Working Paper

Deriving Monetary Values of Nature's Contributions to People (NCP): Conceptual Framework and Methodology developed within ValPar.CH

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Abstract

Nature's Contributions to People (NCP) 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 working paper presents the conceptual framework and the methodological procedure to be used for deriving monetary values for 15 NCPs, selected within the ValPar.CH project for studying benefits and added value of ecological infrastructure in Switzerland. Following the ValPar.CH project approach this paper focuses exclusively on NCP's positive contributions. To measure NCPs´ economic benefits, we propose to apply the exchange value approach, which is used for the valuation of ecosystem services in the United Nations System of Environmental Economic Accounting (SEEA). The contribution of this working paper is two-fold. Firstly, we argue for the inclusion of an analysis 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 whether the resulting monetary value depends on public policies and property rights rather than just market forces. Secondly, we lay out the detailed descriptions of the methodologies that will be used for valuing each of the 15 selected NCPs.

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.

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 (NCP) 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 working paper presents a conceptual and methodological framework for deriving marginal monetary values of NCPs. We further present the economic valuation methods selected to value each of the 15 NCPs 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 totally three non-material NCPs.

The methodology presented in this working paper 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[1]. 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.

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 will influence their monetary values[2].

2. Economic valuation approaches and methods

2.1. Valuation approaches

To measure NCPs´ economic benefits, we propose to 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). This relatively novel approach has two important advantages over the welfare approach and the Gross Value Added (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

[1] 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).

[2] The monetary values obtained with the methodologies described in this working paper 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.

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).

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 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 respective sectors of the economy. All three approaches assess instrumental values of NCPs[3]. The three approaches serve different purposes.

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 will be 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. 2020b), 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).

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 different groups of stakeholders under specific scenarios. A broad set of valuation methods has been applied to measure welfare changes in the literature[4].

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 in Switzerland depends on the provision of selected NCPs in different groups of economic sectors.

2.2. Valuation methods

The SEEA (2021) guidelines propose to use market prices for monetary valuation whenever possible[5]. 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 defense 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

[3] Pascual et al. 2017 define an instrumental value as "the value attributed to something as a means to achieve a particular end"
[4] 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.
[5] SEEA (2021) guidelines refer to ecosystem services, whereas in ValPar.CH we apply these methods to NCPs.

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.

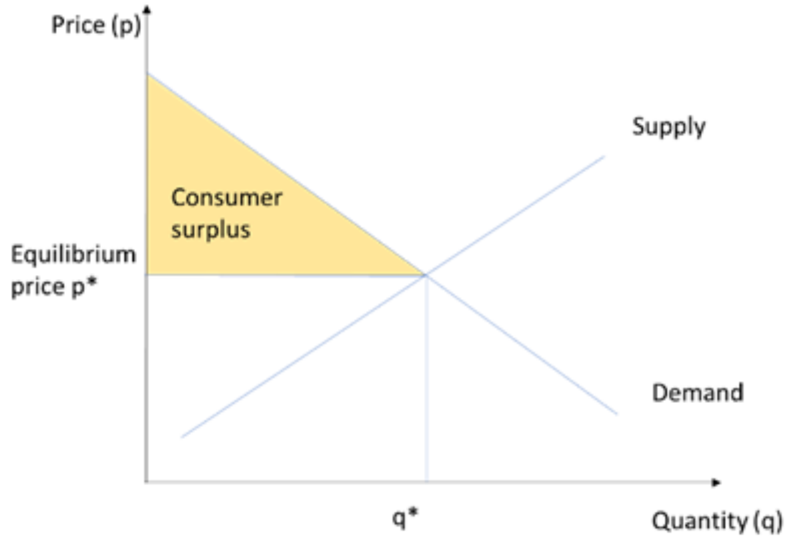

Figure 1: Consumer Surplus. Source: authors´ representation.

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 propose to 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 land owners 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 the substitute in this case (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).
- **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 us to compute 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. 2020b).

3. ValPar.CH approach to economic valuation of NCPs

We will structure the discussion for each NCP using the framework presented in **Figure 2**, which is a simplified 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.

