditure at different levels of government and for various functions: Fundamental research, Museums and fine arts, Waterway constructions, Species and landscape protection, Air pollution control and climate protection, Pollution control n.e.c., Environmental protection n.e.c., Land use planning, Production improvements livestock, Production improvements crops, Direct payments, Forestry, and Hunting and fishing. The main positions in the total biodiversity expenditure in the 2016-2020 period were expenditures on fundamental research (41.1%) and direct payments (24.4%).

- Pollination and dispersal of seeds

The aggregate contribution of pollination can be easily computed using statistics on agricultural land use for production of pollination-dependent crops. Our aggregation results suggest relatively similar magnitudes of the pollination contribution to agricultural production when applying the monetary values derived using the production function approach and as the replacement cost estimates of manual pollination, whereas the pollination contribution assessed based on the replacement costs of using domesticated pollinators were found to be considerably lower: 8.7 Million CHF compared to 362.8 and 360.0 CHF according to production function and manual pollination estimates, respectively.

- Regulation of air quality

We use spatially explicit estimates of PM10 captured by vegetation derived by Külling, N. et al. (2024)for year 2019 using InVEST model to measure avoided health and mortality costs for single FOS STATPOP[13] raster hectares. Then, we sum up the avoided damage estimates over all STATPOP raster hectares results to compute the aggregate contribution of vegetation to reduction of excessive PM10 pollution.

According to our measurements, air regulating services of vegetation allow to reduce health and mortality costs by 106 Mio. CHF given current levels of PM10 pollution.[14] The total morbidity and mortality costs due to PM10 pollution, however, remain very high, as much as 4827.8 Mio. CHF (our estimate for 2019). Accordingly, the relative contribution of vegetation to reducing social costs associated with air-pollution is relatively low which implies that more rigorous measures are required to reduce air pollution.

- Regulation of climate

The total current contribution of nature to climate regulation is assessed to be 244,430 and 404,070 Mio CHF based on MAC and SCC, respectively, thereof 317 and 524 Mio CHF due to CO2 emissions sequestered annually in the sector Land Use, Land-Use Change and Forestry (LULUCF). These estimates were derived using assessments of carbon stored on the territory of the country by Külling,

[13] For details s. https://www.bfs.admin.ch/asset/de/23528269

[14] Our estimates of avoided mortality and morbidity costs refer to populated areas with vegetation. Accordingly, they account only for local effects of forest and other vegetation when assessing vegetation contribution to air regulation but do not consider spill-over effects of air-regulating services of forest and other vegetation situated beyond populated areas.

N. et al. (2024) and the volumes of GHG emissions sequestered in LULUCF according to the Swiss GHG inventory.

- Regulation of freshwater quantity, location and timing

The estimated monetary volume of consumed drinking water is computed as the product of the median of the cantonal exchange value estimates for surface water and an estimate of the quantity of consumed surface water from lakes, rivers, channels and creeks (Björnsen Gurung and Stähli 2014, p. 27).

- Regulation of freshwater quality

The volume of avoided export of N per year is computed as product of the exchange value estimate and the estimate of the physical flow that was computed at the national scale with the software InVEST. We do not compute the corresponding volume for P due to complexities in the estimation of the physical flow.

- Formation, protection and decontamination of soils

The physical volume of retained sediments was estimated with the InVEST software by Külling, N. et al. (2024). The monetary volume of retained sediments is computed as an estimate of avoided damage from the perspective of hydropower production. The underlying assumption is that if the sediments were not retained, they would clog waterways and fill impoundments which would reduce the potential for hydropower production. For simplicity, we further assume that 1 ton of sediment would displace 1 cubic meter of water. In our computation, the monetary volume of the tons of sediment retained thus is equivalent to the monetary volume of hydropower produced by water that is not displaced.

- Regulation of hazards and extreme events

For the NCP Regulation of hazards and extreme events, we multiplied the areas of Swiss protection forests and flood plains (data provided by Külling, N. et al. (2024)) by the corresponding exchange value estimates. In the case of protection forests, we use the estimate that more closely represents the protection value rather than the value of the forest as an asset.

- Regulation of organisms detrimental to humans

The aggregate contribution of biocontrol by raptor species at the national level is asessed to vary from 26 to 45 Mio. CHF subject to the probabilities of common vole outbreaks used in our estimations. These estimates were derived by multiplying the avoided damage estimates per ha (Table 3) with the area of arable land in the country.

Material NCPs

- Energy

The monetary volume of energy wood is computed as the product of the average for 2013-2018 of the weighted averages of our exchange value estimates for different assortments and an average of the amount of energy wood harvested (2013-2018). The monetary volume of water for hydropower production is computed as the product of the median exchange value estimate and an estimate of the overall national quantity of water used for hydropower production (Björnsen Gurung and Stähli 2014, p. 22).

- Food and feed

We value the aggregate contribution of soil ecosystem services to food and feed production in Switzerland by aggregating FOS statistics on agricultural land use with our production function estimates of land marginal contributions to agricultural production. Considering agricultural land use in the 2015-2019 period, this NCP contributed 3640.0 Mio. CHF to agricultural production in the country.

- Materials and assistance

The monetary volume of material wood is computed as the product of the average for 2013-2018 of the weighted averages of our exchange value estimates for different assortments and an average of the amount of construction wood harvested 2013-2018.

- Medicinal, biochemical and genetic resources

Given a lack of data on the quantities of the medicinal plants harvested in nature (not cultivated) we cannot compute the monetary volume of this indicator for the NCP Medicinal, biochemical and genetic resources.

Non-material NCPs

- Learning and inspiration

For the NCP Learning and inspiration we present a range for the monetary volume. The range is based on the number of pictures that are presented on the picture platform 'gettyimages.ch' when searching for pictures with the search terms "Natur Schweiz" (nature Switzerland) and the range of exchange value estimates for different picture qualities.

- Physical and psychological experiences

Given current preferences of Swiss population and foreign tourists for recreation, the total contribution of nature/ecosystems to Swiss tourism is 5,363 Mio. CHF. It has been derived as the value added of expenditures incurred on nature-related tourism activities in the country (Nathani and Steg 2024).

8. Conclusions

This report presents an application of the conceptual framework and methodology for deriving monetary values for the 18 NCP economic benefit indicators for 15 NCPs selected in the ValPar.CH project for studying the benefits and added value of ecological infrastructure in Switzerland. It also reports the monetary values for these NCPs while applying the developed framework and procedures.

As any methodological approach, ours has certain limitations: we focus exclusively on NCPs' positive contributions, we assess NCP values from an anthropocentric perspective, we do not consider ecosystems' intrinsic values, and we mostly use only one benefit indicator per NCP. Due to these limitations, the aggregated monetary value of NCP flows on a certain unit of land will be incomplete. However, our ambition was to lay out a general framework and methodology on how to obtain consistent monetary values that can be aggregated for several NCPs and scaled from sub-national to national levels in Switzerland. The approach presented in this report builds on exchange values as proposed in the SEEA framework (UN DESA 2019) and can easily be reproduced and expanded to additional NCP benefit indicators in future research. This in turn will allow for a more comprehensive assessment of the added value of ecological infrastructure. Our approach expands the valuation framework presented by Horlings et al. (2020) and incorporates in the analysis the Institutional Resource Regime perspective (Gerber et al. 2009; Lieberherr et al. 2019). We argue that understanding the public policies and property rights governing an ecosystem and associated NCPs is important, especially in highly regulated economies like Switzerland. This can help address distortions due to market failures and governmental interventions.

Our results demonstrate that NCPs are valuable inputs to the economy and their contributions can be expressed in monetary terms. In addition, our results show that many economic sectors greatly benefit from NCPs. However, as the monetary valuation of the NCPs is based on individual selected indicators of NCP benefits, our economic value estimates are only to be understood as examples and partial aspects and do not represent all benefits of the NCPs to the economy. Accordingly, there should be no competition for the highest economic value when measuring benefits and added value of ecological infrastructure. Furthermore, we recommend avoiding direct comparisons of added values of ecological infrastructure between different locations as our list of NCP indicators is not complete and may be better suited for measuring economic benefits of NCPs in one region than in another.

Finally, monetary values of NCP indicators depend on economic and institutional environments. The values of the NCP indicators presented in this report are pegged to the current economic and regulatory framework. Accordingly, they reflect NCPs' current values for society. They may show significant changes in the future, e.g. due to an amplifying natural resource scarcity and corresponding changes in markets and the regulatory environment.

Part B: Methods and results on monetary value estimates of NCP benefits

9. Regulating NCPs

9.1. Habitat creation and maintenance

The IPBES (Brauman et al. 2019) includes "Habitat Creation and Maintenance" among its main reporting categories, as a regulating NCP, and defines it as "*The formation and continued production, by ecosystems or organisms within them, of ecological conditions necessary or favorable for living beings of direct or indirect importance to humans. E.g. growing sites for plants, nesting, feeding, and mating sites for animals, resting and overwintering areas for migratory mammals, birds and butterflies, roosting places for agricultural pests and disease vectors, nurseries for juvenile stages of fish, habitat creation at different soil depths by invertebrates*".

Maintaining and creating habitats may reduce the risk of biodiversity collapse and therefore constitutes an essential contribution to societies, because biodiversity loss threatens provisions of NCPs essential for human wellbeing. There are important interactions among NCPs, including trade-offs and synergies, and the NCP Habitat creation and maintenance is the most notable example of such interactions. Natural or semi-natural habitat restoration can benefit many NCPs simultaneously, e.g. Pollination; Regulation of air quality; Regulation of climate; Regulation of freshwater quality; Formation, protection and decontamination of soils; Regulation of hazards and extreme events; Regulation of organisms detrimental to humans; Learning and inspiration and Maintenance of options (IPBES 2019).

Over the last century Switzerland has lost a significant part of previously widespread habitats such as *alluvial* zones, mires, and dry meadows and pastures (OECD 2017). Expert assessments indicate that about half of the approximately 235 Swiss habitat types (Delarze et al. 2015) are classified as endangered (FOEN 2017; OECD 2017).

Resource regime

The Constitution of the Swiss Confederation (Article 78 "Protection of natural and cultural heritage") and international agreements provide the keystone legislative framework for the protection of biological diversity (FOEN 2017). As in most OECD countries, biodiversity in Switzerland has been declining continuously for decades – a trend that has not yet been halted (Gubler et al. 2020). Several economic sectors and activities are responsible for these developments. However, since the adoption of the Swiss Biodiversity Strategy in 2012 and the corresponding Action Plan in 2017, there have been more efforts at the federal and cantonal levels, to mainstream biodiversity considerations into sectoral and other policies (OECD 2017).

Three main federal laws and their ordinances are at the core of the modern biodiversity-related legislative framework: i. the Act on Protection of Nature and Cultural Heritage (NCHA, 1966), which mandates the Confederation, cantons and municipalities to preserve habitats and heritage sites requiring ecological protection for native animal and plant species and for biotopes of high ecological value, and to mitigate the extinction of wildlife. ii. the Act on Hunting and Protection of Wild Mammals and Birds (1986), and iii. the Fishing Act (1991) (OECD 2017).

In the following, we discuss negative impacts of human activities on habitats and biodiversity for selected sectors that alter habitats particularly strongly, and therefore are key domains for policy interventions aimed at habitat creation and maintenance.

Agricultural production can be a main cause of habitat destruction. The adoption of some production practices can severely damage habitats. Intensive farming leads to overuse, pollution, fragmentation and destruction of habitats. Under intensive agricultural land use, low-nutrient and humid areas, small water bodies and small-scale structures disappear, and the landscape becomes homogeneous and impoverished. In addition, various habitats are contaminated with pollutants from agriculture, such as nitrates (Gubler et al. 2020).

In the past, agricultural policies did not take into account aspects of environmental sustainability. They instead focused on increasing productivity, ensuring the availability of food supplies, market stabilization and ensuring fair standards of living for farmers. A series of reforms were introduced in Switzerland since the early 1990s to align the agricultural producers support policies with environmental goals, including biodiversity conservation. In addition, the federal government has adopted since the late 90ies the Agriculture Act (1998, last amended 2015), which is one of the federal laws taking into account the interests of nature conservation by protecting biodiversity and natural habitats (OECD 2017). However, some agricultural producer support measures still unintentionally create incentives to adopt biodiversity damaging farming practices (Gubler et al. 2020).

Urban planning and the development of the road and railway network cause land use changes that reduce the size of habitats. Increasing volumes of traffic generate increased air polluting emissions, noise and light which negatively impact the quality of habitats (Gubler et al. 2020). For these reasons, policies related to urban planning and the development of the road and railway network also form part of the resource regime for this NCP.

Forests serve as a habitat for a large number of species. Certain practices applied in the commercially exploited forests may alter habitats and species composition. The age structure of trees becomes more uniform, there is often not sufficient quantity and quality of old and dead wood, and distinctive forest habitats such as sparse or humid forests disappear (Gubler et al. 2020). Hence, policies and ordinances related to forest management are also of high relevance for this NCP. For example, the Forest Act (1991, last amended 2013) introduced near-natural management for all forests, and it is considered another federal law which contributes to protecting biodiversity and natural habitats (OECD 2017).

Energy production places different burdens on habitats and biodiversity, subject to the source and production method (Gubler et al. 2020; Popescu et al. 2020). Even relatively environmentally friendly energy production methods, such as hydropower, can damage biodiversity. For example, small and micro hydroelectric power plants have particularly severe impacts on aquatic biodiversity per kWh generated, because they harness the remaining tributaries in the mountain valleys and prevent them from being passable for water organisms.

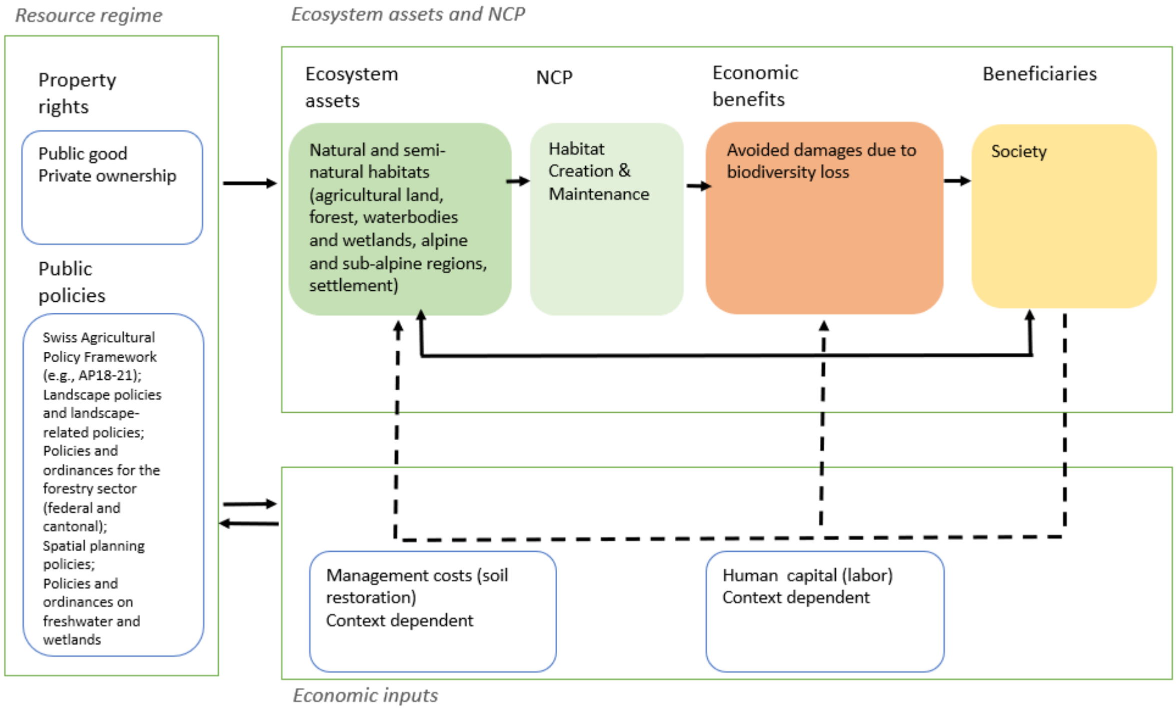

Figure 3: Monetary valuation framework of NCP Habitat creation and maintenance,
Source: authors´ presentation

Economic benefits and beneficiaries

As mentioned above, biodiversity loss threatens provisions of NCPs essential for human wellbeing. Maintaining and creating habitats may reduce the risk of biodiversity collapse and therefore constitutes an essential contribution to societies. Accordingly, the economic benefit of this NCP is avoided damages to society due to biodiversity loss. For this reason, the beneficiary of this NCP is the entire society.

Monetary valuation scope

Swiss policymakers already recognized the danger of biodiversity loss, and introduced a number of policies aimed at improving and restoring habitats and biodiversity conservation, such as the Water Protection Act (1991, last amended 2016), which contains provisions for restoring rivers and lakes so they can fulfil their natural functions and contribute to biodiversity conservation and promotion (OECD 2017)[15].

Habitat creation and maintenance often precludes the use of land for various profitable economic activities or requires restrictions on such activities. Therefore, to incentivize economic actors to comply with regulations aimed at habitats' restoration the Swiss government provides a number of direct payments and other policy support instruments. These payments reimburse economic actors for the net benefits foregone due to compliance with relevant policies/regulations. Although such payments might be insufficient to avoid future damages due to biodiversity loss, they can be considered as a measure of how much it is worth to society today to avoid potential future damages due to biodiversity

[15] The FOEN released in 2013 a video explaining to the public what the restoration of water streams is, and why it is important. Renaturation des cours d'eau en Suisse: http://www.youtube.com/watch?v=4-3jFmtCZy0 (last accessed 30/3/2023)

loss. While direct payments generally promote *conservation* efforts, habitat *restoration* activities are mainly promoted through restoration projects.

Method and data

We report the biodiversity expenditure data compiled by the Federal Finance Administration (Eidg. Finanzverwaltung). The data set contains information on biodiversity expenditure at different levels of government and for various functions: Fundamental research, Museums and fine arts, Waterway constructions, Species and landscape protection, Air pollution control and climate protection, Pollution control n.e.c., Environmental protection n.e.c., Land use planning, Production improvements livestock, Production improvements crops, Direct payments, Forestry, and Hunting and fishing. The federal expenditure data from this data set is used for reporting toward SDG target 15.a of the Agenda 2030 "Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems", as well as the corresponding Swiss target 15.a. The detailed data is provided in the adjoining database. To compute an aggregated exchange value from this data, we sum the biodiversity expenditure at the municipal, cantonal, federal and NGO level. We then divide this sum by the area of Switzerland to obtain a value per hectare (Table 4). Note that dividing by the country's entire surface is somewhat arbitrary, but we lack data on the spatial scope to which the data in the different categories applies.

Table 4: Exchange values for habitat creation and maintenance

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CHF/ha in 2019 prices	2593	2639	2691	2700	2803	2848	2859	2892

Data source: Eidgenössische Finanzverwaltung (2020)

To provide more specific data on financial support that can be received for habitat creation and maintenance, we report on policy incentives in agriculture (see Table 5) and forestry (see Table 6).

Table 5: Biodiversity payments in the agricultural sector as of 2023

Types of biodiversity promotion sites and beneficial insect strips	Contribution quality level I, CHF per ha or tree				Contribution quality level II, CHF per ha or tree				Network contribution	Protection of Nature and Cultural Heritage Act
	Valley zone	Hill zone	Mountain zone I, II	Mountain zone III, IV	Valley zone	Hill zone	Mountain zone I, II	Mountain zone III, IV	Valley zone - mountain zone IV	
Meadows and pastures										
Extensively used meadow	1080	860	500	450	1920	1840	1700	1100	1000	
Low intensity meadow	450	450	450	450	1200	1200	1200	1000	1000	
Vegetation on wet and humid sites with traditional litter use	1440	1220	860	680	2060	1980	1840	1770	1000	
Extensively used pasture	450	450	450	450	700	700	700	700	500	contribution possible, but depends on canton
Forest pasture	450	450	450	450	700	700	700	700	500	
Riparian meadow along watercourses	450	450	450	450					1000	
Species-rich green and litter area in the summer pasture area					150/ha, max 300/NST (only in the summer pasture area)					
Arable land										
Extensively cultivated marginal strip sown or planted with arable crops	2300	2300	2300	2300					1000	
Perennial area seeded with native wild herbs	3800	3800							1000	
Area sown or overgrown with native arable wild herbs	3300	3300							1000	contribution possible, but depends on canton
Perennial strip sown or overgrown with native wild herbs	3300	3300	3300						1000	

Area sown with wild herbs especially attractive for pollinators and beneficial insects	3300	3300								
Wide sowing of winter or summer cereals, especially for the promotion of skylarks and hares as well as the field flora	300	300	300	300					max. 500	
Permanent crops and woody plants										
High stem fruit trees (without nut trees)	13.5	13.5	13.5	13.5	31.5	31.5	31.5	31.5	5	
Nut trees	13.5	13.5	13.5	13.5	16.5	16.5	16.5	16.5	5	
Site-specific individual trees and avenues									5	
Hedges, field and riparian woods (incl. herbaceous border)	2160	2160	2160	2160	2840	2840	2840	2840	1000	contribution possible, but depends on canton
Vineyard area with natural biodiversity					1100	1100	1100	1100	1000	
Beneficial insect strips in permanent crops	4000	4000								
Other										
Ditch, pool, pond										
Ruderal area, cairns, stone mounds										
Dry stone wall										
Region-specific biodiversity promotion area within agricultural land (on open cropland, grassland and pasture, in vines, hedgerows, field and riparian copses)									1000	contribution possible, but depends on canton
Region-specific biodiversity promotion area outside of the agricultural land										

Data source: (Agridea 2023)

For biodiversity conservation in forests, the cantons receive federal lump sums (see Table 6). Each canton can use these resources to devise its own programs for forest owners. Overall, the lump sums are supposed to cover around 40-50% of the total investment needed to achieve the goals of a so-called national forest biodiversity subprogram.

Table 6: Forest biodiversity indicators and payments from the federal to cantonal level

Indicator	Payment specification
Forest reserves ≥5ha but ideally ≥20ha and legally binding protection, secured ideally for ≥50 years	CHF 20 – 140 per ha and year
Mature forest stands usually ≥1ha, legally binding protection	Lump sum CHF3000-150000 depending on area size
Habitat trees with a BHD ≥50cm for deciduous and ≥70cm for coniferous trees with at least one ecologically relevant characteristic, protection secured until the tree decays	One time payment of 250/tree
Upgrading forest fringes and other network elements under consideration of the neighboring grassland as well as habitats and species of national importance	Lump sum per ha CHF5000
Upgrading humid biotopes under consideration of the neighboring grassland as well as habitats and species of national importance	One time payment of CHF4000/ha and CHF10000 lump sum per biotope of min. 0.5 ha
Managed cultural-historical, ecological and scenic valuable forests (middle forest, coppice forest, wooded pastures, copses).	Flat rate per ha of habitat enhanced: CHF 4000 (per intervention) Forestry maintenance on forest (Wyt) pastures: without integrated management plan: CHF 4000/ha; with integrated management plan: CHF 8000/ha, one-time in NFA period Chestnut orchards (Selven) restoration: CHF 20 000/ha (per intervention).

Source: BAFU (2018): Handbuch Pro-grammvereinbarungen im Umweltbereich 2020 – 2024. Mitteilung des BAFU als Vollzugsbehörde an Gesuchsteller. Bundesamt für Umwelt, Bern. Umwelt-Vollzug Nr. 1817: 294 S.

9.2. Pollination and dispersal of seeds

The IPBES (Brauman et al. 2019) includes "Pollination and dispersal of seeds and other propagules" among its main reporting categories and defines this NCP as the *Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae or spores of organisms, beneficial or harmful to humans.* Several studies (see e.g. van Berkel et al. (2021)) explain this NCP with a focus on pollination, stating that pollination services are the ecosystem contributions by wild pollinators to the fertilization of crops. In Switzerland, pollination-dependent agricultural products are cultivated on approximately 5% of the utilized agricultural area and 14% of the arable land (Sutter et al. 2017a). These include commercial crops, also used for value added products, such as apples, pears and colza.

Resource regime

Crop pollination is primarily provided by the ecosystems in the landscape surrounding the crop fields and not by the cropland itself (van Berkel et al. 2021). Wild pollinators require sufficient resources in the agricultural landscape and previous studies e.g. Horlings et al. (2020) indicate that pollination service often depends on small landscape elements such as hedgerows or forest patches. These resources include suitable nesting habitats (e.g. tree cavities, or suitable soil substrate) as well as sufficient floral resources (i.e. pollen and nectar) (van Berkel et al. 2021). Thus, policies designed to preserve, protect and restore small landscape elements are crucial in maintaining the supply of pollination services. In Switzerland, sustainable landscape development is a joint responsibility of the confederation, cantons and communes. At the federal level, the Swiss federal government makes landscape quality contributions as part of its agricultural policy, to assist farmers in implementing agricultural practices that preserve and enhance a diverse landscape. The Swiss Landscape Concept ("*Landschaftskonzept Schweiz*") (SLC) serves as a guideline for the landscape-related activities of the Confederation. The SLC is a concept defined in Article 13 of the Spatial Planning Act (RPG), and its most recent version was adopted by the Federal Council on May 2020. The Swiss parliament also ratified the European Landscape Convention of the European Council in 2012, which came into force one year later. Other important landscape-related instruments for the country include the Swiss Biodiversity Strategy and the Forest Policy 2020[16].

Switzerland also provides an example of application of agri-environment and stewardship schemes that offer monetary incentives to farmers who adopt biodiversity- and environmentally-friendly management practices (IPBES 2016). These schemes are called 'ecological compensation areas' (wildflower strips, hedges or orchards etc.)[17]. Their purpose is to enhance pollinator diversity and plant reproductive success in nearby intensively managed farmland. Notably, farms receiving these payments were found to house a significantly higher pollinator community compared to farms without ecological compensation areas (Albrecht et al. 2007).

In 2013, the Swiss Federal Office adopted the "*Nationaler Massnahmenplan zur Gesundheit der Bienen*", an action plan specifically designed to promote policies, research and practices, targeted to protect pollinators.

[16] The NCP Energy and the NCP Material and Assistance provide more details on the resource regime relevant to forests.

[17] For further information see: www.agroscope.admin.ch/agroscope/de/home/themen/umwelt-ressourcen/biodiversitaet-landschaft/oekologischer-ausgleich/oekologischer-ausgleich.html (last accessed: 30.3.2023).