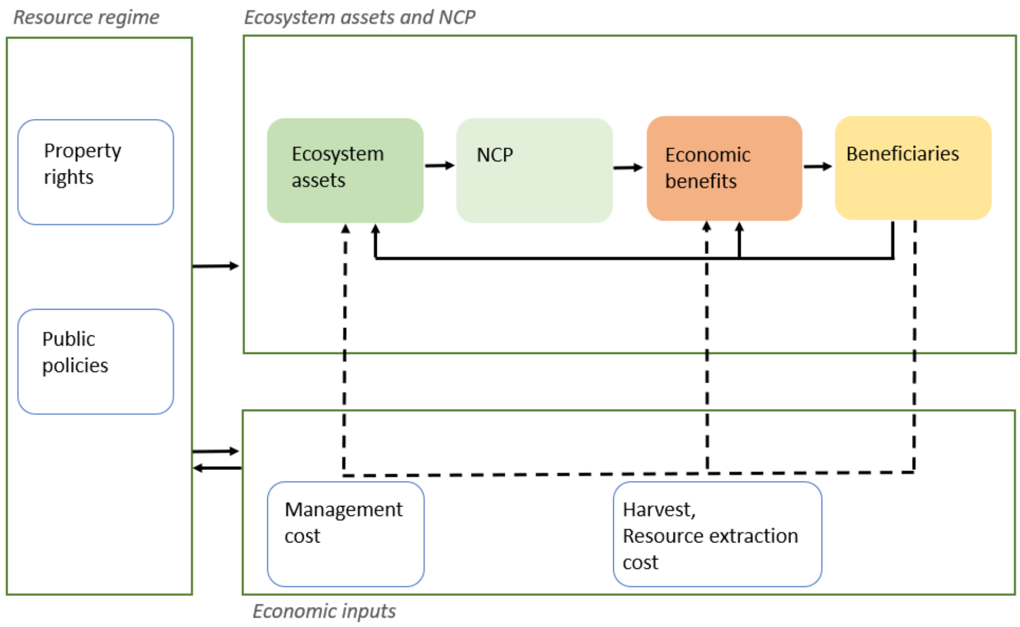

Figure 2. NCP economic valuation framework. Source: authors´ presentation based on UN DESA (2019), Horlings et al. (2020), Gerber et al. (2009) and Lieberherr et al. (2019).

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 for the production of 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 fulfills 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 working paper 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 (2021) 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 (labor costs). A study by Sutter et al. (2017a) also presents monetary values for pollination in Switzerland that are consistent with the exchange value approach.[6] 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 intend to value it as hydropower facilities´ costs for sediment management.

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

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 rental price 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[7].

5. Selection of economic benefits

The list of the selected NCPs consists of all regulating NCPs applicable in the Swiss context (9 out of totally 10)[8], all the material NCPs and two of totally three non-material NCPs[9]. 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 benefits to be applied when valuing NCPs. Accordingly, in Table 1 we present a list of economic benefits, which we propose to apply in 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.

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

Table 1 provides a summary of the proposed NCP benefit indicators and the methods to be used for deriving corresponding monetary values. It also outlines spatial aggregation levels for which the valuation will be undertaken. A detailed description of the methodologies applied for valuing individual NCPs is presented in part B of this working paper.

An economic appraisal requires choosing a reference period for the analysis. We propose to set the reference year to 2019. The two main reasons for that are: (i) some statistics may not be yet available for 2020; (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. In addition, NCPs´ monetary values in prices of 2020 will be generated using the consumer price index for 2020.

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[7] 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.