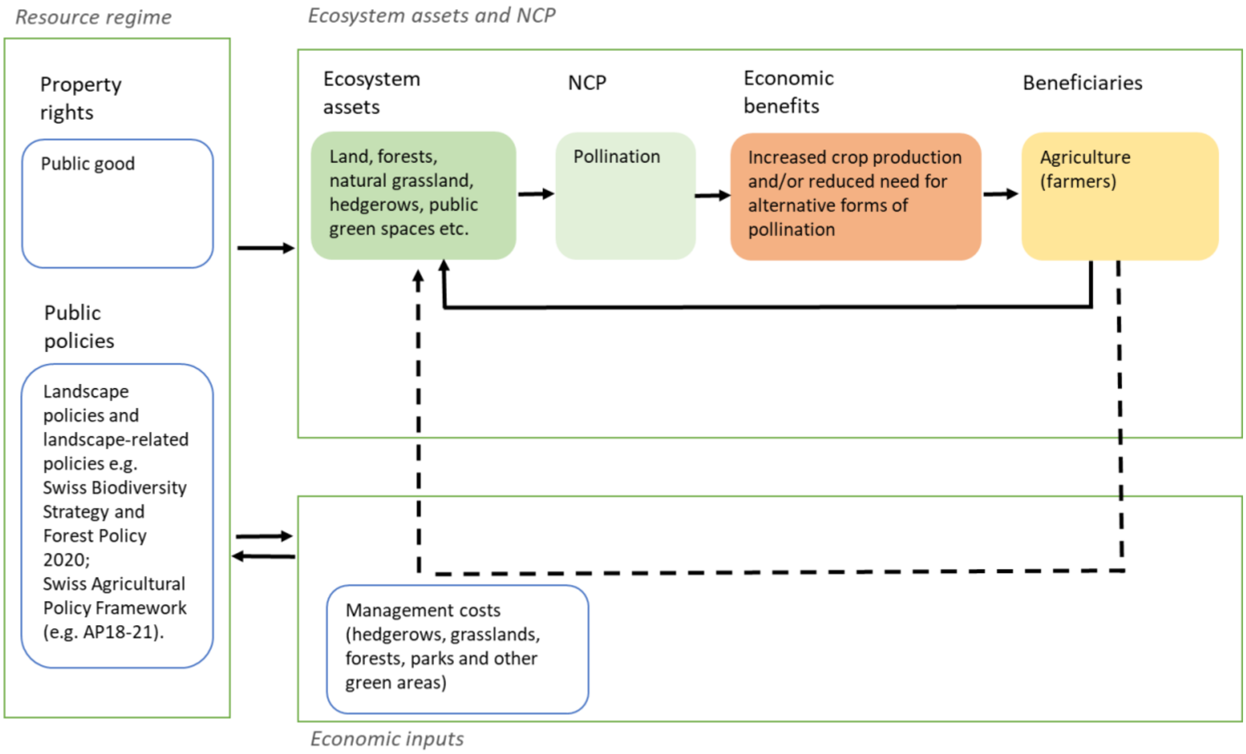

Figure 4: Monetary valuation framework of NCP Pollination
Source: authors´ presentation

Agricultural policies and action plans related to the timing, quantities and type of allowed pesticides also affect this NCP, because many pesticides (including insecticides, fungicides, and herbicides) harm pollinators either directly (killing them and/or affecting their foraging behaviour and pollen collecting efficiency) or indirectly (e.g. through the elimination of plants used for their foraging and nesting materials) (Sponsler et al. 2019; IPBES 2016). Such policies relate to the Federal Law on Agriculture (*SR 910.1 Bundesgesetz vom 29. April 1998 über die Landwirtschaft – Landwirtschaftsgesetz, LwG*) and the current and possibly future agricultural policy frameworks, such as the AP18-21 and AP22+, which contain norms impacting the agricultural sector's ecological footprint[18]. The "*Aktionsplan zur Risikoreduktion und nachhaltigen Anwendung von Pflanzenschutzmitteln*" approved by the Swiss Federal Council in 2017 is another example of an initiative at the core of the resource regime for pollination, because it includes restrictions (applied in Switzerland since 2018) to the use of three neonicotinoids (clothianidina, imidacloprid e tiamethoxam), which are a class of insecticides particularly harmful to pollinators.

Economic benefits and beneficiaries

Crop pollination is a regulating NCP defined as the fertilization of crops by pollinators that increase crop production and may affect crop quality. Sales of plants dependent on pollinators and seed dispersers generate income. Pollination is essential to support the production of a wide range of crops produced in Switzerland. Hence, pollinator decline can result in pollination deficits, which typically manifest as reduced crop yields and/or malformed fruits and vegetables (Rose et al. 2015). Given this background, local agricultural producers are the beneficiaries of this NCP, as a decline/improvement in pollination services directly affect producer surplus (Hein 2009), especially for producers of crops

[18] As of June 2021, the discussion about the AP22+ has been suspended, and the entry into force of this reform is estimated for January 2025. See: https://www.blw.admin.ch/blw/de/home/politik/agrarpolitik/ap22plus.html last accessed: 8/7/2021.

highly dependent from pollination such as apples, apricot, pears and pumpkins. Farmers experience a cost when they (partly) lose pollination in their fields and surrounding environment. The extent of the damage caused by the loss of pollinators varies across agricultural produces and may relate to reduced quantity (yields) and quality, increasing investments in costly adaptation strategies such as carrying out pollination by hand, which translate into higher production costs because of the higher cost of labor inputs, or even the need to switch to alternative crops that may give lower returns or require new investments (Eardley 2006; Hein 2009). Previous experimental studies conducted in Switzerland have shown that even for crops with low dependence on pollination (i.e. their production reduction in absence of pollinators would be in the range of 0-5%, based on global assessments) such as winter oilseed rape (*Brassica napus L.*), insect pollination could increase yields between 7% to 23% (Sutter and Albrecht 2016)[19].

Monetary valuation scope

The literature estimating the monetary value of pollination and seeds dispersal has focused on their contribution to agricultural production. For some crops more than others, pollination can be considered as one of the inputs into agricultural production, together with a range of inputs including labor, capital, land, variable inputs (e.g. seeds, fertilizers, irrigation water). Therefore, the production function approach is one of the valuation methods used for this NCP (Freeman 2014; Hein 2009; Ricketts et al. 2004).

The replacement cost method is another valuation method that has been used for valuing pollination, e.g. (Horlings et al. 2020; Ecoplan and INFRAS 2014; Peter et al. 2021a; INFRAS and Faunatur 2022; Díaz et al. 2015). This method relates the value of an ecosystem service to the costs of an alternative way of obtaining the same benefits. For instance, the value of pollination by wild bees can be obtained on the basis of the costs of bringing in managed bees, or on the basis of the costs of hand pollinating crops in the absence of insect pollinators (Eardley 2006; Hein 2009; INFRAS and Faunatur 2022; Peter et al. 2021a). The study by Peter et al. (2021a) and INFRAS and Faunatur (2022) applies this method in the context of Swiss agricultural production and provides estimations for the annual costs of replacing a share of wild pollinators with hand pollination and with domesticated pollinators.

Choices related to the scope of this ecosystem service pertain to what agricultural products to include. Crops included in this analysis are selected on the basis of the choices made in previous Swiss studies (INFRAS and Faunatur 2022; Peter et al. 2021a; Sutter et al. 2017a), of the importance for Swiss agriculture, considering their dependence on pollination, and data availability.

Method and data

The direct economic value for Swiss agriculture of pollination services was calculated in a previous study by Sutter et al. (2017a). This study applies the FAO Guidelines for The Economic Valuation of Pollination Services at National Scale (Gallai et al. 2009). These guidelines are at the basis of the "Dependency Ratios Approach", which builds upon, but simplifies, the production function approach. Table 7 summarizes the main characteristics of the Dependency Ratios Method for valuing the NCP pollination and dispersal of seeds. Dependency ratios aim to calculate the portion of the production that can be lost in the absence of pollinators, with a focus on wild unmanaged pollinators. Pollinators can be divided into several animal groups (mainly insects, typically bees) or species known to be important flower visitors or pollinators (Klein et al. 2007). This choice is consistent with other European studies

[19] The experiment was conducted in spring 2014 at Agroscope-Reckenholz in Zurich, Switzerland. For further detail refer to Sutter and Albrecht 2016.

using the SEEA approach, e.g. Horlings et al. (2020) for the Netherlands. For several reasons, unmanaged pollinators can only partly be replaced by commercial beehives. Some wild pollinators such as wild bumble bees are able to fly and pollinate at much lower temperatures than honey bees, and in general wild pollinators remain active in more unfavorable meteorological conditions than honey bees (e.g. with moderate rainfall). This is an important aspect considering the climate and topological conditions in Switzerland. In addition, there are crops for which wild pollination cannot be replaced by managed pollination, or can be replaced only to some small extent, for maintaining their yields and products' quality. These crops include important ones for Swiss agriculture, such as pears, blueberries, tomatoes, and some apples varieties (Remme et al. 2018; Sutter et al. 2017a). Sutter et al. (2021), Sutter et al. (2017b), and Sutter and Albrecht (2016) provide further information about pollination ecosystem services in Switzerland. Our suggestion is to build upon the above-mentioned FAO Guidelines, updating the previous analysis presented by Sutter et al. (2017a), e.g. re-calculating the value of this NCP using crop production quantities/yields per hectare, areas under production and producers' prices as of 2019, and including more robustness analysis (described below).

Table 7: Main characteristics of the Dependency Ratios Method for valuing the NCP pollination and dispersal of seeds

Category	Brief Explanation	Strengths	Weakness	Important references
Market based method	Portion of the total market price of crops times the dependency ratio (how much production would be lost if there would be no pollination)	Captures benefits across different crops; Captures producer welfare; Applicable at all scales; Minimal data requirements; Comparability with previous studies conducted for Switzerland	Estimates only producer benefits; might generalise across crops; Does not account of other inputs to crop production, hence it may overestimate benefits; based on global assessments stemming from literature reviews and expert consultations	Klein et al. (2007); Sutter et al. (2017a)

Source: authors´ presentation, adapted from Breeze et al. (2016) and Badura et al. (2017).

Table 8: Value of pollination for selected crops in Swiss agriculture in 2014.

Crop	Classes of dependence of crops on pollination	Producers price in 2014 CHF/t	Production (tons) in 2014	Value of pollination in Mio CHF in 2014
Pumpkins	Essential	1530	11632	16.91
Apples	High	1004	231343	150.97
Currants	Modest	4768	470	0.56
Beans	Low	1009	10729	0.54

Note: Crops have been chosen among commercial crops, based on their dependency on pollination. This was determined based on (Klein et al. 2007). Prices to producers refer to 2014 and production quantities are from FAOSTAT. Source: extract of Table 2 in Sutter et al. (2017a).

As discussed, crops differ in pollination requirements. We suggest assigning to crops produced in Switzerland the five classes of pollination dependence, based on the categories defined by Klein et al.

(2007). In this study, Klein et al. (2007) provide ranges for the proportion of crop production that can be attributed to animal pollination, based on an extensive literature review and expert consultations. The five classes range from crops where i. pollination is essential for production, to crops where the degree of dependence from wild pollination is: ii. high, iii. modest or iv. low, to crops that v. do not depend at all on pollination (Table 9). Although this is the categorization adopted in most of the studies conducting an economic valuation of the NCP Pollination, e.g. Horlings et al. (2020) for the Netherlands, and Sutter et al. (2017b) for Switzerland, a limitation of using such classification is that it is based on assessments conduced at the global scale (Klein et al. 2007; Kleijn et al. 2015). For this reason, we propose to derive potential crop yield losses in the absence of unmanaged pollinators using the minimum, maximum and average values presented in Klein et al. (2007). This is one of the differences from the study by Sutter et al. (2017b) which uses only the average value of each of the five ranges. Another downside of this categorization, whose implications will be discussed in the analysis, is that these ranges assume that wild pollinators are present in habitats that are suitable for them, instead of being based on actual observation data of wild bees and other pollinators and that they all contribute to the pollination of nearby planted crops.

Table 9: Classes for dependence of crops on pollination, based on yield loss in absence of wild pollinators

Classes of dependence of crops on pollination	**Production reduction in absence of pollinators**		**Crops**
	range	class mean	
i. Essential	>90%	95%	Courgette, **pumpkin, kiwi**
ii. High	40% - 90%	65%	**Raspberries**, blackberries, **strawberries, plums**, other berries, annual fruit cultivation, perennial fruit cultivation (e.g. **pear, apple, cherry, apricots), cucumbers, quinces**, summer rapeseed, and winter rapeseed
iii. Modest	10% - 40%	25%	eggplant, **redcurrants, blackcurrants**, summer oilseed rape, winter oilseed rape, **sunflower**
iv. Low	>0-10%	5%	**Peas, broad beans**, other beans and other oilseeds, **tomatoes**
v. No dependence	0	0	Other crops

Source: adapted from Klein et al. (2007). The crops indicated in bold are those included in the Swiss study by Sutter et al. (2017a) and in Sutter et al. (2021), because of their relevance as commercial crops of Swiss agriculture.

To calculate the value of the NCP we further need the production quantities for each selected produce (apples, strawberries, rapeseed, pears, raspberries, pumpkins, squash and gourds, cherries, cucumbers and gherkins, apricots, plums and sloes, tomatoes, sunflower seed, gooseberries, berries nes, peaches and nectarines, beans, green, quinces, kiwi, dry peas, green peas, broad beans, dry horse beans, currants, lupins), and the respective producers' price. Monetary valuation at country level is conducted using production and annual producers prices data (CHF/tonne). These are sourced from FAOSTAT (www.fao.org/faostat/en/#data/PP), which in turn originates from Swiss official sources (e.g. the Federal Statistical Office). These data are provided to FAO through a questionnaire on annual and monthly producer prices received by farmers for primary crops and livestock products.

We source data on annual crop production and area under crop at the cantonal level for a sub-group of relevant agricultural products (apples, pears, apricots, cherries, plums and sloes, kiwi, peaches and nectarines, quinces, rapeseed / colza; sunflower seed). These data are sourced from the 2019 report "Statistiques et évaluations concernant l'agriculture et l'alimentation (SEE)" by the Union Suisse des Paysans. These data allow obtaining more spatially disaggregated results than those calculated in previous studies. However, these results obtained by Canton present some shortcomings and need to be interpreted with care. The shares of total value of pollination in Mio CHF in 2019 are attributed to the Cantons based on their share of areas under production for a sub-group of relevant products. We do not take into account the fact that different Cantons may use different production practices e.g. taking apples as an example, the average distance between trees in a given area may change, also depending on the predominant variety. These aspects are not considered due to data inavailability. Furthermore, as mentioned, the number of crops included in the analysis by Canton is smaller than the number of crops included in the analysis conducted at country level.

We suggest using the prices and production values for 2019, but also report, for sensitivity analysis, results obtained using production volumes and their average for the period 2015-2019, to account for inter-annual variation in crop productivity.

Table 10 presents an example of calculation of value of pollination in Mio CHF for apples, based on a single year (2019) and the class mean.

Table 10: Example of calculation of value of pollination in Mio CHF for apples (2019)

	A	B	C	D	E	F
Crop	Class of dependence and class mean	Producers price in 2019, CHF / t	Production (ton) in 2019 (yield t/ha in brackets)	Value of pollination in Mio CHF in 2019 [(A*C)*B] /1,000,000	Value of pollination CHF per ha under production 2019	Value calculated for 2014 by Sutter et al. (2017a) (Mio CHF)
Apple	High: 65%	1085	191435 (51.28)	135.01	36167	150.97

Source: authors´ elaboration (columns D and E) and Sutter et al. (2017a) (column F) based on FAOSTAT data and Klein et al. (2007) (column A). Apples belong to class "high" following the categorization suggested by Klein et al. (2007).

In 2019, the direct economic value for Swiss agriculture of pollination services, using the method proposed in this study, was about 363 Mio CHF (considering the mean of the class of dependence on pollination for each crop) (see Table 11)[20]. A conservative estimate, which only takes into account the lower bound of dependence on pollination for each crop, shows that the direct economic value for Swiss agriculture of pollination services, was at least 227 Mio CHF, while in case of highest dependence possible for each crop on pollination this value may even increase to 498 Mio CHF.

Table 11: Monetary value of pollination contribution to crop production in Mio CHF in 2019, considering selected pollination-dependent crops

Value of pollination at class mean	Value of pollination at class minimum (conservative values)	Value of pollination at class maximum (maximum damage)
362.80	227.18	498.46

[20] This value is higher, at 376 Mio CHF if we consider five years averages 2015-2019 (see Table in the accompanying excel file). The conservative estimate, which only takes into account the lower bound of dependence on pollination for each crop, shows that the direct economic value for Swiss agriculture of pollination services, was at least 235 Mio CHF, while in case of highest dependence possible for each crop on pollination this value may even increase to 517 Mio CHF (see Table Annexes excel file).

Source: authors´ elaboration based on FAOSTAT data and Klein et al. (2007).

The greatest contribution of this NCP to Swiss agriculture pertains to apples. The cantons where there is the largest area cultivated with apples are the ones that are potentially the most exposed to losses in case pollination is reduced (Wallis and Thurgau) [21].

The value of pollination per ha under production (CHF/ha) in 2019 was 8035 if we consider the mean of the class of dependence on pollination for each crop, 5200 if we consider the lower bound of dependence on pollination for each crop, and 11410 if we consider the highest dependence possible for each crop on pollination (Table 12).

In addition to the monetary value measured using the production approach, as it has been done in other studies on ecosystem services valuation (e.g. van Berkel et al. (2021)), we propose to use pollination value estimates by Peter et al. (2021a) derived using the replacement costs approach (Table 13). To this end, we divided the replacement costs estimates obtained in this study assuming different rates of wild pollinator decline and their current share in total pollinator population of 0.8 by the area of pollination-dependent crops.

Table 12: Monetary value of pollination contribution to crop production in CHF/ha in 2019, considering selected pollination-dependent crops: Production function approach

Valuation approach	**Value of pollination at class mean**	**Value of pollination at class minimum (conservative values)**	**Value of pollination at class maximum (maximum damage)**
Production function approach	8304.62	5200.23	11409.72

Source: authors´ elaboration based on FAOSTAT data and Klein et al. (2007).

Table 13: Monetary value of pollination contribution to crop production in CHF/ha in 2019, considering selected pollination-dependent crops: Replacement cost approach

Valuation approach	**Reduction rates in wild pollinator population**		
	50%	**20%**	**80%**
Replacement cost approach: Manual pollination	8304.6	5200.2	11409.7
Replacement cost approach: Use of domesticated pollinators	196.6	77.7	315.6

Source: authors´ elaboration based on Peter et al. (2021b).

The aggregate contribution of pollination can be easily computed using statistics on agricultural land use for production of specific pollination-dependent crops. In Table 14, we present our estimates derived using agricultural land statistics for the 2015-2019 period. Our results suggest relatively similar

[21] The study by INFRAS and Faunatur (2022) presents wider ranges of possible results, but these cannot be directly compared to our study, as the approaches used are different. INFRAS and Faunatur (2022) finds that the annual costs of replacing a share of wild pollinators with hand pollination would range in Switzerland between 40 Mio CHF and 790 Mio CHF. In the most likely scenario among the ones presented in this study the costs of inaction, which arise if insect mortality is not prevented, would be 230 Mio CHF, with the majority of the costs (about 100 Mio CHF) incurred by arable crops, especially rapeseed and sunflowers. The same study finds that the annual costs of replacing a share of wild pollinators by managed bees would range between 1 Mio CHF and 17 Mio CHF. In the scenario judged as the most likely by the authors the annual cost of inaction would amount to about 5 Mio CHF, with almost half of the pollination costs attributable to tree fruits.

magnitudes of the pollination contribution to agricultural production when applying the monetary values derived using the production function approach and as the replacement cost estimates of manual pollination, whereas the pollination contribution assessed based on the replacement costs of using domesticated pollinators were found to be considerably lower: 8.7 Million CHF compared to 362.8 and 360.0 CHF according to production function and manual pollination estimates, respectively.

Table 14: Aggregate contribution of pollination to crop production: average for 2015-2019, Mio. CHF of 2019

Valuation approach	Value of pollination at class mean / 50% of reduction rates in wild pollinator population	Value of pollination at class minimum / low reduction rates in wild pollinator population	Value of pollination at class maximum / high reduction rates in wild pollinator population
Production function approach	362.8	227.2	498.5
Replacement cost approach: Manual pollination	360.0	150.0	530.0
Replacement cost approach: Use of domesticated pollinators	8.7	5.1	13.0

9.3. Regulation of air quality

High levels of air pollution are a proven cause of disease and premature death. Depending on the pollutant, different organs are affected more severely: for example, the respiratory system by inhalable particles with diameters that are generally 10 micrometers and smaller (PM10), nitrogen dioxide (NO_2), ozone (O_3) and sulfur dioxide (SO_2); the cardiovascular system by fine inhalable particles with diameters that are generally 2.5 micrometers and smaller (PM2.5), NO_2 and carbon monoxide; the nervous system, blood and kidney by lead; the kidney also by cadmium.

Although the air quality in Switzerland has improved gradually since the mid-1980s, levels of air pollutants' concentrations continue to be higher than the legally prescribed ambient limit values for pollutants such as PM2.5 and O3 as well as in some cases for NO_2 and PM10 (BAFU 2021b). PM10 and PM2.5 have proven to be good indicators of the mixture of pollutants relevant to health (BAFU 2021b). The mortality burden of the air pollution assessed based on PM2.5 in Switzerland was equivalent to 3500 deaths in 2018 and for NO_2 and O_3 270 and 350 deaths, respectively (European Environmental Agency 2020).

High levels of the ambient concentration of air pollutants such as NO_2 and O_3 are also proven to cause significant damages to crops such as visible leaf injury, growth and yield reductions, and altered sensitivity to biotic and abiotic stresses (WHO 2000; Weigel and Bender 2012).

Trees and forests play an important role in the reduction of air pollution (Powe and Willis 2004). By absorbing polluting gases and retaining particles on their surface, trees and forests mitigate air pollution and thereby reduce the risk of air pollution related diseases as well as of premature human mortality.

Resource regime

Air pollution reduction measures are stipulated in the Environmental Protection Act[22] and the implementing ordinances such as the Ordinance on Air Pollution Control.[23] The legislation is mainly focused on reducing the air pollution from respirable particulate matter (PM10), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and ozone (O_3) (see Table 15 for details on the limits for these pollutants).

The Federal Constitution provides that the Confederation shall legislate on the protection of the population and its natural environment against damage or nuisance and shall ensure that such damage or nuisance is avoided. The cantons are generally responsible for the implementation of the relevant federal regulations in this area. For details on the resource regime relevant to forests, please consult to the NCP Material and assistance (s. section 10.3).

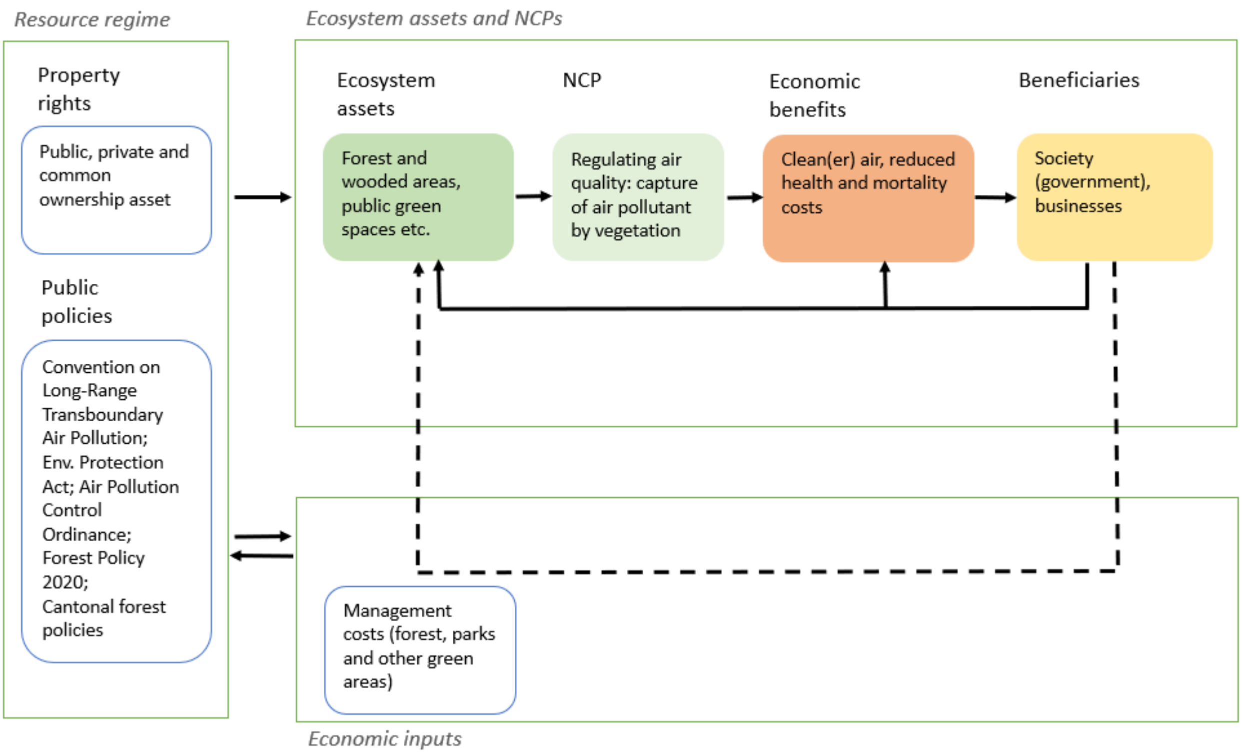

Figure **5**: Monetary valuation framework of NCP Regulation of air quality.
Source: authors´ presentation.

Table 15: Limits and status for selected air pollutants (in German)

Schadstoff	Immissionsgrenzwert	Stand in 2019 und 2020
Stickstoffdioxid (NO_2)	30 µg/m³, Jahresmittelwert (arithmetischer Mittelwert)	nur an verkehrsnahen Standorten überschritten
	100 µg/m³, 95% der ½-h-Mittelwerte eines Jahres ≤ 100 µg/ m³	an allen Standorten eingehalten
	80 µg/m³, 24-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden	an fast allen Standorten eingehalten

[22] https://fedlex.data.admin.ch/filestore/fedlex.data.admin.ch/eli/cc/1984/1122_1122_1122/20180101/de/pdf-a/fedlex-data-admin-ch-eli-cc-1984-1122_1122_1122-20180101-de-pdf-a.pdf
[23] https://www.fedlex.admin.ch/eli/cc/1986/208_208_208/de

Schwefeldioxid (SO_2)	30 µg/m³, Jahresmittelwert (arithmetischer Mittelwert)	an fast allen Standorten eingehalten
Ozon (O_3)	100 µg/m³, 98% der 0.5-h-Mittelwerte eines Monats ≤ 100 µg/ m³	an fast allen Standorten überschritten
	120 µg/m³, 1-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden	an fast allen Standorten überschritten
Schwebestaub: Durchmesser ≤ 10 µm (PM10)	20 µg/m³, Jahresmittelwert (arithmetischer Mittelwert)	an den meisten Standorten eingehalten
	50 µg/m³, 24-h-Mittelwert; darf höchstens einmal pro Jahr überschritten werden	an mehreren Standorten überschritten
Schwebestaub: Durchmesser ≤ 2.5 µm (PM2.5)	10 µg/m³, Jahresmittelwert (arithmetischer Mittelwert)	an vielen Standorten überschritten

Note: Although road traffic emissions reduced in 2020 due to a decrease in traffic volume during the COVID-19 pandemic, the situation with air pollution remained similar to that in 2019 in general. Source: Luftreinhalte-Verordnung and NABEL 2019 and 2020 reports (BAFU 2021a) and (BAFU 2021b).

Economic benefits and beneficiaries

By reducing concentrations of pollutants in the atmosphere, trees and forests provide an important service to society. The beneficiaries of this service are households, and also the private and public sectors, who bear the costs of reduced productivity in case of employees´ sickness and premature death.

Monetary valuation scope

Most studies monetarising the air filtration service apply the damage function approach (DEFRA 2021; Horlings et al. 2020; Ecoplan and INFRAS 2014; ARE 2014; van Berkel et al. 2021). The damage function approach involves estimating a dose/damage function. In a first step, this approach establishes a functional relationship between a measure of environmental quality (or its converse, pollution) and a physical measure of damage or loss. In case of air pollution, so-called concentration-response functions are used to determine health impacts associated with an increase in a specific pollutant, e.g. by 10 µg/ m³. In the next step, a unit price is applied to the physical impact measure to convert it to monetary terms (Freeman 2014). In ValPar.CH, we follow this approach. Specifically, we aim to quantify economic benefits due to a marginal reduction in air pollution as avoided morbidity and mortality damage costs.[24]

Method and data

Air pollutants' concentrations often show a certain degree of correlation. Therefore, the assessment of damage costs associated with air pollution is usually done by choosing a lead pollutant, which well represents the extent of air pollution in general. This procedure allows to avoid double counting of benefits from the pollutant removal. In ValPar.CH, we monetarize health benefits related to the NCP

[24] We considered to quantify also economic benefits of the O_3 removal, specifically, by measuring avoided damage costs due to O_3 pollution in crop production. For this analysis, monthly averages of O_3 concentration estimates for May to July would be required. However, according to the information obtained from Mr. Thomas Künzle from Meteotest (Künzle, communication by e-mail 02.12.2021), spatial dispersion of O_3 has not been modelled for Switzerland on the daily and monthly base yet; it also may require substantial efforts to address model prediction uncertainties when modelling O_3 pollution.