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

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

Table 1: Methods and indicators to be used for the economic valuation

NCP	IPBES reference	Method to be used	Spatial aggregation level (Tier 1: national Tier 2: park)	Benefit(s) and units
Regulating NCPs				
Habitat creation and maintenance	C2.1	Payments for ecosystem services (PES)	Tier 1; Tier 2	Monetary values/payments used to reimburse economic actors for the net benefits foregone due to compliance with habitat restoration and biodiversity conservation policies/projects, and cost of selected habitat restoration/creation activities (implemented mainly through habitat restoration projects). CHF per ha of corresponding land use category and policy measure
Pollination and dispersal of seeds	C2.2	Production function approach[10] (dependency ratios derived therefrom)	Tier 1	Monetary value of pollination contribution to crop production, CHF per ha of selected pollination-dependent crops
Regulation of air quality	C2.3	Avoided damage cost	Tier 1	Avoided morbidity and mortality costs per 10 µg/m^3 of excessive PM10 at the national level.
Regulation of climate	C2.4	Avoided damage cost; replacement costs	Tier 1; Tier 2	Social cost of carbon estimate per 1 ton of carbon; Marginal abatement cost estimate per 1 ton of carbon
Regulation of freshwater quantity, location and timing	C2.6	Rental prices	Tier 1; Tier 2	Monetary value of freshwater per m^3 (average value by watershed)
Regulation of freshwater quality	C2.7	Replacement cost	Tier 1; Tier 2	Costs of engineering solutions per extracted unit of nitrate and phosphorus (not retained by vegetation, CHF/kg of nitrate
Formation, protection and decontamination of soils	C2.8	Replacement cost	Tier 1; Tier 2	Cost of engineering solutions for fine sediment removal at hydropower facilities, CHF per m^3 of fine sediment
Regulation of hazards and extreme events	C2.9	Replacement cost, Avoided damage cost	Tier 1; Tier 2	Monetary value per ha of protection forest, (Monetary value per ha of flood plain)

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

Regulation of organisms detrimental to humans	C2.10	Avoided damage cost	Tier 1; Tier 2	Avoided damage to crop production due to common vole control by common buzzard and common kestrel, CHF per raptor individual
Material NCPs				
Energy	C3.11	Residual value method, rental price, rental price	Tier 1; Tier 2	Stumpage price for energy wood assortments per m^3; Monetary value of water for hydropower
Food and feed	C3.12	Rental price method; production function approach	Tier 1; Tier 2	Monetary value of agricultural land contribution to the value of food and feed production, CHF per ha of crop land and grassland
Materials and assistance	C3.13	Residual value method, rental price	Tier 1; Tier 2	Stumpage price for non-energy wood assortments per m^3
Medicinal, biochemical and genetic resources	C3.14	Residual value method	Tier 1	Net monetary value of selected officinal and edible medicinal plants and herbs, CHF per ha
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
Physical and psychological experiences	C4.16	Consumption expenditure	Tier 2	Travel expenditure to selected locations (parks and municipalities) per km of hiking trails, CHF per km

Source: authors´ representation

6. Conclusions

This working paper presents an application of the conceptual framework and methodology for deriving monetary values of NCPs selected in the ValPar.CH project for studying the benefits and added value of ecological infrastructure in Switzerland.

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 working paper builds on exchange values as proposed in the SEEA framework (UN DESA 2019) and can easily be reproduced and expanded to additional NCP indicators in future research. This in turn will allow for a more comprehensive assessment of the added value of ecological infrastructure in ValPar.CH. It will be explained in a separate working paper how the NCP assessments from ecological, economical and societal viewpoints are brought together within ValPar.CH.

Methodologically, we expand the valuation framework presented by Horlings et al. (2020) to include the Institutional Resource Regime (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.

Part B: Methods to be used for valuing specific NCPs

7. Regulating NCPs

7.1. 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, last amended 2014), 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, last amended 2014), and iii. the Fishing Act (1991, last amended 2013) (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 aligned the Swiss agricultural producers support policies with environmental goals, including biodiversity conservation. In addition, the federal government has adopted since the late 90s 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 productions 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.

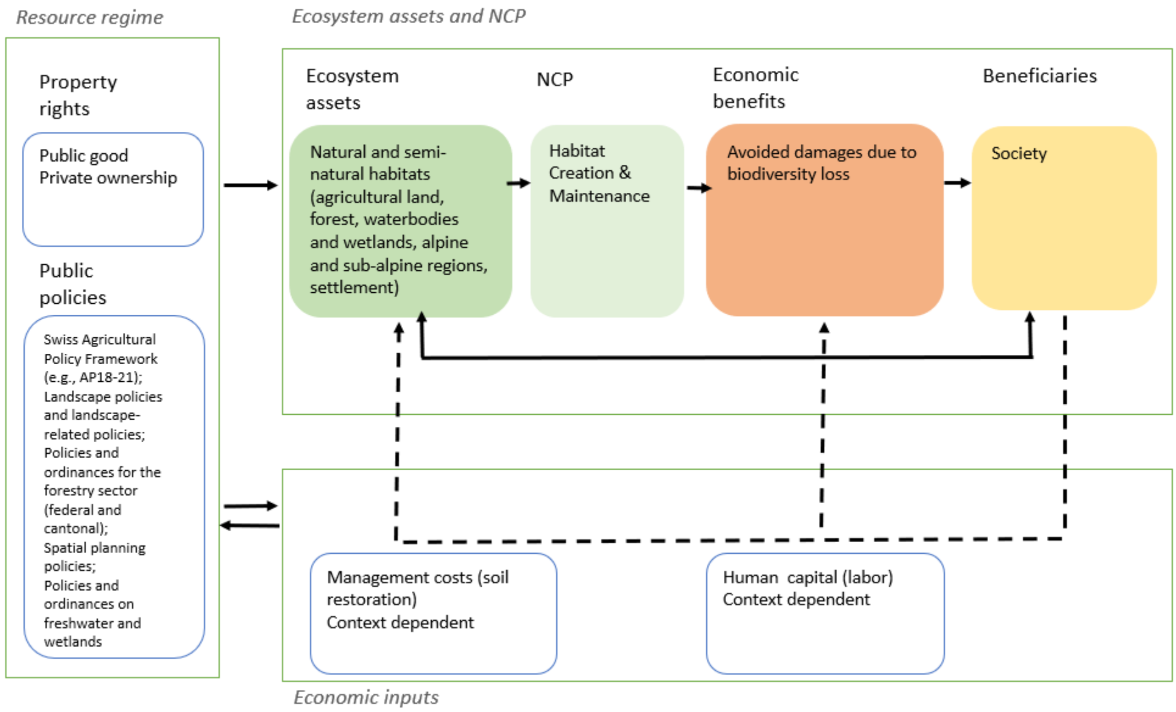

Figure 3: Monetary valuation framework of NCP Habitat creation and maintenance, Source: authors´ presentation

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 fulfill their natural functions and contribute to biodiversity conservation and promotion (EEA, 2015 and OECD, 2017).[11]

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 not sufficient to avoid future damages due to biodiversity loss, they can be considered as proxies for opportunity costs of public policies aimed at biodiversity conservation and thereby a measure of how much it is worth to society today to avoid potential future damages due to biodiversity loss. While direct payments generally promote *conservation* efforts, habitat *restoration* activities are mainly promoted through restoration projects.

Therefore, we intend to map all important policy measures providing monetary incentives for habitat conservation and use them as proxies for avoided damage costs due to biodiversity loss, as well as map and value various restoration projects/efforts of relevance. These can be categorized by main habitat types (FOEN 2017), sectors and land uses[12].

Method and data

We present our procedure, using policies aimed at improving and restoring habitats and biodiversity conservation in agriculture, because it is a sector where direct payments are well documented and earmarked. An important instrument for biodiversity conservation in agriculture are the Contributions to biodiversity ("*Contributions à la biodiversité / Biodiversitätsbeiträge*"). They comprise two categories: Contributions for biodiversity quality ("*Contributions pour la qualité / Beiträgen für die Qualität*"), which are fully funded at the Federal level, and the scheme called Creating networks of highly valuable biodiversity areas ("*Contributions pour la mise en réseau / Vernetzungsbeiträge*") funded up to 90% at the Federal level, with the remaining amounts funded by the cantons, municipalities and private institutions (**Table 2**).

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[11] 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 5/7/2022)

[12] The Swiss land use statistics condense these into four broad designations: 1. settlement and urban areas, 2. agricultural areas, 3. forest areas (forest and woods) and 4. unproductive areas (lakes and rivers, unproductive vegetation, rocks and screes, glaciers and perpetual snow). The currently used classification developed by the Swiss Statistical Office (NOLU04, first adopted in 2004) further divides these four designations into 10 classes and 46 basic categories.