Regulation of air quality for Switzerland based on PM10 that is used in the project for modelling PM removal through vegetation[25].

Though the O_3 pollution also significantly increases morbidity and mortality risks (and does not show significant correlation with particulate matter pollution), establishing a clear functional relationship between health damages and this air pollutant appears to be complicated. In particular, O_3 pollution exceeds its mean hourly limit value of 120 µg/m^3 in the late summer days, in the late afternoon hours usually. However, due to people being more mobile in the summer months, it is practically impossible to determine the actual location of the residents in the affected areas for these time intervals and therefore obtain consistent estimates of population exposure to the O_3 pollution.

In our analysis, we compute health benefits attributable to removing each excessive 10 µg/m^3 of PM10 using the concentration-response functions applied in Switzerland to measure health costs associated with traffic-induced air pollution (Ecoplan and INFRAS 2014; WHO 2013; INFRAS und ecoplan 2019), the prevalence rates for relevant health outcomes in the Swiss population per 100.000 persons and the information about Swiss population exposition to individual pollutants produced by the FOEN using air pollutants´ spatial dispersion models (s. e.g. (INFRAS / Meteotest 2020). Proxies for costs of health damage such as costs of medical treatment per case, costs of workdays lost, reoccupation costs as well as immaterial costs from the most recent publication on External costs and benefits of transport in Switzerland (Bundesamt für Raumentwicklung 2022) are then applied to relevant health impact categories using the methodology developed by (Ecoplan and INFRAS 2014; INFRAS und ecoplan 2019) to measure avoided morbidity and mortality costs.

The avoided mortality costs are assessed based on the value of life year lost (VLYL) derived for Switzerland by INFRAS and ecoplan (2019) adjusted to the year 2019 – the reference year in our analysis. This VLYL estimate is based on the OECD Value of Statistical Life (VOLY) estimate adapted to Switzerland (INFRAS und ecoplan 2019; Ecoplan 2016).[26] The VOLY measure is derived using willingness-to-pay estimates and, therefore, incorporates a consumer surplus, which should not be considered when applying the exchange-value approach. However, given a very individualistic character of each person‘s own well-being and a relatively large number of applications of this measure in policy assessments in Switzerland and other OECD countries, we believe that its use is justified in

[25] Currently, the health costs of air pollution in Switzerland are calculated based on PM10 only (ARE, 2014 and 2019). An ongoing research project implemented by the Swiss Tropical and Public Health Institute (TPH) on behalf of the FOEN investigates whether and which other pollutants should be included in the assessment of the health costs of air pollution in Switzerland and which methodological adjustments would be necessary for this. Because concentrations of multiple pollutants in air are correlated, calculating the health costs of air pollution from multiple pollutants requires the use of multi-pollutant models. Given that the TPH research project was not completed during the implementation of the valuation task In ValPar.CH, the co-lead of TPH's project Prof. Martin Röösli recommends assessing the health costs of air pollution based on PM10 (personal communication on phone on 11.02.2022). Furthermore, long time observations/estimates for corresponding pollutants are required for modeling air pollution removal by vegetation. The estimates of spatial dispersion of PM2.5 were available so far for two years – 2015 and 2010 – only in the period of the project implementation. In the medium and long term, it would be however recommendable to use PM2.5 instead of PM10 for the monetization of health effects as it has been done in the two most recent national assessments of ecosystem services – the Natural Capital Accounting in the Netherlands van Berkel et al. 2021 and the Scottish natural capital accounts (Scottish government 2020). In addition, the Scottish natural capital accounts estimate avoided health costs from the removal of multiple pollutants, in particular PM2.5, SO2, NO2 and O3. These estimates show that removal of PM2.5 resulted in nearly 90% of total avoided health costs in 2017 in Scotland (Scottish government 2020).

[26] While VOLY values premature deaths, VLYL assesses the value of years of life lost. The later is derived by applying most recent survival probabilities.

our analysis of the value-added of ecological infrastructure in Switzerland.[27] Furthermore, similar to the procedure proposed by INRAS and ecoplan (2019), we incorporate in our valuation in addition to the average VLYL estimate also its estimates accounting for variation in VOLY by ±50% to consider prediction uncertainty associated with this measure.

Table 16 summarises the average exchange values at the national level derived considering PM10 pollution and mortality and morbidity costs for 2019 (Bundesamt für Raumentwicklung 2022). The corresponding estimates for the STATPOP hectare pixels are available on request from the authors of the report. Our estimates show that morbidity and mortality costs caused by PM10 pollution go back primarily to immaterial costs, in particular, those associated with the VLYL. When accounting for these costs and applying the average VLYL estimate (100% VLYL), the exchange value of air filtration service is equal to 2900 CHF of 2019 per 1 mg/m2 of PM10.

Figure 6 demonstrates the spatial distribution of our estimates for the air regulation services of forests and trees for the city of Luzern and its agglomeration area. It exemplifies that the monetary values in areas with high vegetation density and concurrently a high density of population and a relatively high PM10 pollution are higher than in the areas that either have a high vegetation density but scarcely or not populated or have a high population density in combination with high particulate matter pollution but miss vegetation.

[27] An additional option were to use a recently developed alternative to the value of statistical life (VSL) measure, which is called the maximum societal revenue value of statistical life year (MSR-VOLY) (Hein et al. 2016). This measure represents "the (hypothetical) maximum producer surplus society could obtain in case society would be able to offer life years, at a price, to people in that society" (Hein et al. 2016, p. 1650025-15). According to the authors of the MSR-VOLY, this indicator is potentially better aligned with a natural capital accounting approach Hein et al. 2016. However, this approach shows also an important limitation; specifically, the authors of the study suggest to approximate the distribution of the Willingness-To-Pay (WTP) for an additional life-year obtained using survey data by fitting a Weibull distribution using just two characteristics of the empirical distribution – the mean and the median – to derive the MSR-VOLY in the absence of empirically derived WTP estimates. Additionally, no statistical goodness-of-fit can be implemented in this case. Accordingly, it is not clear, how well a distribution fitted in that way may represent the underlying distribution of WTP estimates. Considering this aspect, we contacted Prof. Jeanrenaud from University of Neuchatel, who implemented the WTP survey for Switzerland and requested access to relevant WTP estimates for Switzerland (Jeanrenaud and Marti, 2007). Unfortunately, there is no access to these estimates anymore (Jeanrenaud, e-mail 10.05.2021). Accordingly, we intend to work with the VLYL estimate derived using the conventional VSL measure in our analysis.

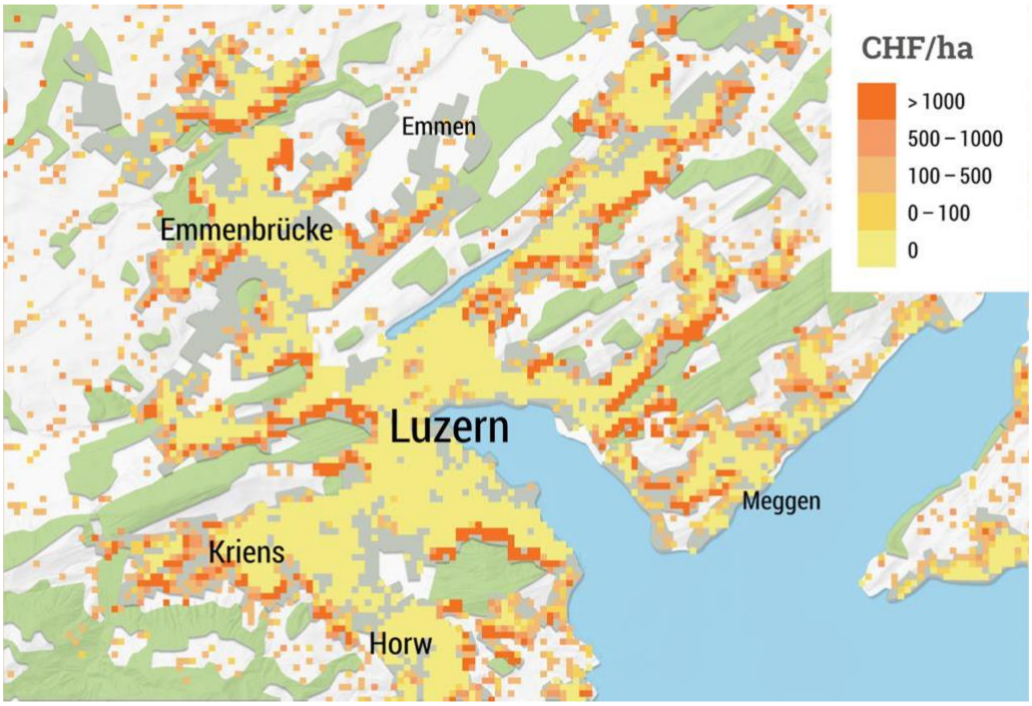

Figure 6: Figure 1Spatial distribution of avoided morbidity and mortality costs estimates for Luzern and its agglomeration area.
Source: graphic presentation by Ralph Sonderegger based on authors´ estimates.

Considering the extent of PM10 pollution in 2019, the total mortality and morbidity costs due to PM10 pollution were 4827.8 Mio CHF of 2019 according to our estimates (as evaluated at mean risk ratios and for 100% VLYL). This estimate is higher than the corresponding indicator from the ARE report on External costs and benefits of transport in Switzerland in 2019 (Bundesamt für Raumentwicklung 2022), i.e. 4134 Mio. CHF of 2019, because the latter report considers PM10 pollution associated with the transport sector exclusively.

Table 16: Exchange values of NCP Regulation of air quality measured as avoided morbidity and mortality costs per 1 µg/m3 of excessive PM10

Indicator	**Assumptions**	**Total costs, CHF of 2019 per 1 mg/m2 PM10, national averages**		
		mean risk ratio	**lower confidence interval risk ratios**	**upper confidence interval risk ratios**
Mortality and morbidity costs excl. immaterial costs (Medical treatment, gross production loss and reoccupation costs)	0% VLYL	238.11	164.57	306.61
Mortality and morbidity costs incl. immaterial costs (Medical treatment, gross production loss and reoccupation costs and VLYL)	**100% VLYL**	**3304.24**	**2198.00**	**4340.22**
	50% VLYL	1771.18	1181.29	2323.42
	150% VLYL	4837.31	3214.72	6357.03

Source: own calculations

We use spatially explicit estimates of PM10 captured by vegetation derived by Külling, N. et al. (2024) for the year 2019 using the InVEST model to measure avoided health and mortality costs for single FOS STATPOP raster hectares. Note, that avoided costs are considered only for those raster grids where vegetation helped to hold PM10 pollution below its threshold level. In addition, the avoided damage estimates are non-zero only for populated hectare grids and grids covered at least partially by vegetation, concurrently. Accordingly, we consider only local effects of forest and other vegetation when assessing vegetation contribution to air regulation, but not their potential spill-over effects. Then, we sum up the avoided damage estimates over all STATPOP raster hectares results to estimate the aggregate contribution of vegetation to reduction of excessive PM10 pollution (Table 17). Currently, vegetation helps to save only 106.5 Mio. CHF of 2019 on morbidity and mortality costs associated with PM10 pollution that corresponds to ca. 2.2% of the morbidity and mortality costs due to PM10 pollution in the country. Our estimates point at high extent of air pollution and also lack of vegetation in populous areas exposed to PM10 pollution.

Table 17: Contribution of vegetation to reduction of excessive PM10 pollution: 2019

Indicator	**Assumptions**	**Total avoided costs, Mio. CHF of 2019**		
		mean risk ratio	**lower confidence interval risk ratios**	**upper confidence interval risk ratios**
Mortality and morbidity costs excl. immaterial costs (Medical treatment, gross production loss and reoccupation costs)	0% VLYL	7.7	5.3	9.9
Mortality and morbidity costs incl. immaterial costs (Medical treatment, gross production loss and reoccupation costs and VLYL)	100% VLYL	106.5	70.8	139.8

Source: own calculations

9.4. Regulation of climate

The NCP Regulation of climate is defined by IPBES (Brauman et al. 2019) as climate regulation by ecosystems (including regulation of global warming) through effects on emissions of greenhouse gases, biophysical feedbacks, biogenic volatile organic compounds, and aerosols. ValPar.CH assesses this NCP by quantifying carbon sequestered and stored for long periods of time in biomass and soils.[28] Accordingly, the economic valuation of this NCP refers to the price of 1 ton of carbon.

Resource regime

Switzerland ratified the Paris Agreement on 12 December 2015. The goal of this international treaty is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. In January 2021, The Swiss Federal Council adopted the "Long-Term Climate Strategy for Switzerland" that set the country's strategy to combat global warming. This strategy formulates basic principles required to achieve the net zero emissions target by 2050. It also shows that Switzerland can reduce its greenhouse gas emissions by 2050 to around 90% of the 1990 level. The remaining 10% must be balanced with negative emission technologies (FOEN, 2021). To reach the emissions reduction targets declared in the Long-Term Climate Strategy, the CO_2 Act, which has been in force since 2013,

[28] Carbon that is sequestered but not expected to be stored, e.g. carbon in crops, is not considered as a component of the ecosystem service (SEEA 2021, Ch. 6.4.3).

was revised. The revised CO_2 Act, called the Climate and Innovation Act, was approved by the Swiss population in a national referendum on June 18 2023. It is expected to come into force on January 1, 2025. After a sequence of deliberations in the National Council and the Council of States, several policy measures discussed in earlier versions of the Act were removed. This applies, for example, to the reduction path for CO_2 emissions for new vehicles, the relationship between domestic and foreign CO2 emission compensation or the support of the infrastructure for charging stations.

The CO_2 levy introduced in Switzerland in 2008 has been a key policy instrument to achieve the country CO_2 emissions targets so far. It is imposed on fossil combustible fuels, such as heating oil and natural gas.[29] Operators of greenhouse gas-intensive installations can be exempted from the CO_2 levy if they commit to reducing their emissions. Operators of large greenhouse gas-intensive installations must participate in the emissions trading scheme (ETS) and are also exempted from the CO_2 levy (BAFU 2021b). The CO_2 levy was set at CHF 12 per ton of CO_2 initially. Its level had to be adjusted several times however, since the CO_2 emissions were reduced in the reference periods less than the corresponding targets according to the CO_2 Act. The last adjustment took place in January 1 2022, when the CO_2 levy was raised to 120 CHF per ton of CO_2.

Soils and forests are important sinks of carbon.[30] From 1900 to 2019, the country's Land Use, Land-Use Change and Forestry (LULUCF) sector was a sink of on average –2400 kt CO_2 per year. Human activities affect land use and management, and thereby induce soil carbon loss (in form of CO_2 emissions) or its improved storage. The Spatial Planning Act (RPG) stipulates the general legal framework for spatial planning and land use that applies nationwide. Strategic and operational spatial planning is the responsibility of the cantons and the municipalities. In addition, there are several federal policy measures that directly or indirectly impact LULUCF and through that influence carbon sequestration and storage. Some examples of such policies are biodiversity promotion areas combining payments for habitat conservation with an agglomeration bonus scheme as well as direct payments for reduced-tillage soil cultivation, precision farming, organic farming and grassland-based milk and meat production. In addition, the Swiss government provides financial assistance to forestry enterprises based on the "Neuer Finanzausgleich" program agreement for measures that support the forest in being able to fulfil its functions, also under changed climatic conditions.

Resource regimes for forests and agricultural land – two important LULUCF categories – are described in the sections NCP Materials and assistance (section 10.3) and NCP Food and feed (section 10.2).

[29] Transportation is exempt from the CO2 levy and other policies to reduce GHG emissions in Switzerland.

[30] Through the process of photosynthesis, trees and other plants absorb carbon dioxide from the atmosphere. When they die, the carbon collected in their biomass goes into the soil. Soils can store carbon for substantially longer periods than trees and plants that decay fast after they die. Some ecological interaction processes in soils such as the decomposition of carbon through microbes release part of the carbon stored in soils back into the atmosphere.

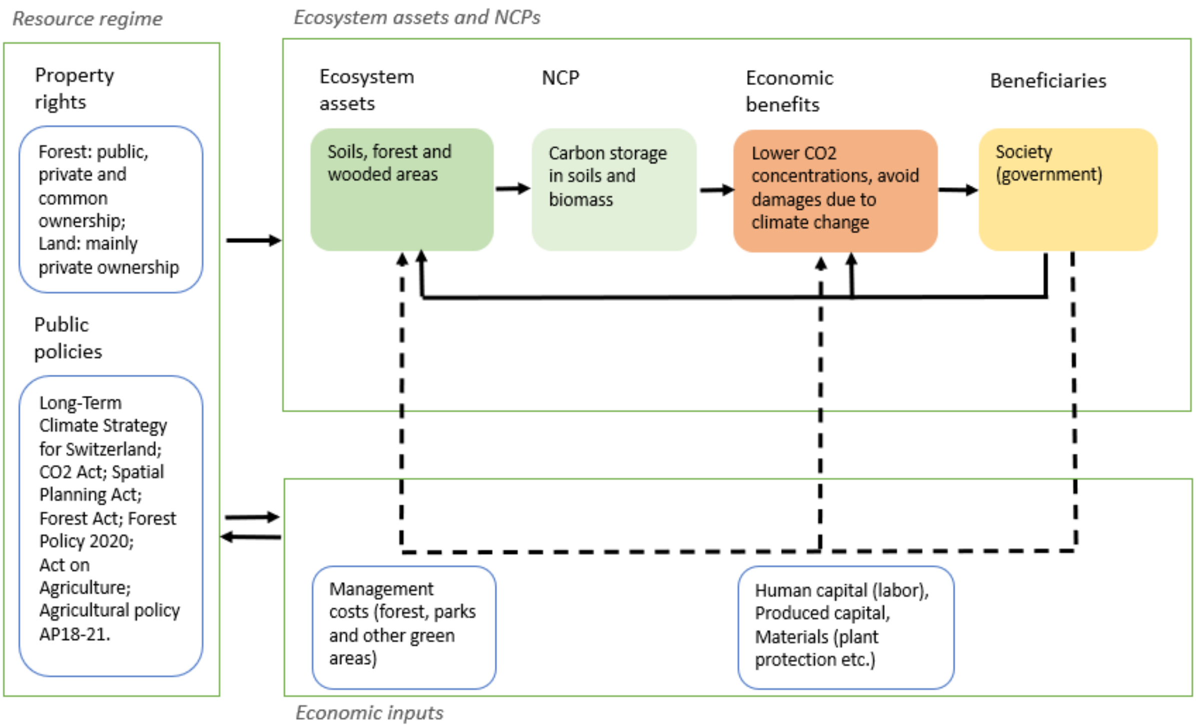

Figure 7: Monetary valuation framework for NCP Regulation of climate.
Source: authors´ presentation.

Economic benefits and beneficiaries

By capturing and storing carbon, plants avoid CO_2 emissions to the atmosphere and reduce potential future damage costs associated with global warming. Accordingly, the economic benefit of capturing and storing carbon can be assessed as avoided damage costs to the society. The beneficiary of the NCP Climate regulation is the entire society in the national context and the global community on a global scale. In the SEEA EA framework (SEEA 2021), which builds upon the System of National Accounts, the beneficiary of the climate regulation service is considered to be the national government.

Monetary valuation scope

By reducing concentrations of CO_2 in the atmosphere and thereby stabilizing the climate, soils, forests, and other wooded areas avoid potential future damages related to climate change. In this context, the Social Cost of Carbon (SCC) appears to be a rational choice for monetarizing the climate regulating services of soils and forests. The SCC is an estimate of future economic damages from 1 ton of carbon emitted today as CO_2 discounted back to the present period (Fisher et al. 2007). An alternative for the SCC is the target-consistent marginal abatement costs (MAC) approach that estimates the price of carbon by defining a specific greenhouse gas emissions reduction target. While the SCC measures of avoided damage cost, the MAC corresponds with abatement costs of technical options for reducing CO2 emissions and therefore is a replacement cost measure.

The carbon price assessed using the MAC approach[31] was used in the UK National Ecosystem Assessment (Bateman et al. 2014) and also more recently in the Scottish natural capital accounts (2020),

[31] This is the approach generally used by the UK Government for policy appraisals (Bateman et al. 2014).

while the SCC was applied along the target-consistent MAC in the Dutch monetary valuation of ecosystem services and assets (van Berkel et al. 2021). In ValPar.CH, we aim to proceed similar to the Dutch National capital accounting (van Berkel et al. 2021) and consider both measures to value a ton of carbon sequestered and stored in biomass and soils.

Method and data

The SCC estimates vary much across studies subject to scenarios about mitigation pathways, discount rates used for calculating the present value of future damages as well as other assumptions used in different models. A meta-analysis of 588 estimates of the SCC from 75 studies conducted by Tol (2013) found the mean and mode SCC values to correspond with 196 and 49 U.S. dollars of 2010 per 1 ton of CO_2 emissions in 2010, respectively. The author of the study draws attention to a wide range of SCC estimates across studies and points at the discount rate magnitude as an important source of variation in the SCC estimates.

According to the UK Treasury's Green Book (HM Treasury), the carbon price used for policy appraisals in the UK was 69 pounds of 2018/t CO_2eq for 2020 for non-ETS sectors, which corresponds to 254 pounds of 2018/t carbon[32]. The Dutch ES valuation study applied the carbon price of 195 Euro of 2018 per ton of carbon (equivalent to 53 Euro/t CO_2) derived for the high-reduction scenario using a discount rate of 3.5% (van Berkel et al. 2021).

The German Environment Agency (Matthey and Bünger 2019) recommends using a SCC rate of 180 Euro of 2016/t CO_2eq obtained using the social rate of time preference (SRTP) of 1%[33]. Since damage caused by climate change spans various generations, it also recommends a sensitivity analysis using a SCC rate of 640 Euro 2016/t CO_2eq (corresponding with 0% SRTP), as this reflects an equal weighting of the benefits of todays and future generations. Converted to the cost rate per ton of carbon, these two SCC estimates correspond to approximately 660 and 2,345 Euro of 2016 per 1 ton carbon, respectively (Matthey and Bünger 2019).

To evaluate external costs of transport, Ecoplan and INFRAS (2014) and INFRAS und ecoplan (2019) apply a MAC estimate of the German Environment Agency derived for the 2°-target using social discount rate (SDR) of 3% based on the meta-analysis at the global scale conducted by Kuik et al. (2009) (Umweltbundesamt Deutschland 2013). The reference value of this MAC estimate is 77 Euro of 2010/t CO_2. To derive an equivalent for Switzerland, the study by Ecoplan and INFRAS (2014) adjust this estimate by the exchange rate for Euro in 2010 and obtain the value of 107 CHF of 2010/t CO_2. By extrapolating this result to the year 2015, INFRAS und ecoplan (2019) obtain a MAC estimate for Switzerland for 2015 of 121.5 CHF of 2015/t CO_2. We propose to use the same reference estimate of MAC of 77 Euro of 2010/t CO_2 as by Ecoplan and INFRAS (2014) and INFRAS und ecoplan (2019), however, to utilize the purchasing power parity (PPP) exchange rate for 2010 to convert the MAC estimate obtained for Germany. This procedure yields a value of 140.3 CHF of 2010/t CO_2 instead of 107 CHF of 2010/t CO_2 as in Ecoplan and INFRAS (2014). Consequently, we employ the same SDR of 3% as proposed by INFRAS und ecoplan (2019)[34] as well as the consumer price index (CPI) of the Federal Statistical Office to obtain a MAC estimate for 2019 (in prices of 2019). This results in a MAC estimate of 182.3 CHF of 2019/t CO_2 that we consider as reference CO_2 price when valuing the NCP Regulation of climate.

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[32] This price is derived using the standard social rate of time preference set by the Green Book to 3.5% (years 0–30), 3.00% (years 31–75) and 2.5% (years 76–125).

[33] The German Environment Agency (Matthey and Bünger, 2019) draws attention to the fact that the recommended value of 180 Euro 2016/t CO_2eq is close to the value of 173.5 Euro 2016/t CO_2eq determined in the 5th IPCC Assessment Report.

[34] This is consistent with assumptions used in the study by Kuik et al. 2009.

Considering the high degree of the economic development of Switzerland and also that, as an alpine country, it is particularly affected by climate change (BAFU 2020b)[35], costs of inaction on climate change may be particularly high. Accordingly, we recommend to use in addition to the MAC estimate obtained by INFRAS und ecoplan (2019) the SCC estimate of 180 Euro of 2016/t CO_2eq recommended by the German Environmental Agency, which was obtained by applying a relatively low SRTP, as a more precautious estimate of CO_2 price. The magnitude of the latter is comparable not only with the average SCC estimate in the meta-analysis conducted by (Tol 2013) but also with the CO_2 price recommended by the IPCC.[36] After necessary adjustments for purchasing power parities, the corresponding value of the latter for Switzerland would be 287.3 CHF of 2016. In accordance with a core assumption introduced to derive this SCC estimate (Matthey and Bünger 2019), we apply the SRTP of 1% to calculate SCC level for 2019. In addition, we use the CPI to adjust it to prices of 2019. This yields an SCC estimate for 2019 of 301.4 CHF of 2019/t CO_2.

Finally, we convert both CO_2 price estimates to the carbon price using the conversion factor of 3.67[37]. Accordingly, the proposed monetary values for measuring the NCP Regulation of climate for 2019 are 669.1 CHF (reference price estimate) and 1106.1 CHF (precautious price estimate), each in CHF of 2019 per 1 ton of carbon (Table 18).

Table 18: CO2eq. and carbon price estimates for 2019, CHF 2019/t.

Indicator	CO2 price CHF 2019/t CO2	Carbon price CHF 2019/t carbon
MAC-based estimate	182.3	669.1
SCC-based estimate	301.4	1106.1

Source: own calculations based on Ecoplan and INFRAS (2014), INFRAS and ecoplan (2019) and Matthey and Bünger (2019).

We use the SCC and MAC estimates to assess the aggregate values of ecosystem services provided by carbon stored and GHG emissions sequestered in the sector Land Use, Land-Use Change and Forestry (LULUCF) in Switzerland using estimates by Külling, N. et al. (2024) and Swiss GHG Inventory data (FOEN 2023), respectively (Table 19).

Table 19: Total contribution of climate regulation: 2019

Indicator	Value of carbon stored, Mio. CHF of 2019	Value of netto GHG emissions sequestered in LULUCF, Mio. CHF of 2019
MAC-based estimate	244,107	317
SCC-based estimate	403,537	524

9.5. Regulation of freshwater quantity, location and timing

This NCP is defined by Díaz et al. (2018) as "Regulation, by ecosystems, of the quantity, location and timing of the flow of surface and groundwater used for drinking, irrigation, transport, hydropower, and as the support of non-material contributions." Water arrives in Switzerland through precipitation

[35] The average temperature has risen by around 2 degrees Celsius since pre-industrial times in Switzerland which is more than double as much as the global average (BAFU 2020b).

[36] In addition, the MAC estimate by INFRAS and ecoplan (2019) was obtained using the 2° CO_2 emissions reduction target, i.e. not the 1.5°-target.

[37] i.e. 1 ton of carbon is equivalent to 3.67 ton of CO_2.

(60km³/year) and an influx from other countries (13km³/year). More than two-thirds of this water leaves the country as runoff (53km³/year) while the rest evaporates (20km³/year). Within the country, the main ecosystem assets in which water is stored are groundwater, lakes, glaciers, and temporarily as snow (Blanc and Schädler 2013). The quantities of water in the environment across time and space are changing due to climate change. Projections suggest that due to higher temperatures in winter, precipitation will partly shift from snow to rain. Consequently, runoff will increase during winter and decrease during summer. The risk of water scarcity is expected to increase, but regionally there can be major differences with some regions having too little while others rather receive superfluous water (BAFU 2020a, 2021a).

Resource regime

In Switzerland, the cantons have sovereignty over (public) waters (Mauch et al. 2000). However, there are exceptions with different forms of private ownership. The use of water is regulated through federal, cantonal and municipal legislations.[38] At the federal level, several laws and ordinances regulate water use.[39] The consumption of small amounts of water ("Gemeingebrauch") are generally free. However, the cantons provide concessions, licenses or permits for the use of larger amounts of water (Mauch et al. 2000). For hydropower production a maximum fee is set at the federal level (WRG, Art. 49). Otherwise, concession fees for the use of water are set at the cantonal level and in some cases the municipal level.

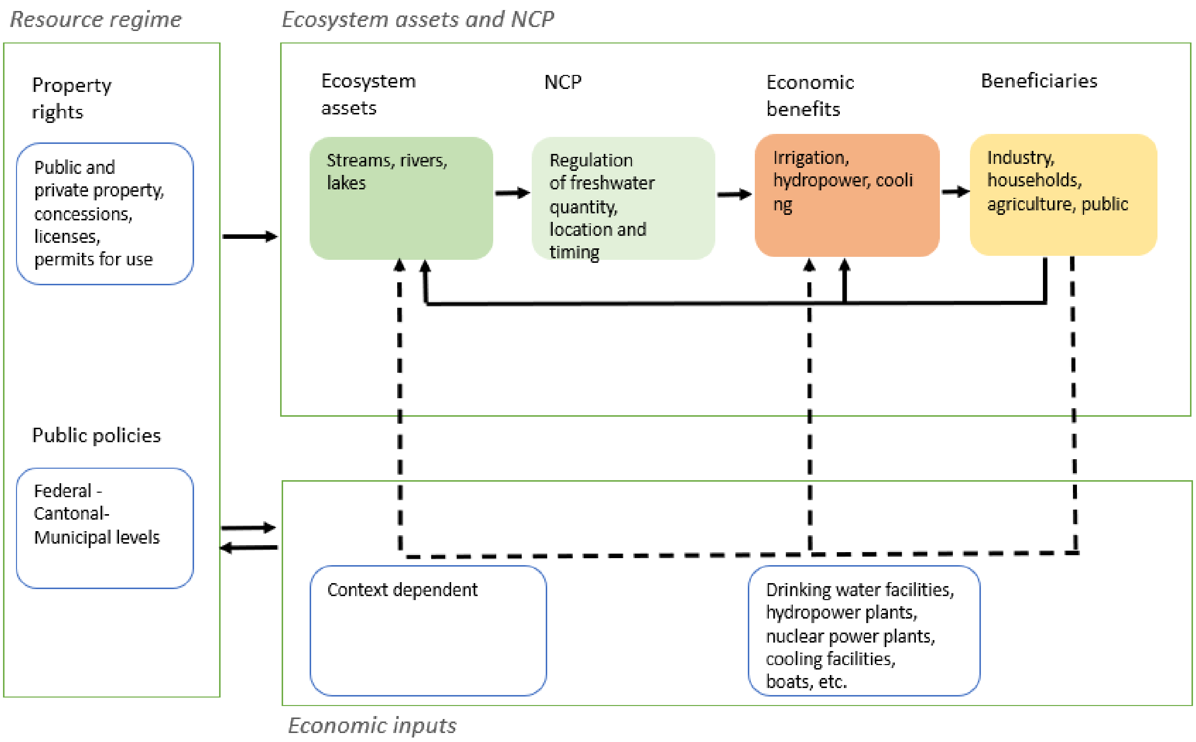

Figure 8: Monetary valuation framework for NCP Regulation of freshwater quantity, location and timing. Source: authors´ presentation.

[38] A detailed discussion on property can be found in Leimbacher and Perler 2000.

[39] Bundesverfassung, Artikel 76 Wasser, Bundesgesetz über die Nutzbarmachung der Wasserkräfte (Wasserrechtsgesetz), Bundesgesetz über den Schutz der Gewässer (Gewässerschutzgesetz), Gewässerschutzverordnung, Bundesgesetz über den Natur- und Heimatschutz, Verordnung über den Natur- und Heimatschutz, Bundesgesetz über die Fischerei, Bundesgesetz über die Raumplanung (Raumplanungsgesetz), Bundesgesetz über den Umweltschutz (Umweltschutzgesetz).

Economic benefits and beneficiaries

Economic benefits arise when water transitions from the ecosystem to the economy. This transition takes place for different types of water, i.e. groundwater, source water, and surface water. In the economy, water fulfills various different purposes, e.g. it serves as drinking water, water for irrigation, navigation, for cooling purposes or for the production of hydroenergy.

According to the broad range of benefits, there are also many different direct and indirect beneficiaries of one or several of the benefits. A classical typology of beneficiaries used in water consumption statistics is commerce and industry, households, agriculture (and fishing), as well as public users.

Monetary valuation scope

The concession, license and permit fees, reflect the exchange values for water at different points of extraction and for different purposes. As an example, take the surface water used for cooling of nuclear power plants. Currently there are four active nuclear power plants in Switzerland. These are Beznau-1 and Beznau-2, Gösgen and Leibstadt. Gösgen and Beznau 1 and 2 use water from the river Aare, while Leibstadt, which is situated after the confluence of Aare and Rhine, uses the water from the river Rhine. The price for the use of the river water is regulated through concessions. For example, the nuclear power plant in Gösgen in 2011 paid CHF0.22/m^3 of water that it extracted from the river and that it let evaporate. The price for river water that was warmed by the power plant but that was redirected to the river (i.e. not evaporated) was CHF0.007/m^3 (Umbach Daniel et al. 2011). In its financial statement, the operating company of the power plant Gösgen reports costs of CHF4,558Mio in 2018 and CHF4,354Mio for cooling water (KKW Gösgen-Däniken AG 2020).

As illustrated with this example, water is not free in Switzerland and prices in the form of concession fees are defined for various transition points from the ecosystem to the economy. Although there may rarely be a perfect market for water, these exchange values for water are already included in the current SNA.

Method and data

Within ValPar.CH, this NCP is modelled as water yield per raster cell. To be consistent with this indicator, we use observable concession fees for surface water. To collect the data on concession fees, we scrutinized the water legislations for all 26 cantons. Whenever the pricing information was not entirely clear, we contacted the cantonal administrations. The results on the exchange values of surface water are presented in Table 20. The canton of Thurgau has the lowest concession fee (0.001CHF/m3), Obwalden the highest (0.5CHF/m3, as a maximum value), and the median is at 0.011CHF/m3. In Grissons, water sovereignty is with the municipalities. The canton only charges water fees for the use of water for energy production. Data on municipal-level concession fees was not available (Personal communication, Office for Energy and Transport Grisons, October 2022). For the canton of Valais, no information on concession fees at the municipal level could be obtained.

Table 20: Exchange values for surface water in CHF/m3

Canton	Exchange values for surface water, CHF/m3	Canton	Exchange values for surface water, CHF/m3
Aargau	0.015	Nidwalden	0.055
Appenzell A.Rh.	0.4	Obwalden	0.5
Appenzell I.Rh.	0.21	Sankt Gallen	0.051
Basel-Landschaft	0.04	Schaffhausen	0.011

Basel-Stadt	0.02	Schwyz	0.01
Bern	0.08	Solothurn	0.011
Freiburg	0.004	Tessin	0.007
Genf	0.006	Thurgau	0.001
Glarus	0.029	Uri	0.025
Graubünden	/	Waadt	0.001
Jura	0.002	Wallis	NA
Luzern	0.009	Zug	0.003
Neuenburg	0.002	Zürich	0.003

Sources: Please refer to the adjoining excel file for the references to the legal documents for each canton.

Previous valuation studies on fresh water in Switzerland were mostly conducted as case studies and often used choice experiments or travel cost valuation as methods (Logar et al. 2014; Veronesi et al. 2014; Logar et al. 2019; Buchli et al. 2003). However, these methods are not recommended for the estimation of exchange values in the SNA context. The approach of using concession fees as exchange values is novel for Switzerland. It is important to keep in mind that the fees are set by the administration and are not necessarily equilibrium market prices.

To compute the monetary volume of surface water consumption, we multiply the median of the cantonal exchange values by estimates of surface water consumption for irrigation purposes (Table 21) (Björnsen Gurung and Stähli 2014).

Table 21: Monetary volume of surface water consumption

Consumption of surface water for irrigation	million m3	Median value of cantonal exchange values for freshwater quantity measured as CHF of 2019 per m3 of surface water	Value of surface water consumption (CHF)
Lakes	1	0.011	11000
Rivers	9		99000
Channels and creeks	6		66000
SUM			**176000**

9.6. Regulation of freshwater quality

Generally, the quality of ground water in Switzerland is high. Roughly 80% of the drinking water is ground or source water that can be used as drinking water either directly or after a simple treatment. The remaining 20% of the drinking water is lake water that requires a more thorough treatment (BAFU 2021a). Various undesired substances from agriculture and society are negatively impacting the surface and groundwater quality. Pressure on water quality is particularly coming from residues of fertilizers and plant protection substances, components of personal care, cleaning products, and medicines, as well as micropollutants from roads and sealed surfaces (BAFU 2021c; Eggen et al. 2014). Water quality is regularly monitored at various sites across Switzerland. Currently, at 15% of the monitoring sites the nitrate content exceeds the threshold level (BAFU 2022).

Excessive phosphorus that is washed into surface waters leads to high primary production of algae. The degradation of this biomass consumes oxygen, thereby decreasing the oxygen content of the water with negative effects on aquatic biodiversity. In the past decades, the objective was mainly to reduce excessive runoff of phosphorus into water bodies. Since the 1980ies, decreases in phosphate concentrations in lake water were achieved through bans on phosphorus in detergents, improvements in wastewater treatment processes, and farmers' efforts to decrease runoff (BAFU 2016). Given the global scarcity of phosphorus and a lack of natural deposits in Switzerland, recycling of phosphorus from wastes has become an additional important objective.

Resource regime

Water protection is regulated through the Federal Act on the Protection of Waters (SR.814.20) and the Waters Protection Ordinance (SR.814.201). The former applies to all surface and underground waters irrespective of the property titles. It prohibits introducing and infiltrating polluting substances into waterbodies and requires treatment of polluted wastewater. Furthermore, it requires everyone to 'take all the care due in the circumstances to avoid any harmful effects to waters'. The quality requirements for surface water and for ground water are specified by the Federal Council and laid out in the Waters Protection Ordinance. As threshold it defines that for waters which serve as a source of drinking water the nitrate content may not exceed 25 mg/l. For phosphorus there is no corresponding threshold for drinking water. The Ordinance on the Avoidance and the Disposal of Waste stipulates that from 1st of January 2026, "Phosphorus must be recovered from municipal waste water, from sewage sludge from central waste water treatment plants or from the ash produced by the incineration of such sewage sludge and then recycled. Phosphorus in animal and bone meal must be recycled, unless the animal and bone meal is used as animal feedstuffs."

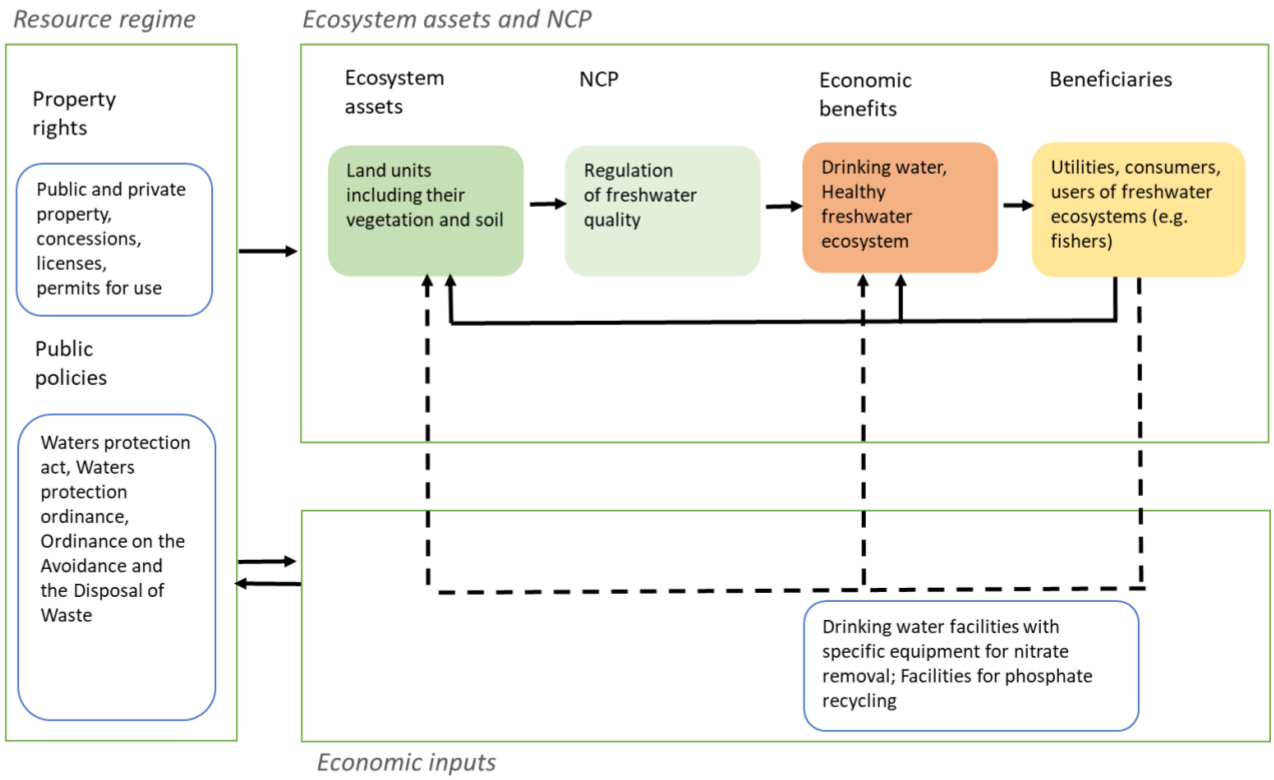

Figure 9: Monetary valuation framework for NCP Regulation of freshwater quality.
Source: authors´ presentation

Economic benefits and beneficiaries

At all points at which water transitions from the environment to the economy, the quality of the water is relevant. Together with water quantity it impacts the scope of economic benefits that can be gained. In a framework for describing and valuing water quality-related services, Keeler et al. (2012) list various economic benefits and beneficiaries related to good water quality.[28] For instance, water that is of high quality at its source is a benefit to water utilities (due to foregone treatment cost). It is also a benefit to consumers in terms of health benefits but also lower cost for water consumption. High water quality in surface waters provides economic benefits to fishing, either by commercial or leisure fishers and consumers of the fish. The quality of surface water is also relevant to the hospitality sector with various beneficiaries including recreationists, swimmers, and all types of lake side touristic infrastructure.

Monetary valuation scope

Nitrate that is retained by vegetation and soil does not enter ground and surface water. We thus focus on estimating the monetary value of retaining nitrate per unit of land. This value can be inferred from the avoided damage cost, i.e. avoided treatment cost for drinking water. Similarly, phosphorus that is retained does not enter the waterbodies. However, the extracted phosphorus can be recycled and thus also has a monetary benefit. We will estimate the monetary value of retaining phosphorus per unit of land as the difference between the avoided cost of extracting it from wastewater subtractive of the market price of phosphorus.

Method and data

In Valpar.CH the indicators for modelling this NCP are the amount of nitrogen and phosphorus retained annually in kg per pixel. We apply the replacement cost method to estimate the avoided cost of technically removing nitrate and phosphate from the water. Recovered phosphate has a market price that we additionally take into account.

Nitrate

In practice, water utilities in Switzerland do not remove nitrate from the water. This is because the threshold for nitrate in drinking water is higher (40mg/l) than the threshold for nitrate in water bodies that may be used as source for drinking water (25mg/l). In case the nitrate content is too high at a certain well, a common strategy is to dilute the water with water from a different, cleaner, source. According to an expert's opinion, the infrastructure cost for this dilution process is very case specific which makes it impossible to compute any representative numbers on cost per unit reduction in nitrate (personal communication SVGW expert, May 2022). Other possibilities are to relocate, or deepen a problematic water well (Oelmann et al. 2017).

Cost estimates for technological nitrogen removal are made available by Oelmann et al. (2017) for four exemplary case studies in Germany using several different technologies including reverse osmosis / nanofiltration, carbondioxide regenerated ion exchange, electrodialysis, biological denitrification and carbon adsorption and oxidation using ozone. Their cost estimates are based on literature reviews, experiences of their project team and expert interviews with technology providers. We use these cost estimates to compute an average for the avoided damage cost of nitrate retention by the ecosystem.

Using the cost estimates from the study by Oelmann et al. (2017), converting the values to CHF and deflating them to 2019 prices, we arrive at an average avoided damage cost estimate of 10.15CHF/kg of nitrate (see Table 22).

Phosphorus

Similar to nitrate, phosphate that is retained does not enter the waterbodies. However, the extracted phosphate can be recycled and thus also has a monetary benefit. We thus estimate the monetary value of retaining phosphate per unit of land as the difference between the avoided cost of extracting it from wastewater subtractive of its market price.

We build on existing estimates on the cost of extracting phosphate from wastewater (Nättorp et al. 2017) and market prices for phosphate. From the different technology scenarios presented in Nättorp et al. (2017), we chose 'Ash leaching 1' which is described as "Leaching of ash with H2SO4, solid-liquid separation, pH increase and precipitation of CaP with Ca(OH)2." (Nättorp et al. 2017). We selected this cost scenario because the material recovered is comparable to phosphate rock for which there are observable market prices. In a personal communication, the study's first author also suggested to use this scenario. The recovery cost estimate is 7.50 CHF/kg P which decreases to 7.01CHF/kg P under the assumption that the recovered material can be sold at a price of 0.49CHF/kg.

Table 22: Exchange value estimates for nitrate and phosphate removal

Indicator	CHF 2019/kg
Cost of nitrate removal	10.15
Cost of phosphate removal including sale of recovered phosphate	7.01

Source: own estimation based on (Nättorp et al. 2017; Oelmann et al. 2017)

We multiply the estimate of the amount of annually retained N (91990392kg) by the conversion factor 4.42 (in 4.42 tons of Nitrate there is 1 ton of N) to express the amount of N retained in units of Nitrate and then multiply by the exchange value in Table 22. The monetary volume of retained N is CHF 4130 million.

9.7. Formation, protection and decontamination of soils

This NCP is defined as "Formation and long-term maintenance of soil structure and processes by plants and soil organisms." (Díaz et al. 2018). As examples and for further specification Díaz et al. (2018) state that it includes "physical protection of soil and sediments from erosion, and supply of organic matter and nutrients by vegetation; processes that underlie the continued fertility of soils important to humans (e.g. decomposition and nutrient cycling); filtration, fixation, attenuation or storage of chemical and biological pollutants (pathogens, toxics, excess nutrients) in soils and sediments".

Soil formation is estimated to lay between 0.3–4 t per ha and year for conditions prevalent in Europe (Verheijen et al. 2009). As a natural process, a certain share of the soil erodes and enters waterways.

However, land management forms that induce excessive erosion can substantially increase the amount of sediment, nutrients and pesticides that enter waterways as run-off (Remund et al. 2021). Soil loss on agricultural fields creates direct on-site costs due to reduced productivity of the land, but the off-site costs that sediments cause in terms of damages e.g. from muddy flooding and abrasion in hydropower facilities, as well as costs for damage prevention measures are far higher (Boardman 2021; Patault et al. 2021). Considering that this NCP is modelled as sediment retention in ValPar.CH, we will follow suite and limit the scope of the monetary valuation to this benefit.

Resource regime

The process of soil erosion on unvegetated alpine surfaces is a key factor for silting of storage lakes in the Alps and discharge of sediments to mountainous rivers and further downstream. The extent of soil erosion in the Swiss Alps depends on rock type, slope steepness, soil cover, the intensity of precipitation and runoff discharge (Beyer Portner 1998).

Vegetation increases soil resistance and thereby reduces soils' exposure to climatic stress factors such as extensive rainfalls, runoffs and frost, and in this way reduces the extent of soil erosion. Thus, by reducing soil erosion, forests and other vegetation types fulfil an important regulating function. The forest presents one of the best protections against soil erosion. A forest, even if degraded, protects the soil 20 to 40 times better than cultivated plants on an agricultural area. However, cultivated areas are still better protected than bare land (Müller-Hohenstein 1992 as cited in Beyer Portner 1998). Accordingly, human activities altering vegetation cover in Alpine areas may provoke soil erosion and thereby significantly increase volumes of sediments discharged in mountainous rivers and water streams.

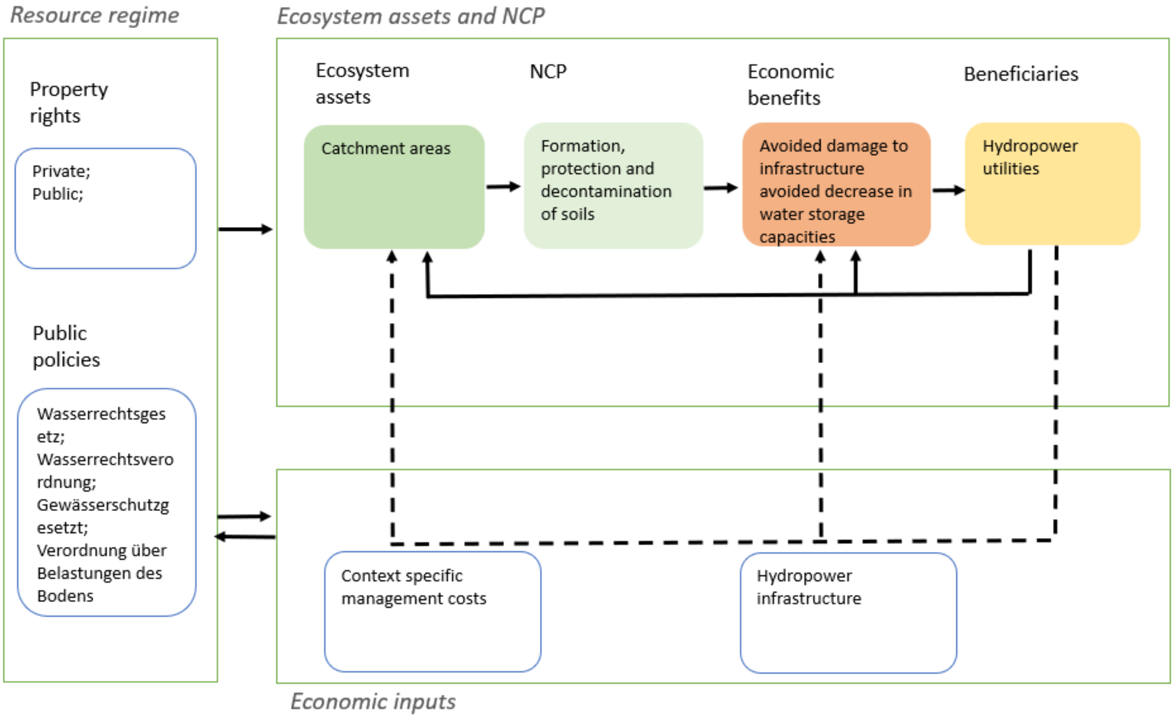

Figure 10: Monetary valuation framework for NCP Formation, protection and decontamination of soils.
Source: authors´ presentation.

Management of sediments is a complex and costly task. Sediment management measures can be taken in the catchment basin, in the retention capacity or at the dam (see Table 23). The cost of sediment management appears to be particularly high in the Swiss hydropower sector (Boes, personal communication 23.09.2021). Given that the act on energy adopted in 2017 specified the objective of increasing electricity production from hydropower by 2050, sediment retention and management can be expected to gain on importance in the upcoming decades.

Economic benefits and beneficiaries

The beneficiaries that we refer to for the monetary valuation of this NCP are hydropower facilities. Switzerland today has 677 hydropower plants with a capacity of at least 300kilowatts each. In total, they annually produce around 36,741 gigawatt hours (GWh/y) with run-of-the-river power plants (48.7%) and storage power plants (47%) contributing about equal shares while pumped storage power plants contribute a comparatively smaller share (4.3%) (BAFU 2021c).

Monetary valuation scope

For the monetary valuation of this NCP, we focus on the costs that sediments cause to hydropower facilities. Sediments can be differentiated into two groups – fine sediments including sand, silt and clay, as well as coarse sediments including gravel and debris (Weber et al. 2017). Fine sediments can cause costs to hydropower facilities for several reasons: efficiency losses in hydropower production, increased maintenance costs due to abrasive effects on turbines as well as on the larger infrastructure. Coarse sediments create costs due to impoundment filling, which results in decreased storage capacities and thus decreased ability to adjust power production to market circumstances (Boes, personal communication 23.09.2021).

Table 23: Sediment management options.

Measures in the catchment area	Measures in the retainment capacity	Measures at the dam
• Erosion control (mechanical or vegetative) • Bed load sampler • Upstream temporary dam • Drainage tunnels • Bypass facilities	• Dead storage capacity • Mechanical excavation • Flushing (short or complete) • Avoiding sediment deposition • Control of turbidity currents	• Heightening the dam • Raising the location of the discharge • Cleaning of the discharge • Allowing turbidity current to pass • Decreasing the storage level during floods • Controlled turbination of water containing sediments.

Source: Boes (2021) cited in (Wenger 2022)

Method and data

Initially our intention was to monetarily value the regulating function of soils with vegetation cover by assessing costs of hydropower enterprises associated with management of one additional cubic meter of fine sediments. Considering that no secondary data exists on this subject, we initiated and co-supervised a project thesis on the cost of sediment management among Swiss hydropower stations at the Chair of hydraulic structures at ETH Zurich (Wenger 2022). In the thesis, the student conducted expert interviews with a sample of operators to collect data on sediment volumes, management techniques and their costs. In total, responses were obtained from 8 operators on 22 hydropower stations. Generally, the operators confirmed that vegetation, e.g. forested areas, help retain sediment flows.

The reported sediment management techniques and the associated costs varied substantially (see Figure 11). The diversity of techniques and costs in combination with the comparatively low sample size does not allow to detect any cost patterns based on which we could draw inferences for all Swiss hydropower plants.

Wenger (2022) concludes that there is no universally efficient and cost-effective sediment management option. The costs per measure can be very different at different locations and at some locations the number of permitted methods is confined. For example, not all operators are authorized to completely flush their basins or to pass the turbidity currents. Figure 11 presents the interview data from 19 hydropower stations on sediment quantities and management costs by management measure taken.

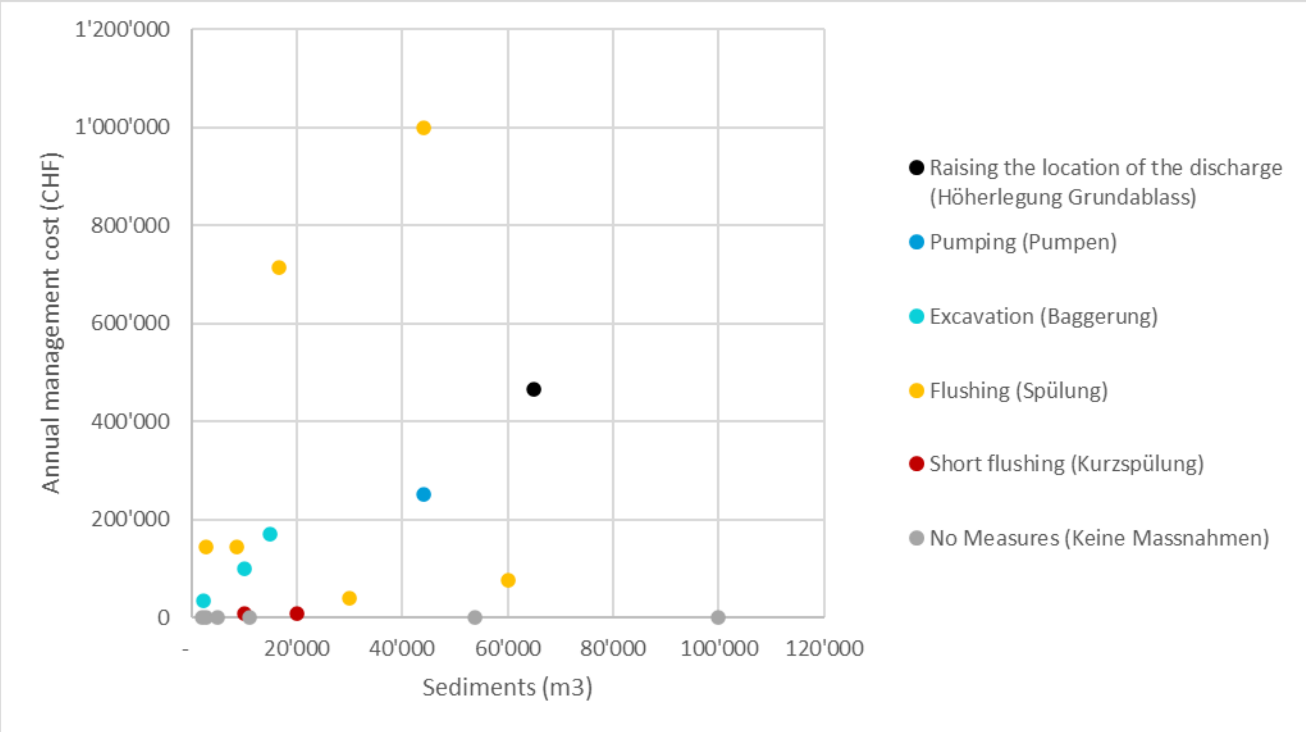

Figure 11: Annual sediment quantities and management costs of 19 large run-of-the-river power plants and storage power plants across Switzerland
Data source: (Wenger 2022)

The analysis of the survey data revealed that the annual sediment management costs were not, or only weakly, correlated with sediment volume, the fine sediment volume, or the sediment volume per km^2 of the catchment basin. Further, it was not possible to detect a relationship between the costs and the proportion of vegetation in the catchment.

The operators of storage power plants were also asked what their economic loss would be in the case of a complete impoundment filling. They answered that in this case, they would not be able to produce electricity. In lack of better data, we thus monetarily value a m^3 of sediment retained in the ecosystem at storage power plants by the monetary value of a m^3 of water used for hydropower production in the same catchment basin. The derivation of the monetary values of water for hydropower production are described in section 10.1 on the NCP Energy. Using this coarse estimate, at the Swiss storage power plants on average, the exchange value is 0.04CHF/m^3 of sediment retained in the environment and the median value is 0.02CHF/m3. For data on the exchange values of retained sediments at each storage plant, please refer to the adjoining excel sheet. However, we recommend revisiting this NCP once sediment management cost data from a larger sample of hydropower stations across Switzerland becomes available.

To compute the monetary volume for this NCP indicator, we multiply the median exchange value by an estimate of the annually avoided tons of erosion. The estimate on avoided erosion (5669650617 tons) was computed using the InVEST software Külling, N. et al. (2024). For simplicity, we assume that 1 ton of erosion has a volume of 1 cubic meter. Each unit of erosion is assumed to fill a water course or impoundment, and thereby decrease the potential for hydropower production. Our estimated monetary volume for this NCP indicator is CHF 113 million.

9.8. Regulation of hazards and extreme events

The NCP Regulation of hazards and extreme events is defined as the “amelioration, by ecosystems, of the impacts on humans or their infrastructure caused by e.g. floods, wind, storms, hurricanes, heat waves, tsunamis, high noise levels, fires, seawater intrusion, tidal waves” as well as the “reduction or increase, by ecosystems or particular organisms, of hazards like landslides, avalanches" (Díaz et al. 2018).

In Switzerland 47% percent of the forest area is categorized as protective forest (BAFU 2020b). Forests protect human lives but also private property and public infrastructure from gravitational risks, such as rock fall, landslides, debris flows and avalanches. Floodplains play an important role in the regulation of flood hazards. A major aim of the Swiss water protection policy is to preserve near-natural stretches of watercourses, or if degraded, to revitalize them. Revitalized floodplains not only contribute to the regulation of flood hazards, but also contribute to the NCPs Habitat creation and maintenance and Physical and psychological experiences.

The methodology presented in this section focuses on protective forest. A box at the end of this NCP's section describes in brief the method for floodplains.

Resource regime

Art. 77 of the Federal Constitution states that the confederation shall ensure that forests are able to fulfil their protective function and determines that the principles of forest protection are specified at the federal level. The Forest Act (Art. 19) stipulates that "where necessary for the protection of human life and significant material assets, the cantons shall secure avalanche, landslide, erosion and rockfall areas and carry out torrent control works in forests".

Furthermore, the Forest Act states that it is the cantons' task to issue planning and management regulations and that the cantons shall ensure minimum maintenance of the protection forest (ForA Art. 20). The forest ordinance further stipulates that the cantons locate protection forests and ensure that the population may be involved in the corresponding forest planning (ForO Art. 18).

The regulations on financial payments through program agreements for the protection of human life and significant material assets against natural events are laid out in Art. 36 of the Forest Act. The corresponding regulations on financial assistance measures for the fulfilment of function of the protective forest are laid out in Art. 37 of the Forest Act.

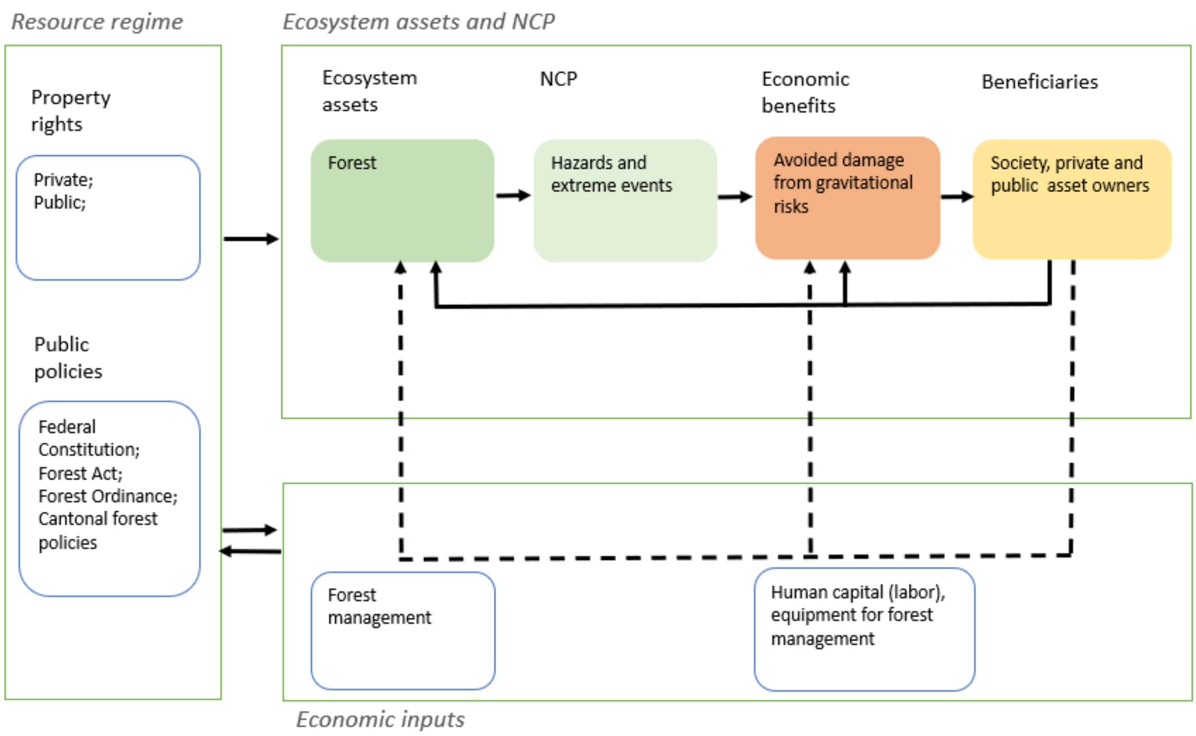

Figure 12: Monetary valuation framework for NCP Regulation of hazards and extreme events.
Source: authors´ presentation

Monetary valuation scope

The objective is to reflect the monetary value of protection forests' function in preventing hazards and extreme events. This is distinct from the values for the material and assets NCP as well as the energy NCP for which we also use indicators on forests.

Method and data

The EconoMe tool hosted by FOEN is a platform for cost-benefit analysis for comparisons of different measures to mitigate natural hazards. It provides lists of monetary base values (Basiswerte) for common assets in the landscape that can be used to compute costs and benefits of different scenarios (BAFU unspecified). Examples include monetary values for bridges, roads, and different types of buildings. Importantly, this list also includes a value for protection forests CHF 1000/a, which corresponds to CHF 100'000/ha (or 97378CHF/ha in prices of 2019) (see Table 24). The suggestion by the tool developers is to use this value for cost-benefit analyses for measures that protect the protection forest. Indeed, there often are avalanche barriers above the tree line, that serve to protect the protection forest below. The given value for production forests is far lower (CHF 20'000/ha).

We propose to interpret this value as the value of the ecosystem asset rather than the NCP flow. Also, there is some reservation on the side of the EconoMe managers given that their values were not developed for NCP valuation purposes. For studies that focus on spatially small and very specific areas of interest, we propose to use the EconoMe tool that allows to investigate in detail the value of assets that are protected by a protection forest. In combination with assumptions on different parameters including the probabilities of hazard occurrence, it is possible to derive site specific monetary estimates for patches of protection forest.

We also contacted several insurance companies in Switzerland and Germany and asked whether they insure protection forests. We received the following information:

- Basellandschaftlichen Gebäudeversicherung (BGV): Insurance of properties including forests is mandatory in Basel-Landschaft. However, BGV does not differentiate between different types of forest.
- Gebäudeversicherung Bern (GVB): They do not insure forests, only properties with buildings.
- Schweizer Hagel: They do not offer insurance for forests in general or protection forests in specific.
- AXA Schweiz: They do not offer insurance for forests in general or protection forests in specific.
- SwissRe: No response.
- AXA Germany: At the moment, the concepts of forest insurance are based exclusively on the timber value or the forest expectation value, which can be realized from the timber growth. There also is a possibility to insure a protection forest with a lump sum - which is due in case of storm or fire damage. This money and possibly a compensation of the increased clearing costs can be used for the restoration of the protective function. (We could not obtain further information on details of the lump sum insurance.)

Previous studies investigating monetary values of protection forests provide data that is not easily transferable to our context. For example, (Olschewski et al. 2008) provide estimates for avalanche protection as absolute values for a case study in Davos. However, they do not present any per hectare values. Olschewski et al. (2011) present a choice experiment conducted in Andermatt on the populations' willingness-to-pay for different avalanche protection measures. As mentioned earlier, WTP estimates contain consumer surplus and thus are not conform with the exchange value approach.

Using an exchange value approach, i.e. estimating the cost of technical measures to substitute for protection forests, Getzner et al. (2017) arrive at a value of EUR 268 per ha of protection forest and year in Austria. This is substantially lower than the CHF 100'000/ha based on the EconoMe tool. In lack of better data from Switzerland, we propose to use the Austrian value as an estimate of the NCP flow.

Floodplains: a second indicator for the NCP Regulation of hazards and extreme events

The Water Rights Act and the Water Protection Act both lay out ecological requirements for flood protection and revitalization projects. Indeed, the requirements are basically the same (Art. 37.2 Water Protection Act (GSchG) and Art 4.2 Water Rights Act (WBG) are identical).

An issue with the monetary valuation of the protective function of (near)natural floodplains is that specific data on their capacity to decrease flood hazards is lacking. According to *UN DESA (2019)* exchange values can be computed as restoration cost of the ecosystem. However, a disadvantage of this approach that is relevant also to floodplains is that the restoration cost represents a basket of NCPs, not only the regulation of hazards. Taking into account this limitation, we investigated whether cost data from NFA-funded projects on water way restorations could be used. Unfortunately, from the available project financial data, it is not possible to specify the costs explicitly related to floodplains (A. Schertenleib 28.09).

The KIP INCA project developed a sophisticated model to assess flood control in the European Union in physical and monetary terms (Vallecillo et al. 2019). Their summary data for Europe can be used to compute a rough estimate of the monetary value of flood control per hectare of wetland. According to their model, in 2012 the value of flood control by wetlands (that also provide support to defense measures) amounted to €244million and the area of wetlands providing flood control was 67508ha. From this we can compute a value of 6222CHF/ha (in 2019 prices).

Table 24: Exchange value estimates for the NCP Regulation of hazards and extreme events

Indicator	CHF/ha
Protection forest (as asset)	97378
Protection forest (based on replacement cost)	405
Wetland	6222

Sources: (BAFU unspecified; Vallecillo et al. 2019)

Note: The value for protection forest was observed in 2022 and then deflated to 2019

To compute the monetary volumes of these NCP indicators, we multiply the exchange values by the area of protection forest (527591ha) and wetlands (28525ha) in Switzerland. For protection forests we use the value based on replacement costs and arrive at a monetary volume of CHF214 million. The estimated annual monetary volume of protection by floodplains is CHF177 million.

9.9. Regulation of organisms detrimental to humans

The IPBES (Brauman et al. 2019) defines the NCP Regulation of organisms detrimental to humans as "regulation, by ecosystems or organisms, of pests, pathogens, predators, competitors, parasites, and potentially harmful organisms". An important benefit provided by ecosystems in this context is regulation of invertebrates presenting important pests in agriculture, horticulture, forestry and stored products.

Predator-prey relationships are known to be very complex and, in many instances, still not fully studied. An additional aspect related to quantifying benefits of this NCP is availability of observations on pest or/and damages caused by pests as well as data on their predators. These two aspects are of a particular importance for monetary valuation of this NCP and has determined the scope of its valuation. In particular, in ValPar.CH, we value common vole biocontrol by avian raptor species in agricultural landscapes. In particular, we utilize the results of a controlled trial conducted by Machar et al. (2017) to compare the effectiveness of the common vole control by avian raptors with that based on the application of a rodenticide.

Resource regime

An option for farmers whose crops and orchards are damaged by common vole populations is to try to combat this pest with rodenticides – chemicals inhibiting blood clotting in voles. The relevant ecosystem in this case is land used for agricultural production. Accordingly, the resource regime described for the NCP Food and feed in section 10.2 applies also for the NCP presented in this section. Moreover, given that pest control of relevant predator species, in our case raptors, strongly depend on their presence/abundance in relevant landscapes, aspects of the resource regime discussed in section 9.1. Habitat creation and maintenance apply here too, with biodiversity and habitat conservation policies implemented in agricultural and semi-agricultural areas being of a particular relevance.

Two further regulatory documents of importance for this NCP are the Biocidal Products Ordinance ("Biozidprodukteverordnung, VBP") and the Ordinance on the placing of plant protection products on the market ("Pflanzenschutzmittelverordnung, PSMV"). When used for human hygiene or material protection, rodenticides fall under the VBP (and are referred to as biocides); while when used in agriculture as plant protection substances they are regulated by the PSMV. Both documents make provisions on the authorization, placing on the market and use as well as the control of rodenticides products.

Rodenticides used in Switzerland (offered in form baits) contain an anticoagulant as an active ingredient. The anticoagulants are very toxic to humans and animals and poorly degradable in the environment. They also do accumulate in living organisms. The PSMV permits the use of three rodenticides in plant protection – aluminum phosphide, bromadiolone, potassium nitrate and calcium phosphide and provides important safety instructions for their use. In particular, it lists the following instructions to be respected:

- Place baits concealed and inaccessible to other animals. Secure bait so that it cannot be carried away by rodents.
- The area must be marked during the treatment. The danger of (primary or secondary) poisoning by the anticoagulant and its antidote should be mentioned.
- Remove dead rodents daily during the application period. Do not dispose of in waste containers.

Due to their high toxicity, anticoagulants are re-assessed in the EU every 5 years (with the last re-evaluation in 2016). Switzerland has adopted the assessment procedures for biocidal active substances from the EU (https://www.anmeldestelle.admin.ch/chem/de/home/themen/pflicht-hersteller/zulassung-biozidprodukte/biozide-wirkstoffe.html).

No rodenticide is currently approved as a plant protection product for the control of the common vole in Switzerland; however, bromadiolone is approved for the control of the European water vole that is more widespread in the country.

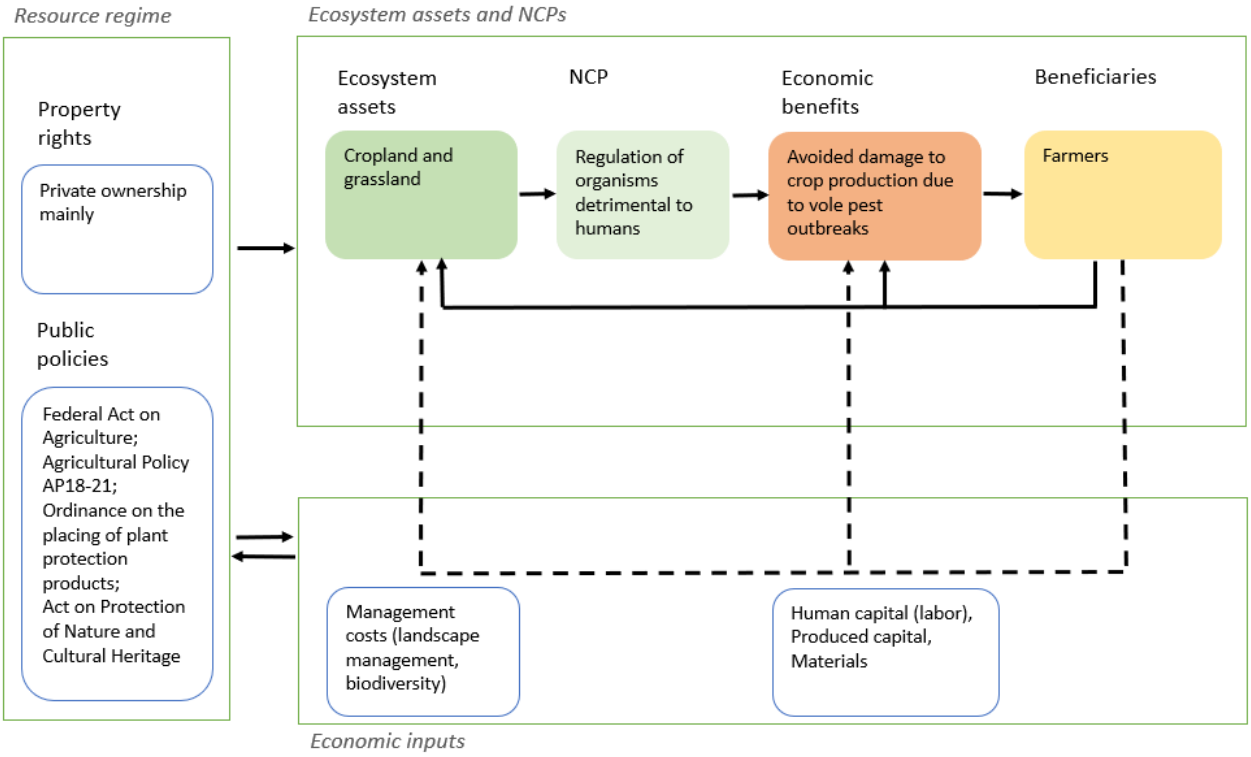

Figure 13: Monetary valuation framework for NCP Regulation of organisms detrimental to humans.
Source: authors´ presentation.

When predators regulating vole populations ingest prey contaminated with anticoagulant rodenticides this can suppress predator populations by secondary poisoning. A recent study by Baudrot et al. (2020) has shown that spreading anticoagulant rodenticides to control vole pests in agriculture may suppress mustelid and fox populations and therethrough inhibit predation ecosystem services to an extent that vole population dynamics have to be fully regulated by rodenticides´ use.

Baudrot et al. (2020) also show that maintaining sufficient voles as prey resources may lead to less rodenticides to be applied and also extend the periods without rodenticides´ treatments. Accordingly, novel rodenticides´ treatment protocols that accounts for secondary poisoning effects may benefit predators while simultaneously avoiding significant vole outbreaks.

Increasing concerns about rodenticides´ damaging effects on biodiversity (through potential secondary poisoning) caused strong interest in biological control of rodent pests in recent years. Regulating rodent populations through avian raptors may be a lower cost alternative compared to rodent control through rodenticides´ application. Two main methods of controlling rodent populations by avian raptors are: (i) installing human-made nest boxes to enhance raptors´ reproduction in agricultural landscapes; and (ii) installing perches to support an increased presence of raptors in often treeless agricultural areas. Such perches are used by raptors as lookouts and resting places (Machar et al. 2017).

In Switzerland, there have been several projects and initiatives supported by policies at the federal and cantonal levels that install in agricultural landscapes infrastructure elements such as nest boxes, stone cairns, dead hedges and ponds to provide sufficient protected areas for birds and small mammals´ and support their reproduction[40].

Labuschagne et al. (2016) found several empirical studies reporting the effectiveness of avian predators as biological control agents for rodent pest management in agricultural systems. These authors also refer to some advantageous features of avian rodents´ predators compared to mammalian species regulating rodent populations in agriculture. In particular, the presence of avian predators creates comparatively less human-wildlife conflicts than mammalian predators. In addition, raptors are also able to respond more quickly to increased pest rodent populations than mammalian predators.

Economic benefits and beneficiaries

Rodent pests are of significant economic and health importance. During their outbreaks, they cause substantial damages to orchards and crops. In addition, some rodents can transmit various infectious diseases that can influence public health. Rodents are often controlled chemically by using rodenticides. In farming, that takes place largely in open space, raptors´ vole control services present an alternative option for regulating rodent populations.

As we assess economic benefits of raptors´ regulation services in agricultural production, the beneficiaries of these services are farmers. The economic benefit to be assessed is avoided damage costs to crops or plants due to vole outbreaks. The proposed measure presents a lower boundary of economic benefits associated with replacing the chemical vole control by the biological one, because it considers neither health benefits nor positive externalities to biodiversity associated with this NCP.

Monetary valuation scope

Labuschagne et al. (2016) draw attention to a low number of studies analysing rodent pest control through avian predators in agriculture and lack of control-treatment studies that quantitatively assess the effects of the predator species´ presence/abundance on rodent populations. A recent study by Machar et al. (2017) addresses this research gap and provides a statistical analysis of the data obtained in an experiment implemented in the Czech Republic (Haná region) to compare the effectiveness of biocontrol of common vole populations by raptors with that of a rodenticide treatment under vole outbreak conditions. In particular, the study tests the effectiveness of artificial perches for raptors in stubble fields undersown with fodder crops. In the experiment five raptor perches[41] per hectare were installed on treated fields to increase presence of raptors and ease their hunting efforts. The study results show that the number of two major raptor species – the common buzzard and the common kestrel – counted on the treated fields was on average 8.5 times larger than on control fields in the two years with vole outbreaks (2005/2006 and 2009/2010). Furthermore, the experiment has demonstrated that controlling the common vole through avian raptors can be as effective as by a standard rodenticide treatment (Machar et al. 2017).

Considering that common vole populations appear to be already well controlled by avian raptors and similar experiments have not been done yet for Switzerland, in our approach we rely on the results of the study by Machar et al. (2017) and derive a monetary value of common vole pest control provided by two raptor species, the common buzzard and the common kestrel, which can be found also in Switzerland.

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[40] http://www.bff-spb.ch/fileadmin/pdfs/DE/Direktzahlungen_BFF.pdf

[41] A wooden pole 2 meters high with a T-shaped vertical cross piece on the top. Similar perches are used also in Switzerland, https://www.vogelwarte.ch/de/voegel/ratgeber/fuetterung-im-winter/sitzstangen-fuer-greifvoegel.

Method and data

The study by Machar et al. (2017) provides the information on the number of the two raptor species required to control common vole populations (in stubble fields) as effectively as by means of the chemical vole control used in their study, in particular by applying per hectare of cropland 5 kg of an anticoagulant rodenticide at a concentration of 0.005%. Accordingly, we can calculate costs of rodenticide application per hectare of agricultural land while applying corresponding rodenticide´s price and labour costs associated with its purchase and distribution (in Swiss agriculture) that will proxy farmers´ avoided damage costs in case of a common vole outbreak. Although rodenticides are currently not used in Swiss agriculture for the control of common vole populations (but for the control of the European water vole), we assume that in the absence of an effective avian raptor control, damage to agricultural production caused by this rodent species would be comparable with that reported in the study by Machar et al. (2017) and hence could be proxied by costs of chemical rodent control. Subsequently, we multiply the cost of rodenticide application by three different probabilities of hypothetical common vole population outbreaks to calculate farmers' costs for chemical control per year.

In the next step, we measure costs of building and installing perches (5 perches/ha) and divide these costs by the total useful life of a perch in years, namely 20 years; that is we apply linear depreciation to measure annual costs associated with installing perches. In the final step, we compute the difference between the annual costs of chemical control and those associated with building and installing perches. This procedure results in a monetary value of biocontrol services provided by two considered avian raptor species per hectare of arable land that varies subject to assumed probability of a common vole outbreak.

Table 25: Exchange values measured as avoided damage to crop production due to common vole control by common buzzard and common kestrel, CHF of 2019 per ha of arable land

Probability of common voles outbreak	Avoided damage costs, CHF of 2019 per ha of arable land
0.33 (once every 3 years)	163.83
0.25 (once every 4 years)	119.74
0.20 (once every 5 years)	93.28

Source: own calculations

The aggregate contribution of biocontrol by raptor species can be computed by multiplying the avoided damage estimates in Table 26 with the area of arable land.

Table 26: Total avoided damage to crop production due to biocontrol of common vole populations by raptor species: average for 2015-2019

Probability of common voles outbreak	Total avoided damage costs, Mio. CHF of 2019
0.33 (once every 3 years)	44.79
0.25 (once every 4 years)	32.74
0.20 (once every 5 years)	25.50

Source: own calculations

10. Material NCPs

10.1. Energy

In 2018, of the primary domestic energy production (266,310 TJ), 50.6 % came from hydropower, 15.0 % from wood, 22.4 % from household and industrial waste, and 12.0 % from other renewable energy sources (solar, wind, biogas, biofuels and ambient heat).

For the monetary valuation of this NCP, we selected wood-sourced energy and hydropower as two different indicators for one NCP. Especially wood for energy production is in accordance with previous studies, which defined the Energy NCP as the production of biomass-based fuels such as fuelwood (Díaz et al. 2018; Martín-Forés et al. 2020). Below, we focus on hydropower as indicator. The resource regime as well as method and data for wood-sourced energy are basically identical to those for the NCP Material and assistance. To avoid duplication, we refer the reader to section 10.3 for details and only touch upon this indicator shortly in the box below.

Wood for energy production

In brief, we count energy wood as economic benefit. (Stem wood and industrial wood are taken into account in the NCP Material and assistance.) Various types of users who make use of energy wood, including households, industry and the public sector, are the beneficiaries of this NCP. We use residual values for energy wood as one estimate for the monetary value of the NCP Energy. In terms of method and data, the approach is equivalent to the NCP Material and assistance. The only difference is that the focus here is on energy wood while in the NCP Material and assistance it is on stemwood and industrial wood.

Resource regime for hydropower

The right to exclusively use water from a public water body for hydropower production is formalized in concessions. The concessions lay out the annual fee that the concessionaire must pay to the conceding administrative entity (e.g. canton, district, municipality). The Ordinance on the determination of water fees (Verordnung über die Berechnung des Wasserzinses SR.721.831) stipulates that the fee is to be based on a hydropower plant's annual average gross capacity (in kilowatt), which is to be calculated from the usable water volume and the usable gradient.

According to Art. 76. 4 of the Federal Constitution, the monetary fee based on a plant's annual average gross capacity is determined by the cantons within the limits given by federal law. Currently (i.e. until 2024), the federal price ceiling is set at CHF 110 per kilowatt of gross capacity. About half of Switzerland's hydropower is generated in the two cantons Valais and Grisons.

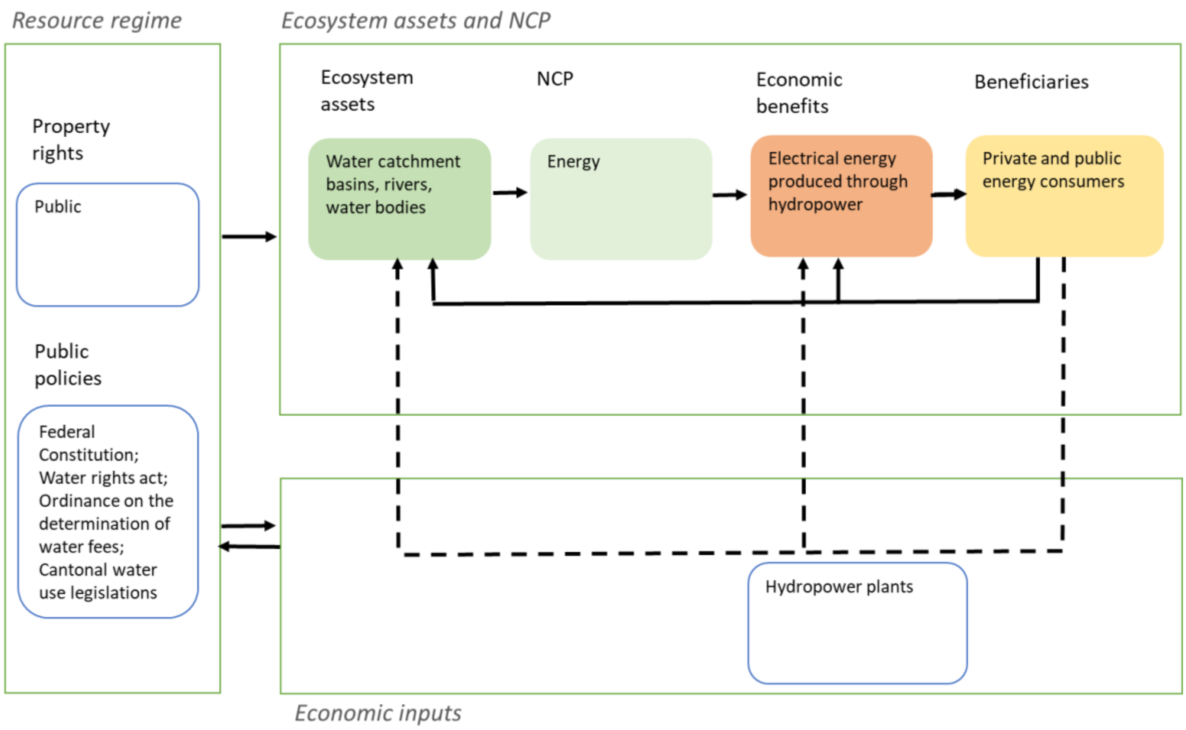

Figure 14: Monetary valuation framework for the hydropower indicator for the NCP Energy.
Source: authors´ presentation

Economic benefits and beneficiaries

The economic benefit is the energy that can be generated with water in run-of-the-river power plants, storage power plants, and pumped storage power plants. The beneficiaries are all private and public consumers of electrical energy.

Monetary valuation scope

We compute the monetary value of water in terms of the energy that it can generate if turbinated (CHF/kWh). Our computations refer to hydropower plants with a gross capacity above 2 megawatt that are obliged to pay full concession fees.

Method and data

We apply the residual value approach to compute the exchange value of water for hydropower production. Below, we present two versions of this approach. In the first, we simply subtract the production cost of electricity generated in hydropower plants from the energy market price. The resulting values are negative for the years 2016, 2019 and 2020. Given the findings of the analysis of the resource regime, we argue that we can obtain a more accurate estimate by correcting for the concession fee and the deficiency payment. As can be seen from the last row of the table, the adjusted residual value is positive for all years. (For more details on the computations, please refer to the adjoining excel sheet).

Table 27: Energy market prices and production costs

CHF/kWh in 2019 prices	2015	2016	2017	2018	2019	2020	2021
Spotmarketprice[1]	0.0649	0.0602	0.0743	0.0840	0.0641	0.0529	0.1714
Production cost [2]	0.0635	0.0686	0.0658	0.0653	0.0650	0.0655	0.0651

Concession fee[2]	0.0147	0.0148	0.0147	0.0146	0.0145	0.0146	0.0145
Average deficiency payment [3]			0.0028	0.0018	0.0021	0.0038	0.0007
Simple residual value: Spotmarketprice-Production cost	0.0014	-0.0085	0.0085	0.0188	-0.0009	-0.0126	0.1063
Adjusted residual value: Spotmarketprice-(Production cost – deficiency payment) + Concession fee	0.0161	0.0063	0.0259	0.0351	0.0157	0.0058	0.1215

Data sources: 1: annual average of power spot-market price for Switzerland at European Power Exchange (EPEX SPOT SE) based on Index Swissix Day Base (www.bricklebrit.com) converted from € to CHF using PPP exchange rates. 2: production cost and concession fee for 2015 and 2016 in values of 2019, from 2017 onward average of 2015 and 2016 in 2019 prices (BFE 2018). 3: Media releases (BFE 2017-2022). All values in 2019 prices (deflated using the consumer price index).

By multiplying the annual residual values computed in Table 27 by the energy produced per cubic meter of water, we obtain estimates of the exchange value in CHF/m³ of water at the various hydropower stations in Switzerland.

The amount of energy produced per cubic meter of water can be estimated by dividing each plant's expected average energy production by the amount of water that is turbinated. Unfortunately, data on turbinated water quantities is not available, but we can approximate the amount by using available data on the turbines' capacity in terms of cubic meters of water per year. Given that it is unlikely for turbines to run at full capacity throughout the year, our computed values likely underestimate the amount of energy produced per unit of water. Given the large number of hydropower stations, we do not present this data here (the data is available in the adjoining excel sheet).

Results for Energy wood

As presented in the box above, we use energy wood as a second indicator for the NCP Energy. The residual value approach and data sources are equivalent to those for stemwood and industrial wood that are discussed in more detail in the section on the NCP Material and assistance. For this reason, we only present the results here (see Table 28).

Table 28: Exchange values for Energy wood (CHF/m³), deflated to 2019 prices

		2013	2014	2015	2016	2017	2018	2019	2020
Coni-ferous fuelwood	**Jura**	-19.56	-10.13	-23.74	-20.27	-23.81	-15.03	-15.15	-17.47
	Central Plateau	-25.31	-20.40	-24.10	-17.06	-20.82	-21.51	-22.93	-22.77
	Pre-Alps	-27.58	-19.01	-23.96	-19.93	-16.78	-12.71	-15.38	-17.21
	Alps	1.96	10.99	10.21	-3.35	14.30	-8.34	5.53	9.04
	Southern Alps	3.35	17.01	20.40	4.26	26.87	5.11	21.41	24.89

Hard-wood fuelwood	**Jura**	23.85	31.44	20.07	38.02	35.79	43.72	52.40	41.02
	Central Plateau	14.69	18.73	11.26	12.78	20.63	18.81	29.65	36.10
	Pre-Alps	15.79	23.75	16.00	19.83	23.31	28.90	36.54	44.20
	Alps	60.25	72.18	75.69	31.30	48.47	25.40	60.52	73.62
	Southern Alps	77.92	99.91	94.30	57.70	69.67	44.88	78.80	108.14

Data sources: (BAFU 2014-2021; OFS, WaldSchweiz, Agristat 2022; Swiss Federal Statistical Office 2022a, 2022b)

The results for both indicators, water for hydropower production and fuelwood, reveal that there can be substantial differences in the exchange values of this NCP over time and space. For coniferous fuelwood our estimates are negative in many regions. This is because the market price plus subsidies was lower than the harvest cost. As discussed in section 10.3 below, the market price is influenced by international markets and may not capture the total value of this NCP. In the case of hydropower, the government may want to hedge against energy supply and price risks by subsidizing unprofitable hydropower plants. In this sense, the deficiency payment can be interpreted as the risk premium that society is willing to pay to avoid energy supply and price risks. How real these risks are, has become apparent over the past year.

We compute the monetary volume of water for hydropower production by multiplying the median of the exchange values of water based on hydropower production (0.02 CHF/m3 in 2021 in prices of 2019) by the estimated volume of water used for hydropower production (550'000 million m^3) (Björnsen Gurung and Stähli 2014). The resulting value is CHF11000 million.

Similarly, we compute the monetary volume of harvested energy wood by multiplying the quantity harvested (average 2013-2018: 1797984.5m^3) by the corresponding exchange value (average 2013-2018 of weighted average exchange values for the different assortments: 66.86CHF/m^3). This results in a monetary volume of CHF 120 million.

10.2.Food and feed

The IPBES (Brauman et al. 2019) provides a rather broad definition of the NCP Food and feed as "Production of food from wild, managed, or domesticated organisms on land and in the ocean; production of feed". This definition of the NCP includes food and feed produced and/or harvested in diverse terrestrial and aquatic ecosystems. In addition, it comprises in addition to food and feed produced in agricultural production, produces generated by living organisms in natural ecosystems. Finally, it appears to consider not only final NCPs and therefore to bear a potential for double counting contributions of Nature to food and feed production. In particular, in addition to listing domesticated organisms as one of food categories, it also incorporates feed produced for breeding them.

Similar to recently implemented national ES assessments (van Berkel et al. 2021; Scottish government 2020; Bateman et al. 2014), in ValPar.CH we propose to value Nature´s contributions to producing food and feed in agricultural systems exclusively. In particular, we define the associated benefit as contributions of ecosystem processes supplied by agricultural land, specifically cropland and grassland, to food and feed production.[42] Food produced from livestock production is not considered as an NCP indicator, as it is produced using feed which itself already captures Nature´s contribution to food production.

Resource regime

Agricultural production is in most industrialized countries strongly determined by national agricultural policies and the magnitude of public support to agricultural producers. Switzerland's overarching agricultural policy objectives reflect societal concerns and are summarized in the Swiss Constitution as follows: (i) ensuring food supplies for the population; (ii) preserving natural resources and maintaining agricultural land in a cultivated state; and (iii) supporting decentralised settlements. To attain these objectives, a number of agricultural policy instruments are implemented. These instruments comprise sector general support instruments, direct payments to farmers as well as border protection.

Since 1999, all direct payments provided to Swiss farmers are subject to ecological cross compliance regulations – "ÖLN (Ökologischer Leistungsnachweis)". Within this policy setting, the following seven types of direct payments were provided to Swiss farmers under the most recent agricultural policy framework – AP18-21[43]: (i) Payments for ensuring food supply ("Versorgungssicherheitsbeiträge"), (ii) Contributions for open landscapes ("Kulturlandschaftsbeiträge"), (iii) Biodiversity payments ("Biodiversitätsbeiträge"), (iv) Contributions to landscape quality ("Landschaftsqualitätsbeiträge"), (v) Contributions for organic and extensive production systems ("Produktionssystembeiträge"), (vi) Contributions for efficient use of resources ("Ressourceneffizienzbeiträge") and (vii) Transitionary payments ("Übergangsbeiträge").

An evaluation of the relevance of the current border protection regime for agriculture in Switzerland (Gray et al. 2017) has shown that border protection is a relatively inefficient and expensive policy instrument because it does not specifically promote services that are demanded by the society (such as e.g. environmental services, animal welfare, decentralized settlement). Consequently, the OECD (Gray et al. 2017) recommends several alternative policy measures that may provide more targeted contributions to achieving the constitutional goals.[44] Implementation of such policy measures could considerably influence the magnitude of agricultural production in Switzerland as well as its structure and spatial distribution. However, as it is currently not foreseeable, whether and when policies proposed by the OECD or other significant reforms in agriculture will be adopted and implemented in Switzerland, we value the NCP Food and feed in ValPar.CH considering the current agricultural policy framework including border protection measures. Accordingly, we do not adjust the value added from agriculture measured in producer prices to account for price differentials that exist for certain categories of agricultural products compared to border prices.

[42] Agricultural production is highly dependent on multiple services provided by ecosystems such as nutrient re/cycling, soil structure and fertility, water provision, pollination, carbon sequestration and pest control (Power 2010). Many of these services are considered in corresponding specific NCP categories such as e.g. Pollination and dispersal of seeds, Regulation of climate, and Regulation of freshwater quantity, location and timing. The scope of the valuation of the NCP Food and feed encompasses contributions of soil ecosystems and processes to agricultural production as carried out by cropland and grassland.

[43] https://www.fedlex.admin.ch/eli/fga/2016/997/de

[44] In particular, the authors suggest a stronger regionalization of direct payments, stricter environmental requirements and the introduction of new instruments for risk management.

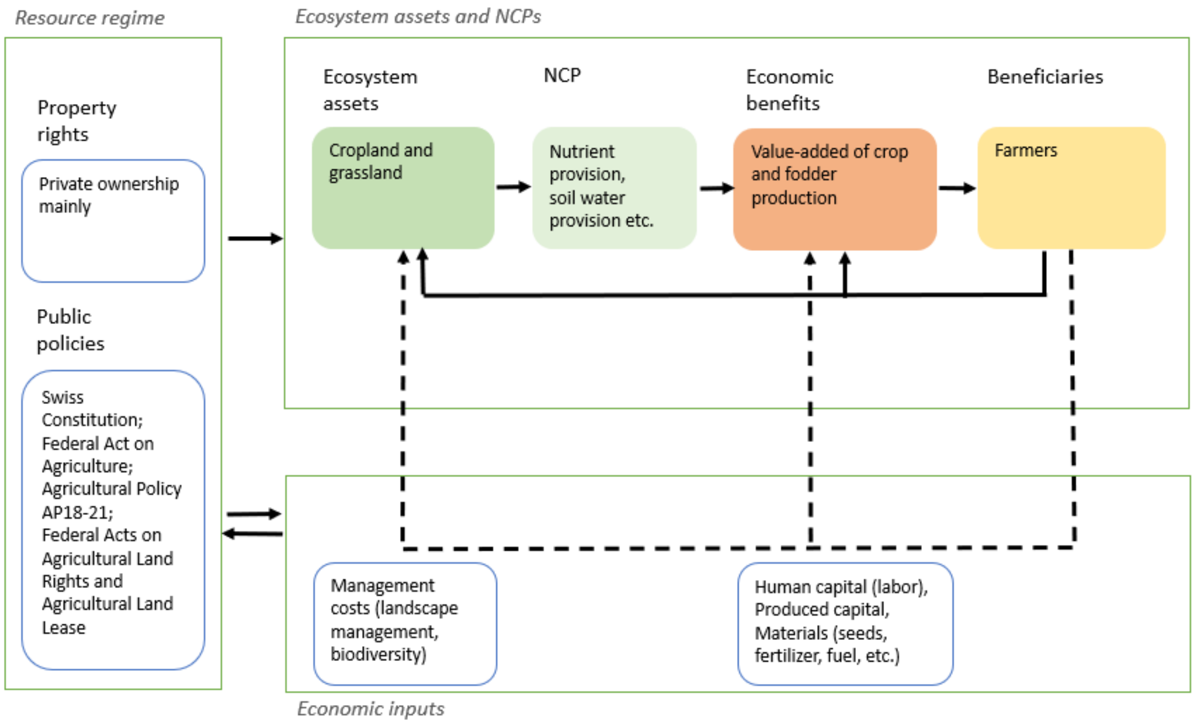

Figure 15: Monetary valuation framework for the NCP Food and feed.
Source: authors´ presentation.

The two important legal acts regulating agricultural land use are the Federal Act on Agricultural Land Rights ("Bundesgesetz über das bäuerliche Bodenrecht, BGBB"[45]) and the Federal Act on Agricultural Land Lease ("Bundesgesetz über die landwirtschaftliche Pacht, LPG"[46]). To prevent overshooting of rental prices, agricultural land rental prices are capped in Switzerland. The Ordinance on the Agricultural Rent Assessment ("Verordnung über die Bemessung des landwirtschaftlichen Pachtzinses"[47]) and the Guidance on the Estimation of the Agricultural Yield Value ("Anleitung zur Schätzung des landwirtschaftlichen Ertragswertes"[48]) stipulate the rules for determining agricultural land rents.

Economic benefits and beneficiaries

We define the NCP Food and feed similar to earlier national ES valuation studies as contributions of ecosystem processes to production of food and feed that are directly supplied by agricultural land (van Berkel et al. 2021). These contributions may vary subject to climate, soil type as well as past and current production practices used by farmers. The associated economic benefit is the value added generated in agriculture using this natural resource. Accordingly, its monetary value can be measured as resource rent that is the difference between the value of output produced and all human-induced costs or costs of other factors used in production. The monetary value of agricultural land can be also proxied by observed rents for land of similar quality. Under a competitive rental land market, marginal

[45] https://www.fedlex.admin.ch/eli/cc/1993/1410_1410_1410/de
[46] https://www.fedlex.admin.ch/eli/cc/1986/926_926_926/de
[47] https://www.fedlex.admin.ch/eli/cc/1987/406_406_406/de
[48]https://www.blw.admin.ch/dam/blw/de/dokumente/Instrumente/Boden-%20und%20Pachtrecht/Bodenrecht/Sch%C3%A4tzungsanleitung_20180131.pdf.download.pdf/Sch%C3%A4tzungsanleitung_20180131.pdf

contribution of land to agricultural output (marginal product of this factor) should coincide with rents paid for corresponding land parcels.

The beneficiaries of this NCP are farmers, who utilize land along human capital, produced capital (machine and equipment), and materials as an input in the production process.

Monetary valuation scope

Due to market failures and also policy interventions aimed at addressing the earlier, land and other production factors´ prices may deviate considerably from their marginal productivity. Under these circumstances, production factor prices such as rental prices for agricultural land might be inadequate measures of factors´ marginal contributions to final goods produced using these factors. In addition, as argued by Horlings et al. (2020), market conditions might eliminate resource rents in some sectors. This may result in biased estimates of resource rents – they might be too low or even get negative estimates. To address this issue, we propose to value the NCP Food and feed using the production function approach, which shall allow us to derive marginal products for all factors used in the production including utilised agricultural land.

Method and data

Production function method. The application of this method enables deriving the marginal product for each relevant production factor. The marginal product of a factor expresses the change in the output associated with a marginal change in the use of this factor. Under the assumption of profit-maximizing behaviour, estimates of marginal productivity of factors can be considered as implicit prices applied by farmers when making their production decisions. Accordingly, differences between marginal product estimates and corresponding observed factor prices are supposed to indicate the presence of some further (unobserved) factors such as e.g. transaction costs that influence farmers´ decisions.

The ecological cross-compliance regulations in Switzerland put constraints on production practices used by Swiss farms and hence also on (short-run) agricultural land productivity. In this context, direct payments and border protection measures may present not necessary most efficient but nevertheless important instruments aimed at overcoming market failures. In particular, by compensating farmers for the efforts/costs that might be not paid by consumers/markets in the presence of market failures, they incentivize farmers to adopt/use more sustainable production practices. Although subsidies and market price support measures may overpay farmers for complying with regulations, it might be still reasonable to consider social benefits such as those associated with production of food under environmental cross-compliance measures when deriving monetary values of the NCP Food and feed. Accordingly, to assess land marginal productivity in the production function method, we propose to formulate the farm output as the farm total output from agricultural and para-agricultural activities supplemented by direct payments aimed at reducing negative externalities from agriculture, in particular direct payments for organic and extensive production systems and contributions for efficient use of resources.

To derive marginal product estimates for different categories of agricultural land, we use Swiss FADN data for crop and dairy farms[49] for the period from 2003 to 2013. Although the FADN data are also available for the period after 2013, these data cover substantially less farms due to the sampling methodology reform implemented by Agroscope in 2015 and accordingly are less suited for a statistical

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[49] We propose to focus our analysis on these two types of farms, as the FADN samples for other types of farms are quite small and therefore less suited for a statistical analysis. Furthermore, these two types of farms present two main agricultural production systems of Swiss agriculture.

analysis.[50] In addition to land, we consider three other production factors, in particular, labour, capital (incl. depreciation of dairy livestock) and materials. To control for farm unobserved heterogeneity and technical ineffciency, we formulate a true fixed effects (TFE) stochastic frontier model as proposed by Greene (2005). To this end, we also reduce corresponding FADN farm samples to farms with at least 5 annual observations for the period covered by the data.

We specified a production function model that allows to control for differences in agricultural land productivity between farms situated in different soil suitability climatic suitability zones as captured in the FOAG maps of soil and climate suitability for agricultural production[51]. Unfortunately, we did not receive reasonable estimates for these model specifications. This outcome may be related to relatively small sizes of corresponding farm sub-samples, especially those for crop farms. We also tested model formulations distinguishing between differences in productivity of crop land and grassland. However, differences in output elasticities for these two categories of land use were not found to be statistically significant. An explanation for this result could be a very low share of arable land in total agricultural land in dairy farms and a low share of grassland in crop farms. Considering these outcomes of our analysis, we estimated production function models for totally 4 sub-samples, in particular, one sample of crop farms and three sub-samples of dairy farms each associated with a particular agricultural production zone. Subsequently, we derived marginal products of land as a product of output elasticity estimate for land input and average productivity of land for corresponding farm sub-sample.[52,53]

According to our estimates (Table 29), exchange values for the agricultural land contribution to food and feed production vary from 2558 to 6314 CHF of 2019 subject to farm specialisation and agricultural

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[50] There have been several studies, which estimated production technology parameters for Swiss farms, which could be used for deriving shadow prices of agricultural land (Bokusheva et al. 2012; Mamardashvili et al. 2014; Lakner et al. 2015; Renner et al. 2021). Given the importance of dairy farming in Switzerland, most studies focused on studying economic performance of dairy farms. The most recent study by Renner et al. (2021) shows that agricultural land elasticity of Swiss dairy farms varied between 0.18 and 0.22 subject to the level of farm technological upgrading in the period from 2003 to 2013. These estimates indicate that an increase in land use by 1 percent leads to an increase in the Swiss dairy farm output by 0.18-0.22 percent. Mamardashvili et al. 2014) obtained an estimate of the land elasticity equal to 0.38 for Swiss dairy farms for the period 2003–2009. However, in contrast to (), who formulated farm output as the sum of total farm revenue from agriculture and para-agricultural activities supplemented by ecological direct payments, Mamardashvili et al. 2014) used in addition to the farm agricultural output and para-agricultural output all types of direct payments received by farms as an additional output category in their model specification. Accordingly, the difference in the agricultural land elasticity estimates between these two studies may be explained by different formulation of the farm output. For Swiss organic mixed and grassland farms, (Lakner et al. 2015;) obtained an estimate of land elasticity of 0.18. In this study, the farm output was formulated as the sum of agricultural and par-agricultural outputs. Furthermore, the results of the study by Bokusheva et al. 2012) indicate that differences in marginal productivity of land between two main types of Swiss farms (crop and dairy farms) observed during the 1990s disappeared after the introduction of the environmental cross-compliance regulations in 1998. This empirical finding suggests that output elasticity estimates of land may show similar magnitudes across different farm types, on average.

[51] https://map.geo.admin.ch

[52] All four production function specifications were formulated using a flexible functional form (Translog) and as fixed effects stochastic frontier models to control for unobserved farm heterogeneity and the presence of technical inefficiency.

[53] Rental price method is an alternative method used for valuing provisioning ecosystem services. Land rents are payments made by a tenant to a landowner for its use over a specified period. As mentioned earlier, agricultural land rental prices are determined in Switzerland in accordance with the provisions of the Federal Act on Agricultural Land Lease. In particular, rental prices for agricultural land are calculated on the basis of the land parcel productivity and other specifics such as soil quality, slope, shape, potential use limitations as well as considering location aspects of individual parcels. However, according to the personal communications with Mr. Martin Würsch from the Federal Office of Agriculture (FOAG) and Mr. Felix Peter from the Department of Finance and Resources in Canton Aargau, actual (observed) rental prices are often considerably higher than corresponding guiding rental prices calculated according to the Ordinance on the Agricultural Rent Assessment (further on referred to as the guiding rental prices). In addition, neither actual nor guiding rental prices have to be reported by farmers to federal and cantonal authorities. Agroscope also does not systematically collect land rental price data. Accordingly, we limit the scope of our valuation of the NCP Food and feed to the production function approach.

zone in which corresponding sample farms are located in. The highest estimate is associated with agricultural land in crop farms, which are situated mainly in the plain zone and have a relatively low share of pastures. Dairy farms situated in the hill zone with high shares of pastures in total utilized land were found to have the lowest marginal contribution of land to agricultural output measured as the revenue from agricultural production including environmental and hill slope subsidies.

Table 29: Exchange values derived as marginal product of agricultural land by agricultural zone and farm specialisation

Agricultural zone	Farm specialisation	Pasture share (sample farms average)	Marginal product of land estimate, CHF of 2019[1)]/ha of agricultural land	Based on 95% confidence interval land elasticity values	
				Lower bound	Upper bound
Plain zone	Crop farms	15.20%	6314.4	4063.2	8565.6
	Dairy farms	89.60%	4781.1	3041.8	6520.4
Hill zone	Dairy farms	91.00%	2557.8	1152.1	3963.4
Mountain zone	Dairy farms	96.90%	2841.3	2355.2	3327.4

Note: Agricultural zones are defined according to the Ordinance on the agricultural production cadastre and the designation of zones (https://www.fedlex.admin.ch/eli/cc/1999/46/de)

Source: own estimations

We approximate the aggregate contribution of soil ecosystem services to food and feed production in Switzerland using the above-presented estimates of land shadow prices and FOS statistics on agricultural land use for the 2015-2019 period in three agricultural production zones. The results of our assessment show higher contributions of soils to agricultural production in the plain and mountain zones than in the hill zone.

Table 30: Contribution of soil ecosystem services to food and feed production: average for 2015-2019, Mio. CHF of 2019

	Average estimate	Lower confidence interval estimates	Upper confidence interval estimates
Total	3640.0	2147.7	5132.4
Plain zone	2336.4	1283.3	3389.5
Hill zone	333.9	109.4	558.4
Mountain zone	969.7	755.0	1184.4

Source: own estimations

10.3.Material and assistance

According to Díaz et al. (2018), the NCP Material and assistance refers to "Production of materials derived from organisms in cultivated or wild ecosystems, for construction, clothing, printing, ornamental purposes (e.g. wood, peat, fibers, waxes, paper, resins, dyes, pearls, shells, coral branches)". Díaz et al. (2018) also explain and exemplify this NCP as "live organisms being directly used for decoration (i.e. ornamental plants, birds, fish in households and public spaces), company (e.g. pets), transport, and labor (including herding, searching, guidance, guarding)". In the context of the Swiss economy, wood may be the most relevant production material derived from cultivated ecosystems.

Therefore, we use wood for construction as the benefit from the NCP Material and assistance in ValPar.CH.

Resource regime

The public sector owns 898 000 ha or approximately 71% of Swiss forests. Private owners own just under 373 000 ha or 29% of the forest area. However, there are large regional differences in terms of ownership; on the one hand between public and private ownership, and on the other hand between the public ownership categories themselves (BAFU 2020a).

Independent of the type of the ownership, harvesting in Swiss forests must follow sustainable forest management practices (Art. 20, ForA, quoted in Creutzburg et al. (2020)). These practices exclude certain harvesting practices, such as for example clear-cutting (Art. 21, ForA).

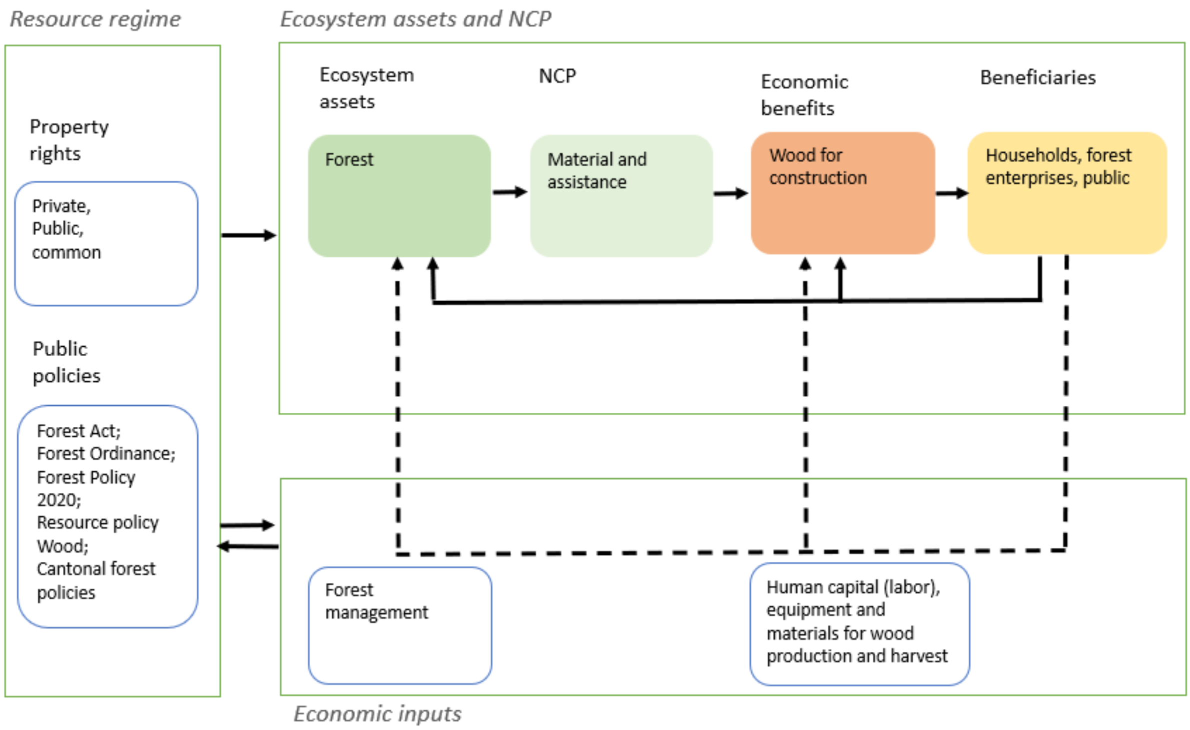

Figure 16: Monetary valuation framework for NCP Regulation of freshwater quantity, location and timing. Source: authors´ presentation

Forests provide, in addition to wood as a material, a number of further NCPs, among them regulation of hazards and extreme events, habitat for species, regulation of air quality and climate, energy, learning and inspiration, and physical and psychological experiences. By imposing sustainable forest management practices, public policies seek to ensure a continuous flow of various NCPs provided by the forest ecosystem. However, by doing so, public policies may induce high forest management costs for domestic forest enterprises. Since not all NCPs provided by forests are traded in markets and accordingly present a source of revenue for forest enterprises, costs of sustainable forest management may exceed revenues generated by forest enterprises.

Economic benefits and beneficiaries

During the past two decades, the total annual wood harvest ranged roughly between 4.5 and 5.5 million cubic meters. For example, in 2019 the total harvest amounted to 4.6 million cubic meters of which 48% was stemwood, 11% was industrial wood, and 41% was energy wood (BAFU 2020a). For the NCP Material and assistance, we count only the first two categories, stemwood and industrial wood, as economic benefits. Energy wood cannot be considered in this NCP because it is not used as a material but a source of energy. Various types of users who produce or make use of construction wood, including forest enterprises, households and the public sector, are the beneficiaries of this NCP (BAFU 2020a).

Monetary valuation scope

For the monetary valuation of wood as indicator for the NCP Material and assistance, we need to obtain the price of construction wood at the point in time when it transitions from the ecosystem to the economy. The price of a standing tree, i.e. the value of the tree in bark before harvest, is called the stumpage price. In many countries, wood is traded in bark before harvest, which allows using stumpage prices as market prices. In Switzerland, this trading practice is uncommon and there exists no market for wood in bark. However, in 2014 the Federal Statistical Office (FSO) started computing stumpage prices within the project "Ökonomische Bewertung des stehenden Holzvorrates" (Murbach 2016). However, unfortunately, these computed stumpage prices are not differentiated by stem-, industrial, and energy wood. For our purpose, we thus use a residual value approach to compute the exchange values for stemwood and industrial wood.

Method and data

We calculate the exchange value of stemwood and industrial wood by subtracting the harvest costs from the price of wood and adding subsidies paid at the level of the harvest process. The latter is because due to market failures, the residual value computed using only wood market prices and harvest cost may underestimate the real social benefits of wood production under sustainable forest management practices and may result in negative values. We argue that it is important to consider that Swiss forest enterprises have to comply with sustainable forest management practices which may not be reflected in the wood selling prices that can be volatile and follow price developments in international markets.

Our objective in computing the exchange values of wood as indicator for the NCP Material and assistance was to remain consistent with the economic accounts for the primary sector provided by the Federal Statistical Office (FSO). These economic accounts are computed by the FSO in accordance with the SEEA guidelines. However, this data is only available at the national level without regional differentiation. A different data set, the Swiss Forest Statistics, provides data on regional wood quantities and observed regional wood prices are available from Agristat. Because these data sources are not fully consistent with the economic accounts, we cannot directly combine the datasets. Instead, based on a discussion with Mr. F. Murbach at the FSO, we use the Forest Statistics and Agristat data as weights to regionalize the economic accounts data.

Harvesting costs differ substantially between forest zones. Data on harvest costs and subsidies by forest zone are available in the 'Forstwirtschaftliches Testbetriebsnetz' dataset (Bundesamt für Statistik 2021). This dataset is based on the accounting data of a sample of 160 forest enterprises throughout Switzerland. For consistency, we deflate the resulting annual exchange values by zone to 2019 prices. The results are presented in Table 31. For some assortments in some regions, the NCP estimates are negative. This is because the harvest cost surpassed the market price plus subsidy. As mentioned above, the market price may not reflect the entire value of this NCP.

Note that the KIP INCA project avoids negative residual values by multiplying the volume of wood in EU countries with an 'ecosystem contribution coefficient', to express the share of the wood that is produced due to ecosystem inputs as opposed to human inputs (Vallecillo et al. 2019). They then multiply the ecosystem's share of the wood by market timber prices, which necessarily will result in a positive value. For the EU, their estimate is close to 30€/m^3 of wood which is within range of our estimates for Switzerland.

Table 31: Exchange values for stemwood and industrial wood (CHF/m³), deflated to 2019 prices

Exchange values for wood as material, CHF/m3 in 2019 prices		2013	2014	2015	2016	2017	2018	2019	2020
Coniferous longwood	Jura	41.40	40.19	32.12	41.80	34.74	37.40	40.19	36.96
	Central Plateau	38.42	38.11	33.95	44.15	38.49	34.89	33.77	17.50
	Pre-Alps	38.82	40.46	35.15	27.89	45.41	44.52	43.25	41.20
	Alps	59.29	62.55	61.34	38.97	50.25	26.08	43.27	45.39
	Southern Alps	59.08	61.03	59.91	38.97	50.25	26.08	43.27	45.39
Long hardwood	Jura	56.58	62.85	62.09	68.12	65.92	74.71	63.85	81.32
	Central Plateau	54.61	60.77	64.05	71.89	64.87	50.17	57.74	23.44
	Pre-Alps	56.92	62.73	65.03	39.65	65.52	51.57	67.81	59.82
	Alps	76.97	81.79	88.35	45.75	82.74	44.54	82.81	80.96
	Southern Alps	76.97	81.79	88.35	45.75	82.74	44.54	82.81	80.96
Industrial and other coniferous wood	Jura	-1.04	-0.49	12.51	-0.38	-0.80	8.64	16.32	8.35
	Central Plateau	-2.75	-6.06	10.45	2.05	9.96	5.63	10.32	4.32
	Pre-Alps	-10.65	-6.61	8.23	-2.83	4.37	11.65	18.34	2.49
	Alps	9.63	12.70	31.98	3.28	21.59	4.62	33.34	23.64
	Southern Alps	9.50	12.72	32.48	3.28	21.59	4.62	33.34	23.64
Industrial and other hardwood	Jura	-8.65	-2.73	-11.50	3.21	5.74	17.42	7.86	-9.27
	Central Plateau	-12.68	-6.81	-11.59	5.19	-0.03	6.11	13.49	-13.29
	Pre-Alps	-18.61	-6.86	-12.67	1.60	18.48	23.41	7.76	-10.09
	Alps	2.07	13.10	12.49	7.28	28.03	13.41	20.86	9.87
	Southern Alps	1.66	13.85	15.62	/	28.03	13.41	20.86	9.87

Data sources: (BAFU 2014-2021; OFS, WaldSchweiz, Agristat 2022; Swiss Federal Statistical Office 2022a, 2022b)

We compute the monetary volume as the average quantity of construction wood harvested 2013-2018 (2953340m³) by the average 2013-2018 of the weighted average exchange values in the same time period (83.25 CHF/m³). The estimated monetary volume for this indicator is thus CHF 246million.

10.4.Medicinal, biochemical and genetic resources

The 2019 IPBES conceptual framework (Brauman et al. 2019) explains the NCP Medicinal, biochemical and genetic resources as "the production of materials derived from organisms (plants, animals, fungi, microbes) used for medicinal and veterinary purposes, and production of genes and genetic information used for plant and animal breeding and biotechnology". This definition is adapted from Díaz et al. (2018), who also include in the definition the mention of the pharmacological (e.g. poisonous, psychoactive) purposes of medicinal plants. This NCP is particularly under-investigated in the literature, partly because of the paucity of data and official statistics.

Numerous species of plants, animals and fungi have been used to produce traditional therapies since ancient times. Many of these species continue to support the development of modern pharmaceutical and edible products, and for this reason they are sold commercially (IPBES 2018). These plants can be harvested directly from the wild, grown in home gardens or be cultivated commercially. While in terms of volume, the agriculturally cultivated medicinal plants make up for the bulk of the Swiss medicinal plant market, there is also a market for plants harvested in the wild. We focus on this smaller market because it more directly reflects nature's contribution to people.

Resource regime

The national or international *Pharmacopoeias* constitute the reference source determining the quality and safety of officially recognized medicinal plants. In Switzerland, the Pharmacopoeia comprises both the European Pharmacopoeia (Pharmacopoea Europaea, Ph. Eur.) and the Swiss Pharmacopoeia (Pharmacopoea Helvetica, Ph. Helv.) and contains legally binding quality regulations for pharmaceuticals, excipients and some medical devices.[54] These include monographs for medicinal plants and their components. At the international level, the trade of plants collected in the wild is subject to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further, there is an International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP)[55]. For the national Swiss context, in particular BioSuisse, an umbrella organization of organic farms, provides directives for the collection of plants in the wild. They define that wild plants are those occurring naturally in the wild, in forests and agricultural areas and are not cultivated for agricultural purposes[56]. The directives specify how collectors have to, inter alia, document information on the collection area, the collectors and the collection itself, processing and storage, as well as the collection area's habitat stability and biodiversity.

[54] To access the Pharmacopoeia used in Switzerland, see http://www.swissmedic.ch/swissmedic/en/home/legal/pharmacopoeia.html (last accessed: 1/11/2021).

[55]https://static1.squarespace.com/static/5bec424b297114f64cb908d8/t/6256dca1510d52627bf4bda3/1649859747671/ISSC-MAP_Version1_0.pdf

[56]https://partner.bio-suisse.ch/dam/jcr:88fd5b80-fc6e-492f-83a5-a1afa4a2a231/bio_suisse_richtlinien_2022_de_2.pdf

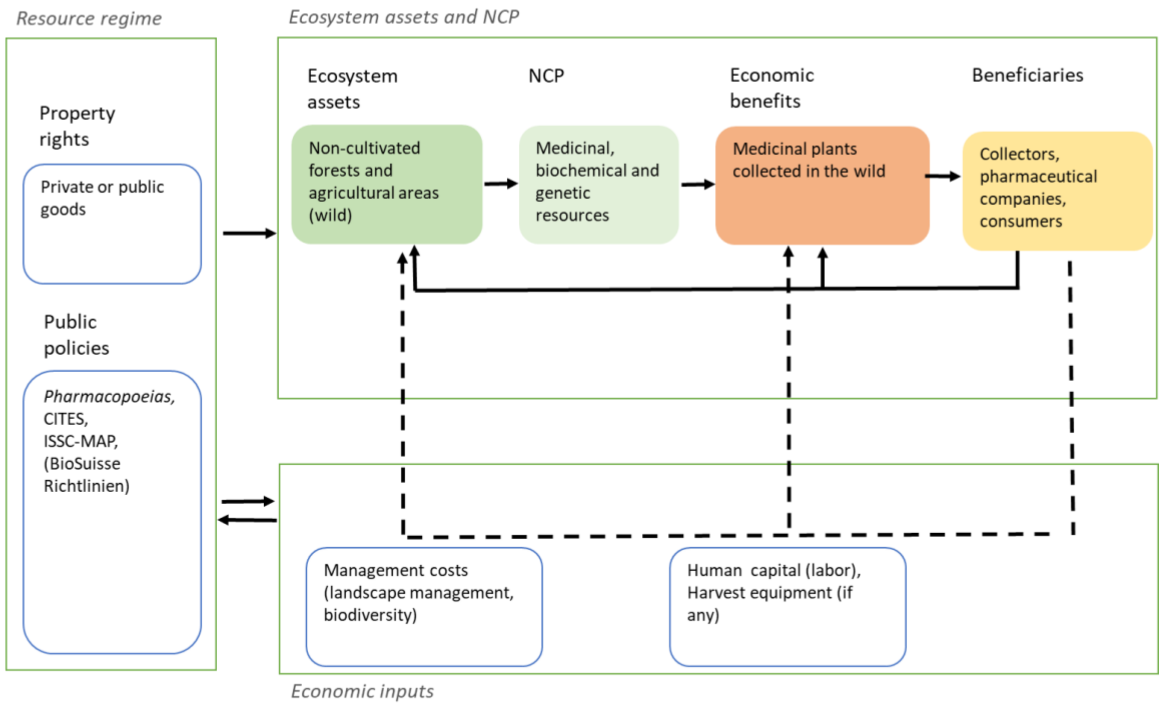

Figure 17: Monetary valuation framework for NCP Medicinal, biochemical and genetic resources.
Source: authors´ presentation

Economic benefits and beneficiaries

Natural Medicinal Products (NMPs) constitute one of the most common human uses of biodiversity (species and related habitats) that contribute significantly to human well-being (Brauman et al. 2019). The main uses for medicinal plants harvested in Switzerland are: food consumption (e.g. as spices, condiments), medicinal products, cosmetics, and animal health and care products (in a veterinary context). The economic benefit of medicinal plants collected in the wild is the economic gain a collector can make when selling the plants to a pharmaceutical company. The final beneficiaries are the consumers of the plant-based medicinal products.

Monetary valuation scope

For the purpose of this study, the economic benefit of concern is the plant or plant part that is collected 'in the wild' in Switzerland and sold to a pharmaceutical company. While such a market exists in Switzerland, the number of commercial collectors is comparatively small. According to experts, only plants are collected for which cultivation makes little sense. By contrast, experts explained that in France, the market is larger and there is more pressure on these natural resources. This has resulted in active collaborations between nature conservation organizations and collector organizations aiming at more sustainable resource use (Medicinal plant expert, personal communication, 2022). In Switzerland, numerous hobby courses on edible plants that can be collected on fields and in forests are offered to the general public. We thus assume that a substantial share of medicinal plants collected 'in the wild' are used for the collectors' own consumption without being traded on a market.

In this context it is important to note that medicinal, biochemical and genetic resources provided by nature in the wild can also be perceived as a cultural NCP through the recreational components of the collecting activity or even by contributing to the cultural identity of the local communities (Tardío et al. 2007; Tardío and Pardo-De-Santayana 2008; Vári et al. 2020). This NCP is an example of fluidity within NCPs in the IPBES framework, as the gathering of wild medicinal and other edible plants could be considered as both material and non-material NCP. However, for the purpose of this research, we focus only on the exchange value of the medicinal plants sold to pharmaceutical companies.

Method and data

Much of the background information as well as price data for the monetary valuation of this NCP was obtained from experts working for pharmaceutical companies or plant producer associations. For confidentiality reasons, we do not provide the experts' names or a complete list of affiliations. However, overall we received information from two pharmaceutical companies, two producers, as well as from Biosuisse, Agridea, the association for organic herb farming (VBKB), the nettle association Brennpunkt Brennnessel, as well as a medicinal plant college in Germany.

For the monetary valuation of the NCP Medicinal, biochemical and genetic resources, we apply the residual value method. We report the market prices paid by a Swiss pharmaceutical company for three medicinal plants, or plant parts, collected in the wild and subtract estimates of a collector's labor cost based on the minimum wage in the agricultural sector. According to two experts from pharmaceutical companies, the cost is strongly dependent on the hourly wage in the respective country and what kind of medicinal herb it is. If a plant is rare, then it takes more time to collect, which is reflected in the price. Additionally, in some cases special equipment and concession fees for collecting plants on communities' land need to be covered by the market price. According to herbal plant associations (personal communication), farmers often collect the medicinal plants 'in the wild' but on their own property (e.g. their own forest or forest fringe) which eliminates the need to pay concession fees.

One pharmaceutical company provided us with prices that they pay for medicinal plants collected in the wild. For three of these plants, we found data on ranges of achievable harvesting capacities (kg/h). We assume that harvesting medicinal plants in the wild can be performed by farm helpers. We thus use the minimum wage in the agricultural sector to estimate the labor cost of harvesting the plants.

Our range of computed exchange values reaches from 0.81-12.74 CHF/kg (see Table 32).

Table 32: Exchange values for selected medicinal plants collected in the wild, in 2019 prices

Medicinal plant	**CHF/kg**
Flowering nettle (Brennnessel, blühendes Kraut)	12.74
Black elderflower (Schwarzer Holunder, Blüten)	12.21
Horse chestnut (Rosskastanien, Früchte)	0.81

Source: own computations

11. Non-material NCPs

11.1. Learning and inspiration

The explanation of this NCP according to Díaz et al. (2018) is the: "Provision, by landscapes, seascapes, habitats or organisms, of opportunities for the development of the capabilities that allow humans to prosper through education, acquisition of knowledge and development of skills for well-being, information, and inspiration for art and technological design (e.g. biomimicry)" The Swiss parks website states that the parks "offer visitors real and inspiring experiences, contact with the local community, fascinating stories and delicious local specialties" (Swiss Parks Network 2020). This description, including the element of inspiration, highlights the importance of cultural NCPs in the parks.

Resource regime

Knowledge and inspiration, in their most general sense, are public goods. Depending on the ecosystem in question, different access rights may apply that affect how or whether the NCP flows can be received. For example, viewpoints offering specific artistic inspiration may be situated on freely accessible public property or private property with restricted entry rights. Similarly, generating knowledge on certain characteristics of the ecosystem may require taking samples, e.g. soil or plant specimens, to a lab. Depending on the location and context, such sampling will affect different sets and combinations of property rights.

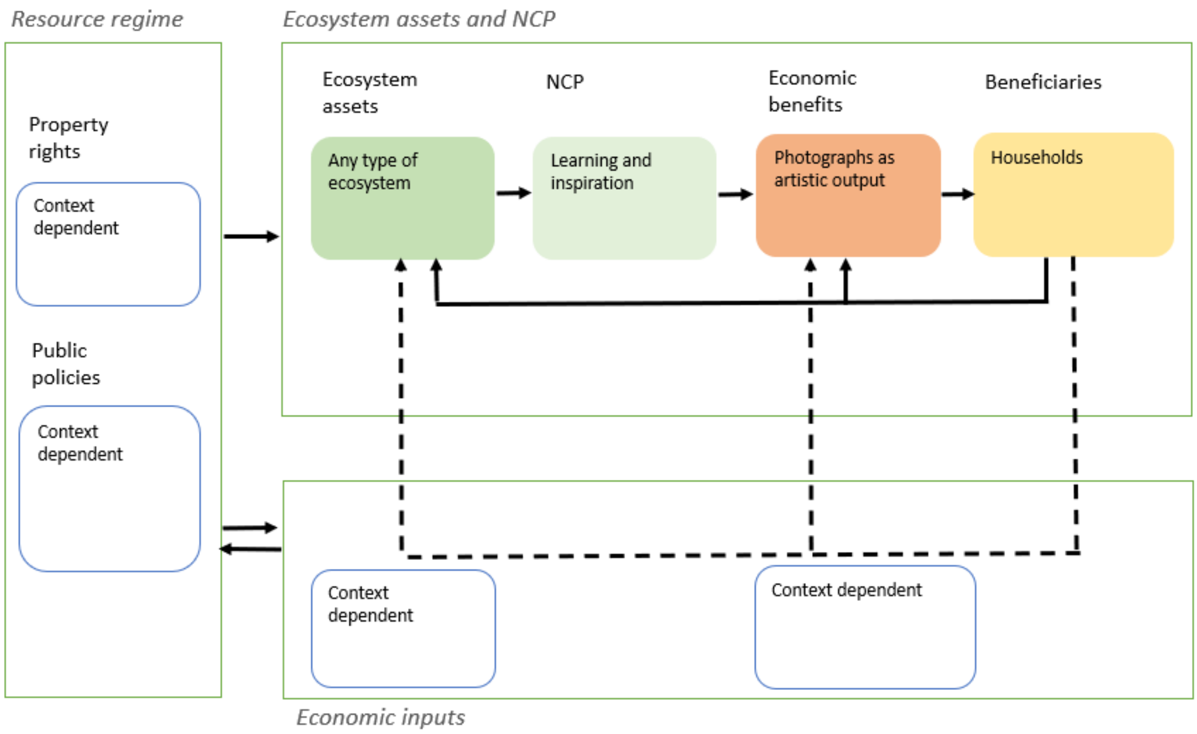

Figure 18: Monetary valuation framework for NCP Learning and inspiration.
Source: authors´ presentation

Apart from property rights, public policies can strongly influence knowledge and inspiration flows in many different ways. Examples relate to research policies including the funding made available, policies on transportation infrastructure that affect the accessibility to the ecosystem, but also policies concerning certain technologies (e.g. on drones) that can affect how information flows for knowledge and inspiration are received.

Economic benefits and beneficiaries

The NCP learning and inspiration is a term that is specific to the IPBES framework but it has similarities to other conceptualizations of cultural ecosystem services (e.g. in the Millennium Ecosystem Assessment, the TEEB and the CICES frameworks) (Havinga et al. 2020). Cultural ecosystem services can be conceptualized as flows of information conveyed by the ecosystem to people. The cultural experience, artistic output, scientific understanding or educated students are examples of benefits obtained from this NCP (Havinga et al. 2020).

The body of literature explicitly addressing 'learning and inspiration' is still rather small and we did not find any monetary valuation studies explicitly referring to this NCP. However, various indicators have been suggested for quantitative measurements of NCP flows:

- Photos on photo-sharing platforms (e.g. Flickr) taken in the geography of interest and showing some aspect of the ecosystem (Havinga et al. 2020)
- Number of contributors to citizen science recording schemes (e.g., eBird, i-Naturalist etc.) (Koellner et al. 2019)
- Number of users and quantity of keywords in digital search engines (Wikipedia, Google, etc.,) with an interest in or related to the relevant ecosystem (Koellner et al. 2019)
- Number of newspaper articles, magazine covers and articles, novels, logos, songs , documentaries reporting on the relevant ecosystem (Müller and Backhaus 2007; Müller 2007; Koellner et al. 2019; Aguilera-Alcalá et al. 2020)
- Number of hours in a school curriculum dedicated to the relevant ecosystem at different education levels (Koellner et al. 2019)
- Numbers related to information in the global biodiversity information facility (Koellner et al. 2019; Aguilera-Alcalá et al. 2020)
- Metrics on scholarly publications on the aspect /ecosystem of interest (Aguilera-Alcalá et al. 2020)

Monetary valuation scope

As mentioned above, several quantitative indicators have been suggested to measure the NCP flows. For most of these indicators it is hard to imagine an associated market price or exchange value. Photos uploaded to sharing platforms are an exception. Market prices exist for pictures sold by hobby and professional photographers on web-based platforms such as shutterstock. However, a shortcoming is that the aspect of inspiration cannot be clearly differentiated from the labor effort that is remunerated through the sales price. Arguably, income generation may be less relevant for hobby than for professional photographers, but we lack data to substantiate this claim. Furthermore, the photos on the sales platforms are not georeferenced. However, market prices obtained from sales platforms can be applied to value the geo-referenced photos on the sharing platforms.

Crowd-sourced data on geo-referenced pictures is increasingly being used to assess cultural ecosystem services and estimate the recreational value of locations such as parks (Sinclair et al. 2018; Cheng et al. 2019; Richards and Friess 2015). The advantage is that picture information is voluntarily provided by users of the photo-sharing platforms. However, people who share pictures through online platforms may not be a representative sample of the population who visit the location and recreate resp. enjoy the learning and inspiration NCP. Sinclair et al. (2020) apply the travel cost method and compare the value of recreation in German parks based on data collected through surveys as well as geo-referenced shared pictures. They find that the similarity of the values obtained is higher in parks with good data availability. For the further use of our price estimates for valuing the learning and inspiration NCP, it will be important to closely investigate the available meta-data attached to the pictures on sharing platforms and test for representativeness, to the extent possible.

Method and data

We compiled information on prices per picture that (hobby-)photographers can expect to obtain on sales platforms. Price plans are made public on one of the platforms, gettyimages.ch. According to the pricing information provided on the website, a non-exclusive photographer receives 15% of the consumer's purchase price. In 2022, consumer prices on gettyimages.ch for pictures taken in the Swiss parks vary from CHF500 for high resolution, CHF335 for medium resolution and CHF150 for low resolution pictures.

We sent emails to ask about revenues for landscape photography to three photography associations, one photography agency and two photography teachers who provide courses for hobby photographers. From the email exchanges it became clear that in Switzerland, professional photographers do not usually sell their work on platforms such as gettyimages.ch because the earnings are too low. There apparently are substantial differences between the professional and the hobby markets. The official price recommendation for press pictures is CHF207 per picture (impressum 2022), which is about four times higher than the royalty for a medium resolution picture sold at gettyimages.

Taking pictures as indicator for the NCP Learning and inspiration, the exchange values range from CHF22.5 (15% of the sales price of a small resolution picture) to CHF207 per picture in 2022 prices. In 2019 prices, this is equivalent to CHF21.91 and CHF201.57 (see also Table 33).

Table 33: Exchange values for Learning and inspiration measured as exchange values of pictures taken in parks

Indicator	CHF per picture in prices of 2019
Small resolution picture	21.91
Medium resolution picture	48.93
Large resolution picture	73.03
Press picture	201.57

Source: own computation

With this data, we can compute a range of the monetary volume of this NCP indicator. The number of pictures posted on the platform gettyimages.ch (as of April 2024) that is found when searching for "Natur Schweiz" (nature Switzerland) is 118292. By multiplying with the lowest and highest exchange values, we arrive at a range spanning from CHF 3 million to CHF 24 million.

11.2. Physical and psychological experiences

Díaz et al. (2018) and IPBES (Brauman et al. 2019) define this NCP as the "*Provision, by landscapes, seascapes, habitats or organisms, of opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism and aesthetic enjoyment based on the close contact with nature (e.g., hiking, recreational hunting and fishing, birdwatching, snorkeling, diving, gardening)*".

Similarly SEEA (2021) and van Berkel et al. (2021) state "Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment (SEEA 2021). This includes services to both locals and non-locals (i.e., visitors, including tourists)".

Switzerland is world-famous for its rich offer of nature-related tourism and recreation activities such as skiing, hiking, cycling and mountaineering. In 2019, tourism gross value added in Switzerland was 19,458 CHF millions, at current prices (FSO – Tourism Satellite Account, 2020). The sector contributed 2.9% to Swiss GDP and 4.4% of total employment.

Landscapes and nature drive the Swiss tourism industry. Many recreational activities that enhance the physical and psychological wellbeing of people are performed outdoor, in the 'natural' environment. The website of the Swiss confederation[57] posits "lakes, forests, mountains and clean air" as Switzerland's most prominent touristic offers. The federal statistical office includes both trips without

[57] www.eda.admin.ch/aboutswitzerland/en/home/wirtschaft/taetigkeitsgebiete/tourismus.html. Last accessed: 29/10/2021.

overnight stay, and with overnight stays, when it provides tourism statistics (see e.g. Strauss et al. (2020) and STF (2020)). More specific studies investigating why visitors travelled to selected Swiss regional nature parks concluded that the main reason to travel there are the opportunities to hike in places with beautiful sceneries and unspoiled nature, and for the psychological benefits derived from the mental peace and quietness hikers feel in such parks (see e.g. Knaus (2018)).

Resource regime

Property and access rights affect how people can receive the flow of the NCP Physical and psychological experiences, similarly as for the NCP Knowledge and inspiration. For example, hiking paths and ski touring routes may be situated on freely accessible public property or on private property with restricted entry rights. The resource regime of the NCP Physical and psychological experiences is also determined by public policies regulating access to sites with high recreational potential. The State Secretariat for Economic Affairs (SECO) is responsible for the development and implementation of Switzerland's tourism policy. SECO enforces the Federal Act on the Promotion of Innovation, Co-operation and Knowledge Building in Tourism (Innotour) and supervises two associations tasked with implementing tourism measures, in particular Switzerland Tourism and the Swiss Society for Hotel Credit. The former carries out marketing activities relating to Swiss tourism, while the latter supports investment in the accommodation sector (OECD 2020).

The main legal basis are the national tourism laws. These comprise (STF 2020):

- Marketing Switzerland as a tourist destination Federal Act on Switzerland Tourism of 21 December 1955, Status as of 1 August 2008 (SR 935.21).
- Promotion of innovation, cooperation and knowledge creation in tourism Federal Act on the Promotion of Innovation, Cooperation and Knowledge Creation in Tourism of 30 September 2011, Status as of 1 January 2017 (SR 935.22)
- Promotion of the hotel industry Federal Act on the Promotion of the Hotel Industry of 20 June 2003, Status as of 1 January 2013 (SR 935.12)
- Regional policy - Federal Act on Regional Policy of 6 October 2006, Status as of 1 January 2013 (SR 901.0)
- Nature parks Federal Act on the Protection of Nature and Cultural Heritage of 1 July 1966, Status as of 1 April 2020 (SR 451)
- Temporary special rate for accommodation services Federal Act on Value Added Tax of 12 June 2009, Status as of 1 January 2020 (SR 641.20)
- Cable cars and chairlifts Federal Act on Cableways for Passenger Transport of 23 June 2006, Status as of 14 August 2018 (SR 743.01)
- Tourism statistics Ordinance on the Conduct of Federal Statistical Surveys of 30 June 1993, Status as of 1 February 2020 (SR 431.012.1)

Various industry organisations, foundations and cooperatives at both national and regional levels (e.g. Switzerland Tourism and the Swiss Society for Hotel Credit) also influence the delivery of the Swiss tourism policy (OECD 2020). The SwitzerlandMobility Foundation, for example, promotes a national network of non-motorized traffic for leisure and tourism focusing on the development and communication of the most attractive hiking, cycling, mountain biking, skating, canoeing, winter hiking, snowshoe walking, cross-country skiing and sledging routes in Switzerland. This is important as land uses (and their spatial patterns) linked to information about their accessibility are directly related to the supply of and demand for recreational services (Grêt-Regamey et al. 2015).

Finally, many ecological factors will influence the provision of this service, including the extent and condition of the ecosystems, but also the presence of certain iconic species or special landscape characteristics. Hence, a variety of policies designed to preserve, protect and restore the landscape and habitats are also important in maintaining the supply of this NCP.

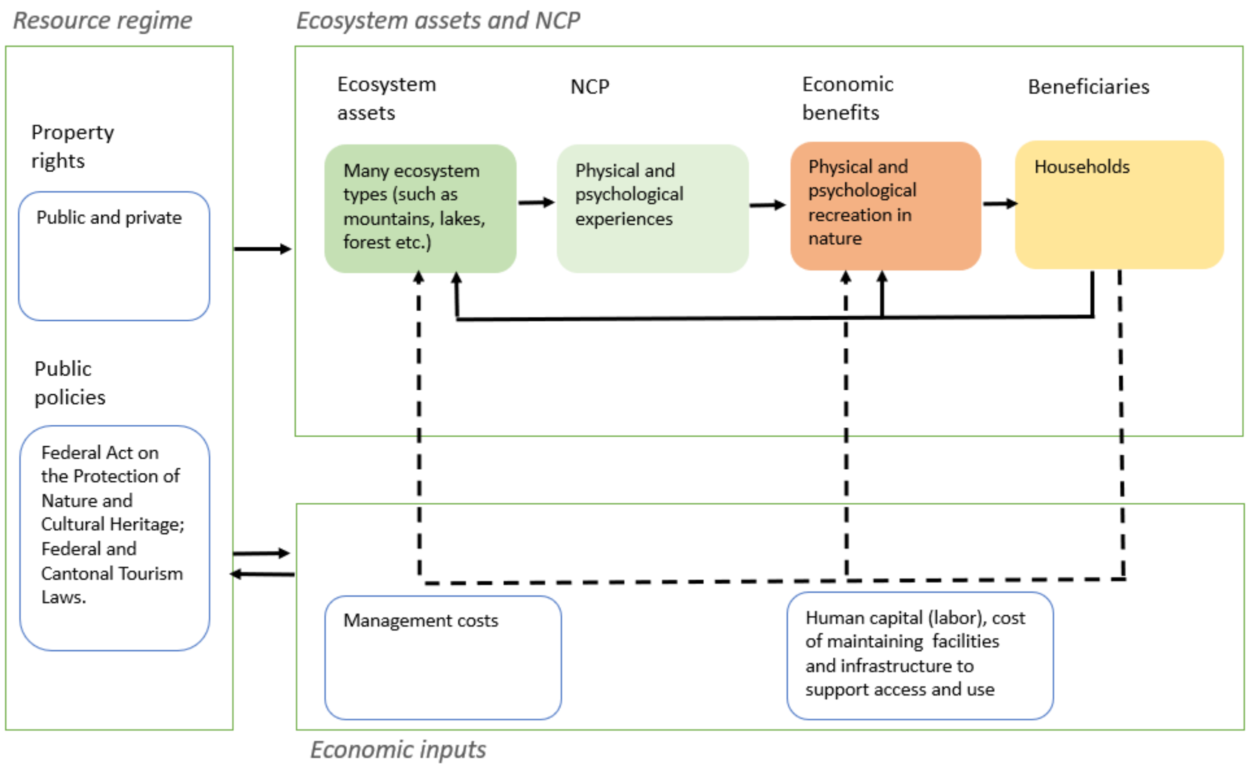

Figure 19: Monetary valuation framework for NCP Physical and psychological experience.
Source: authors´ presentation

Economic benefits and beneficiaries

This NCP relates to the nonmaterial contributions of nature to people's quality of life, as nature provides opportunities for conducting physically and psychologically beneficial activities. In this analysis, the main beneficiaries are the visitors, who benefit from the activity of enjoying being in the natural environment.[58]

Recreational activities in nature also provide indirect economic benefits in the form of reduced healthcare costs, because of their (positive) physical and mental health effects for people. The exact health effects are difficult to quantify, and this value component is not included in the monetary values captured in our analysis, similarly to the approach adopted in other countries (e.g., The Netherlands).

Monetary valuation scope

Nature provides opportunities for outdoor recreational and tourism activities. This leads to several kinds of expenditures by households (van Berkel et al. 2021). Given the strong focus of the Swiss tourism sector on nature, we posit that the majority of tourism expenditure in Switzerland is related with the opportunities offered by the natural environment. According to the Federal Tourism Office, passenger

[58] The secondary beneficiaries are the businesses in the tourism and outdoor leisure service sectors, which benefit from the fact that visitors' activities generate (extra) final consumption of goods and services provided by the tourism and outdoor leisure services sectors. This (extra) final consumption is a direct benefit for the economy.

transport services generate the largest share (over 25%) of the total revenues accrued by the tourism sector in Switzerland (STF 2020) (Figure 20). Transport services include travel to the recreational site by car, train or other means, which involves costs.

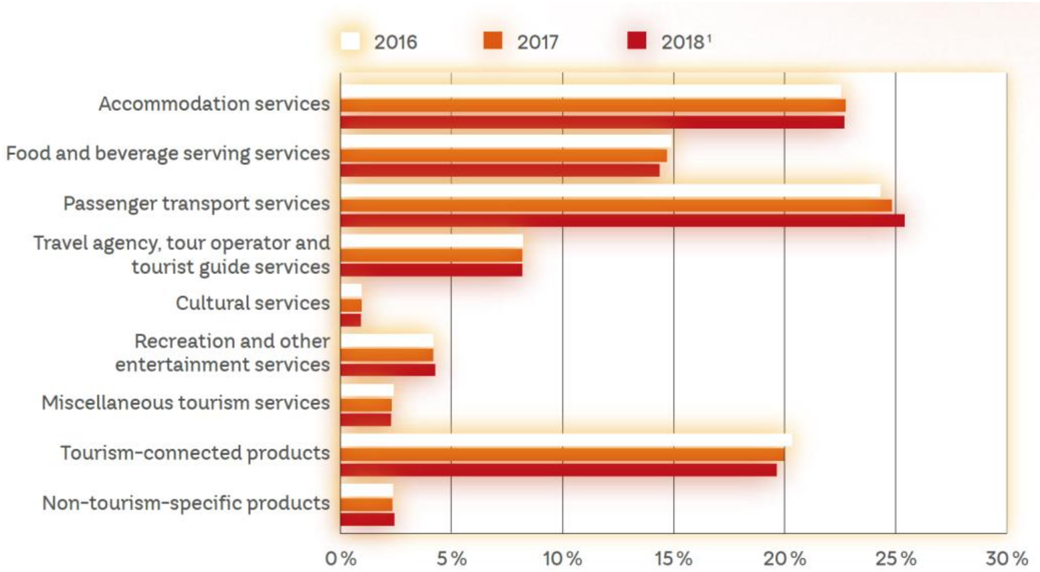

Figure 20: Share of tourism gross value added according to products, 2016–2018.
Source: STF (2020)

Method and data

We suggest calculating the monetary value of the NCP Physical and psychological experience using the consumer expenditure method, with a focus on travel costs. This method uses a demand-oriented approach (i.e., focusing on visitors' spending), and it is compatible with the exchange value approach (ONS 2017).[59] The demand-oriented approach has already been applied in national ecosystem assessments in other countries, such as the UK or the Netherlands (ONS 2020; van Berkel et al. 2021). The studies by Knaus (2018); Knaus and Backhaus (2014); Backhaus et al. (2013); Knaus (2012); Küpfer et al. (2000) include information and data on tourism and travel costs to Swiss parks.

One way to apply the consumer expenditure method is to collect detailed primary survey data on travel costs and other types of expenditures incurred by tourists and daily visitors at selected locations. This was the method used, for example by Knaus (2018). This data collection process would be too costly and time consuming given the scope of our research mandate, hence we rely on secondary data from the latest Swiss National Mobility and Transport Microcensus 2015 (MZMV2015) (FSO and ARE 2017) and complement them with data from the Swiss Federal Statistical Office, the Swiss Tourism Federation and Swisstopo.

The Swiss National Mobility and Transport Microcensus is a continuous survey, conducted at an equal frequency all throughout the year across Switzerland.[60] This dataset captures information from approximately one percent of the Swiss population about their daily travel behaviour. In 2015 a total of

[59] Recreational activities in nature provide positive health effects for people, which in turn generate economic benefits in the form of reduced healthcare costs (van Berkel et al. 2021). The reduction of healthcare costs of various recreational activities are difficult to quantify, and are not considered in this analysis.
[60] As of 28.2.2023 the most recent year available for this census is 2015.

57,090 persons, representative of the resident population in Switzerland and randomly selected within geographic quotas, were surveyed via telephone interviews. About one third of all respondents are asked additional questions about trips during which they leave their familiar surroundings for at least three hours (daily trips).[61] Of particular interest for our analysis are a sub-set of questions regarding the travel itinerary and purpose of the trip.

For each respondent, we retrieve information about the starting and destination points of the trip, the travel distance between these points (the MZMV2015 includes calculated routing distances in kilometers via the chosen itinerary), the mean(s) of transport, the purpose of the trip, the total travel time, and the statistical weight associated to each respondent.[62]

We calculate travel costs for respondents travelling to municipalities within and nearby the ValPar.CH study parks (Tier 2). Notably, we are able to select all trips whose destination is a municipality within and nearby the ValPar.CH study parks and whose purpose are physically and psychologically beneficial recreational activities such as biking, hiking and picnicking. For these trips, we calculate the travel costs by multiplying the distance travelled (in kilometers) by the cost per kilometer (CHF/km) for each of the vehicle-types used for the trip (Table 34).

Table 34: Example of calculation of travel costs by person (CHF) (2015)

	A	B	C	D	E	F	G	H
ID	**Person - weight [wp]**	**Means of transport [wmittel]**	**distances (km) [w_rdist]**	**Cost per km**	**Travel cost per person**	**Destination Municipality**	**Municipality code [z_plz]**	**Destination Park Tier2**
1	0.68	Car	65.88	0.57	37.55	Corbeyrier	5404	Parc Naturel Régional Gruyère Pays-d'Enhaut
2	2.7	Train	54.60	0.45	24.75	Ferrera	3703	Naturpark Beverin
3	0.87	Tram	9.74	0.60	5.84	Mönthal	4106	Jurapark Aargau
4	0.58	Tram	7.08	0.60	5.04	Schinznach	4125	Jurapark Aargau
4	0.58	Bus	3.95	0.20				
5	0.87	Bicycle	1.00	0.10	0.10	Albinen	6102	Naturpark Pfyn-Finges
6	1.23	Motorbike	4.29	1.82	7.81	Albinen	6102	Naturpark Pfyn-Finges

Notes: Variables names as included in the Swiss National Mobility and Transport Microcensus (2015) are indicated in brackets. Sources: Authors´ elaboration (column E) based on data from the MZMV2015 (FSO and ARE 2017) (columns A, B, C and G) and data for costs per kilometer (column D) from: FSO (2022a); Direkter Verkehr Schweiz (2016) and Pro Velo Schweiz (2017).

If a respondent indicated that she took more than one mean of transport (see, e.g. ID 4 in Table 34), these costs are added up for that individual, before calculating the weighted summary statistics for all people travelling to a given park. These values correspond to the travel expenditure for a single visit. A study conducted by Knaus (2018) analysing the main characteristics of visitors to four Swiss Regional Parcs

[61] The Swiss National Mobility and Transport Microcensus does not include information on international trips made to Switzerland by people who are residents in other countries.

[62] For a detailed methodological description of the sampling design, weighting and response rate of the MZMV2015 the reader should refer to FSO 2018.

(Jura Vaudois, Ela, Gantrisch et Binntal) concludes that most of the visitors return to the same park several times and even consider themselves regular visitors. The travel costs obtained from the analysis of this dataset are adjusted for inflation to obtain individual travel costs for 2019, using the annual consumer price index by the Federal Statistical Office (Table 35).

Table 35: Individual travel expenditure to parks (CHF of 2019)

Destination	Individual expenditure (weighted average) CHF
Jurapark Aargau	11.57
Naturpark Pfyn-Finges	26.86
Naturpark Beverin	16.81
Parc naturel Régional Gruyère Pays-d'Enhaut	8.14
All parcs	16.26

Source: Own computation.

In order to obtain an estimate of the total annual travel costs incurred by the Swiss resident population to visit each park we need to multiply the values presented in Table 35 by the total number of visitors to that park in a given year. We requested this information to each of the study parks but the number of annual visitors is either not available or it does not account for all visitors. When proxy data of the number of annual visitors exists, it is not reported consistently across parks. For example, one of the study parks collects information on the number of visitors but only if they engage with activities and courses organized or supported by the park administration. Another park authority reports in its Management Plan the number of overnight stays in the hotel industry, but without including overnight stays in the parahotel industry (such as camping places and guest houses), nor the count of day visitors. Extrapolating one's own data from existing data such as overnight visitor numbers, however, may lead to significant uncertainty and inaccuracies (Knaus and Backhaus (2014)).

Because of this limitation in data availability, we rely once more on the information provided in the MZMV2015 (FSO and ARE 2017) and on the total number of resident population in Switzerland (FSO 2016), to extrapolate a proxy of the number of visitors to each park in 2015. We use information about the number of respondents of the micro census of 2015 who visited the four study parks in 2015 to approximate the shares of the Swiss population which visited the study parks. For that we used the weighting procedure that is proposed and applied by BFS. Finally, we multiply these shares by the resident population in Switzerland at the end of 2015 (832,7126 people) to obtain the estimated number of visitors reported in Table 36 column A.

Table 36: Number of annual visitors and total annual travel expenditure to parks (CHF of 2019)

Destination	A Estimated number of annual visitors	B Total annual travel expenditure CHF
Jurapark Aargau	23,080	266,982
Naturpark Pfyn-Finges	9.759	262,094
Naturpark Beverin	11,000	184,900
Parc naturel Régional Gruyère Pays-d'Enhaut	835	6,797

All parcs	44,673	720,773

Source: Own computation.

Previous studies conducted in Swiss parks (see, in particular, Knaus (2018)) conclude that extrapolation methods used to calculate the number of park visitors lead to uncertain results and inaccuracies, with large differences in results between counting methods. The results presented in Table 36 and Table 37 column B shall be taken with great caution and they do not intend to present precise data on park visitors. Our estimates are based on census data for one particular year. Note that this number may vary from year to year subject to different exogenous factors such as weather and weather forecasts in certain days and holiday periods. The number of visitors per park reported in Table 36 are probably lower than the true visitors count for each park,[63] hence the results presented in Table 36 column B and Table 37 column B are expected to be under-estimations of the annual travel expenditure by all visitors for each park.

Finally, we retrieve from Swisstopo data on the kilometers of hiking trails within each park (Swisstopo 2022). We then divide the individual average travel costs as well as the total annual travel expenditure by the sum of hiking trails (in km) within each park (for a similar application see e.g. Willibald et al. (2019)). The results are reported in Table 37.

Table 37: Travel expenditure to parks per km of hiking trails (CHF of 2019/km)

	A	B
Destination	**Individual CHF/km**	**All visitors CHF/km**
Jurapark Aargau	0.034	788.21
Naturpak Pfyn-Finges	0.038	366.19
Naturpak Beverin	0.013	142.97
Parc naturel Régional Gruyère Pays-d'Enhaut	0.014	11.91

Source: own computation

For robustness analysis, the Parks (Tier 2) information presented in Table 35 and Table 37**Error! Reference source not found.** are compared to the information obtained from a detailed survey of visitor's expenses for four Swiss Natural Parks (Binntal, Parc Ela, Gantrisch and Jura Vaudois) in summer 2017 and winter 2018 (Knaus (2018)). This survey draws from Küpfer et al. (2000) and Knaus (2012). Questions related to the daily expenditures of parks' visitors are identical among these studies. The values obtained in the study by Knaus (2018) are adjusted for inflation, to proxy the values corresponding to the year 2019. These values can be compared to the one we obtained, or even applied to the ValPar.CH study parks (see parks highlighted in green in Figure 21) using "benefit transfer" (Plummer 2009). The basic goal of the "benefit transfer" approach is to estimate benefits for a location interest by taking or adapting estimates generated for comparable sites (see parks highlighted in blue in Figure 21).

[63] For example, the number of visitors to Park Ela, next to our Study Park Naturpark Beverin (see Figure 21), are estimated by Knaus 2018 to be either 195000 or over 1500000, depending on the method applied to extrapolate these values.

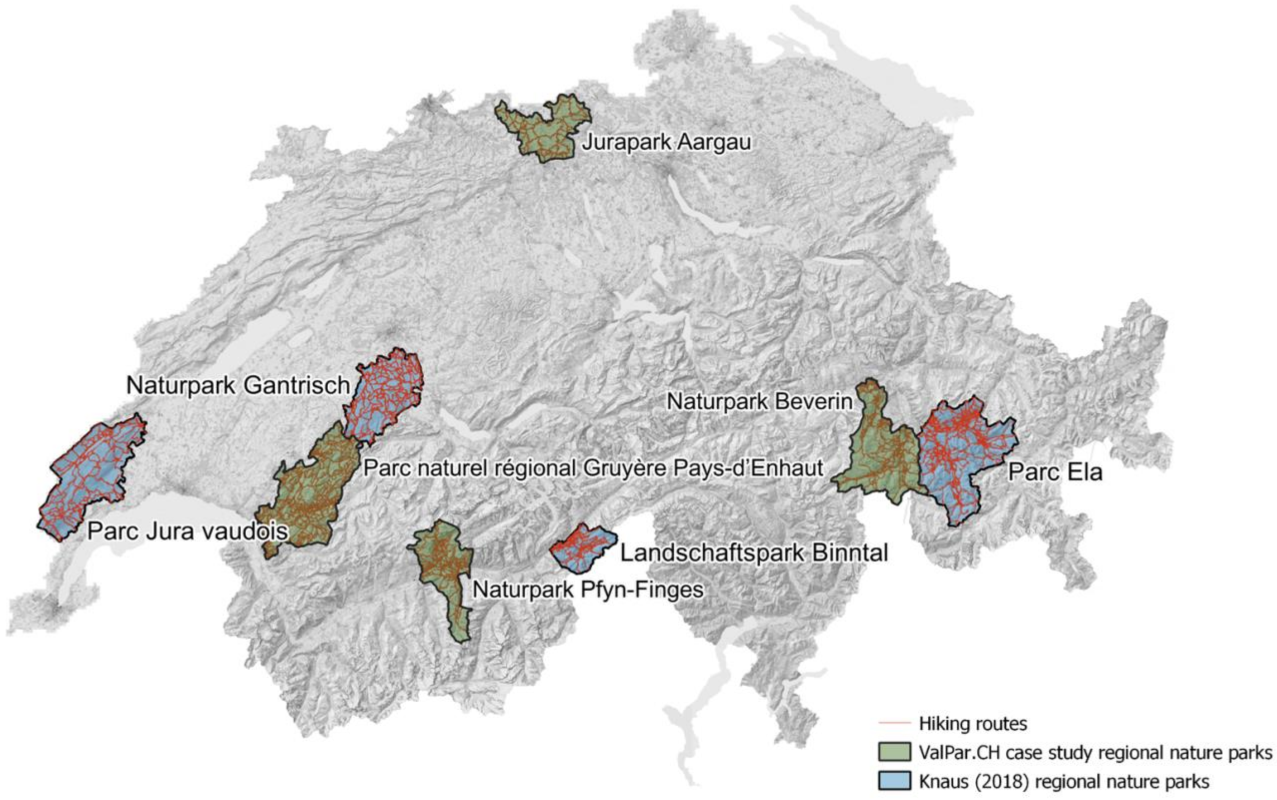

Figure 21: Location of regional nature parks and hiking trails
Source: authors´ presentation based on data by Swisstopo (2022)

There are different ways on how the original values can be adapted. For example, existing values for other parks can be adjusted averaging estimates from existing studies. In this analysis we report the results by park, rather than averages across different sites.

Table 38: Individual travel expenditure to parks (CHF)

Destination	**2017/2018**	**2019**
Jura Vaudois	(2.34; 11.80)	(2.37; 11.85)
Binntal	(5.22; 10.20)	(5.29; 10.24)
Ela	(5.76; 18.81)	(5.84; 18.89)
Gantisch	(3.22; 4.75)	(3.26; 4.77)

Notes: In each bracket, the first value corresponds to the summer season, the second to the winter season. The summer season includes data collected from May 2017 to November 2017. The winter season includes data collected from December 2017 to April 2018. Source: Authors´ elaboration based on data from Knaus (2018) adjusted for inflation to obtain travel costs for 2019.

Table 39: Individual travel expenditure to parks per km of hiking trails (CHF/km)

Destination	
Jura Vaudois	(0.004; 0.020)
Binntal	(0.017; 0.033)

Ela	(0.006; 0.018)
Gantisch	(0.005; 0.008)

Notes: In each bracket, the first value corresponds to the summer season, the second to the winter season. The summer season includes data collected from May 2017 to November 2017. The winter season includes data collected from December 2017 to April 2018. Source: Authors´ elaboration based on data from Knaus (2018) adjusted for inflation to obtain travel costs for 2019. The km of hiking trails are calculated from Swisstopo (2022).

Knaus (2018) also calculates the total tourism value added in the four parks as well as a park-induced value added (in CHF million). The latter captures the amounts the author directly and causally assign to park activities. We report these results (CHF millions) and divide them by the km of hiking trails (reporting the results in CHF /km).

Table 40: Individual travel expenditure to parks per km of hiking trails (CHF/km)

Destination	**Total Value Added (CHF million)**	**Park-induced value added (CHF million)**	**Total Value Added by length of available hiking trails (CHF/km)**	**Park-induced value added (CHF million) by length of available hiking trails (CHF/km)**
Jura Vaudois	11.20	1.70	19,007.44	2,885.06
Binntal	22.30	3.70	70,956.51	11,773.05
Ela	105.80	8.80	101,163.48	8,414.35
Gantrisch	47.70	7.30	76,710.30	11,739.73

Source: Knaus (2018) and authors´ elaboration based on data from Knaus (2018) and Swisstopo (2022).

For further analysis, we report annual data on Tourism gross value added in CHF millions, at current prices, at Tier 1 (country) level. This data is provided by the Swiss Federal Statistical Office, that publishes Annual Indicators of the Tourism Satellite Accounts. This data includes the gross value added for passenger transport (including cableways, funiculars and ski-tows) as well as other two "tourism-characteristic products" of interest, in particular accommodation services and food and beverages serving services. Some natural capital accounts studies aggregated some of these costs to apply a consumer expenditure method, which builds upon the travel costs valuation method (ONS 2017). The latest UK natural capital accounts (2020) aggregates the expenditure of travel costs and admission fees to specific sites (ONS 2020). For the natural capital accounts of The Netherlands, van Berkel et al. (2021) consider these expenses plus expenditure on foods and beverages and accommodation.

Table 41: Tourism gross value added in Switzerland in 2019 at current prices, in millions of CHF

Total	20,353
Passenger transport	4,585
Accommodation services	5,932
Food and beverage serving services	2,868
Other	6,968

Source: FSO (2022b)

Unfortunately, the statistics presented in Table 41 do not allow distinguishing the various types of recreational activities, and thus specifically investigate those depending on the outdoor environment. However, Nathani and Steg (2024) propose to approximate expenditures on recreational activities in nature using information of the tourism monitor Switzerland survey conducted by Switzerland Tourism and the annual survey on travel behaviour of Swiss inhabitants by the FOS. According to the tourism monitor survey, 39.7% of the stated main travel reasons of tourists with overnight stays have a strong link to nature / ecosystems. 25.8% of day trips undertaken in 2019, have travel reasons that can be linked to ecosystems according to the FOS travel behavior survey data (Nathani and Steg 2024). Based on these estimates and data of the Swiss tourism satellite account, Nathani and Steg (2024) assess domestic and foreign tourists' expenditures on recreational activities in nature at CHF 5,363 million for 2019.

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