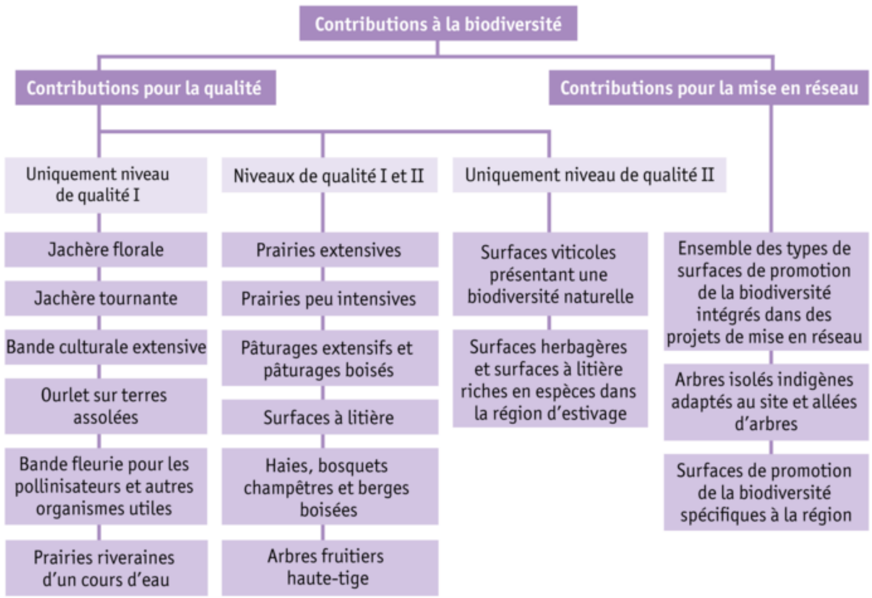

Figure 4: Categories of direct payments contributions to biodiversity. Source: BLW[13]

Table 2: Contributions to biodiversity (2022)

Contributions à la biodiversité 2022				
		QI (CHF/ha)	**QII (CHF/ha)**	**Mise en réseau (CHF/ha)**
Prairies extensives	Zone de plaine	1'080	1'920	1'000
	Zone des collines	860	1'840	1'000
	Zones de montagne I et II	500	1'700	1'000
	Zones de montagne III et IV	450	1'100	1'000
Surfaces à litière	Zone de plaine	1'440	2'060	1'000
	Zone des collines	1'220	1'980	1'000
	Zone de montagne I et II	860	1'840	1'000
	Zone de montagne III et IV	680	1'770	1'000
Prairies peu intensives	Zone de plaine à zone de montagne II	450	1'200	1'000
	Zones de montagne III et IV	450	1'000	1'000
Pâturages extensifs et pâturages boisés		450	700	500
Prairies riveraines d'un cour d'eau		450	-	1'000
Haies, bosquets champêtres et berges boisées		2'160	2'840	1'000
Jachères florales	Plaine et région des collines	3'800	-	1'000
Jachères tournantes	Plaine et région des collines	3'300	-	1'000
Ourlet sur terres assolées	Zone de plaine à zone de montagne II	3'300	-	1'000
Bandes culturales extensives		2'300	-	1'000
Bandes fleuries pour les pollinisateurs et les autres organismes utiles	Plaine et région des collines	2'500	-	-
Surfaces viticoles présentant une biodiversité naturelle		-	1'100	1'000
Surfaces herbagères et surfaces à litière riches en espèces dans la région d'estivage		-	150	-
Arbres fruitiers à haute-tige	par arbre	13.50	31.50	5
Noyers	par arbre	13.50	16.50	5
Arbres isolées adaptés au site et allées d'arbres	par arbre	-	-	5
Surface de promotion de la biodiversité spécifique à la région		-	-	1'000

Source: BLW[14]

[13] Source: www.blw.admin.ch/blw/fr/home/instrumente/direktzahlungen/biodiversitaetsbeitraege.html. Last accessed: 1/6/2022.
[14] Source: www.blw.admin.ch/blw/fr/home/instrumente/direktzahlungen/biodiversitaetsbeitraege.html. Last accessed: 5/7/2022.

We will also consider other direct payments with environmental objectives provided to Swiss farmers that are relevant for habitat creation and maintenance, using the mapping of direct payments with explicit environmental objectives provided by the OECD (2017).

A similar procedure will be used to map and value habitat creation and maintenance instruments used in other sectors. Thereby we will distinguish between habitat maintenance efforts (that are usually supported through direct payments) and habitat restoration/creation activities (implemented mainly through habitat restoration projects)[15].

7.2. 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, pear, strawberries 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. (2020b) 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 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] The Swiss agri-environment scheme enhances 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).

[15] For example, projects aimed to restore extensive meadows, wetlands and water streams or to enable animal free and safe movement.

[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: 3.12.2021).

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.

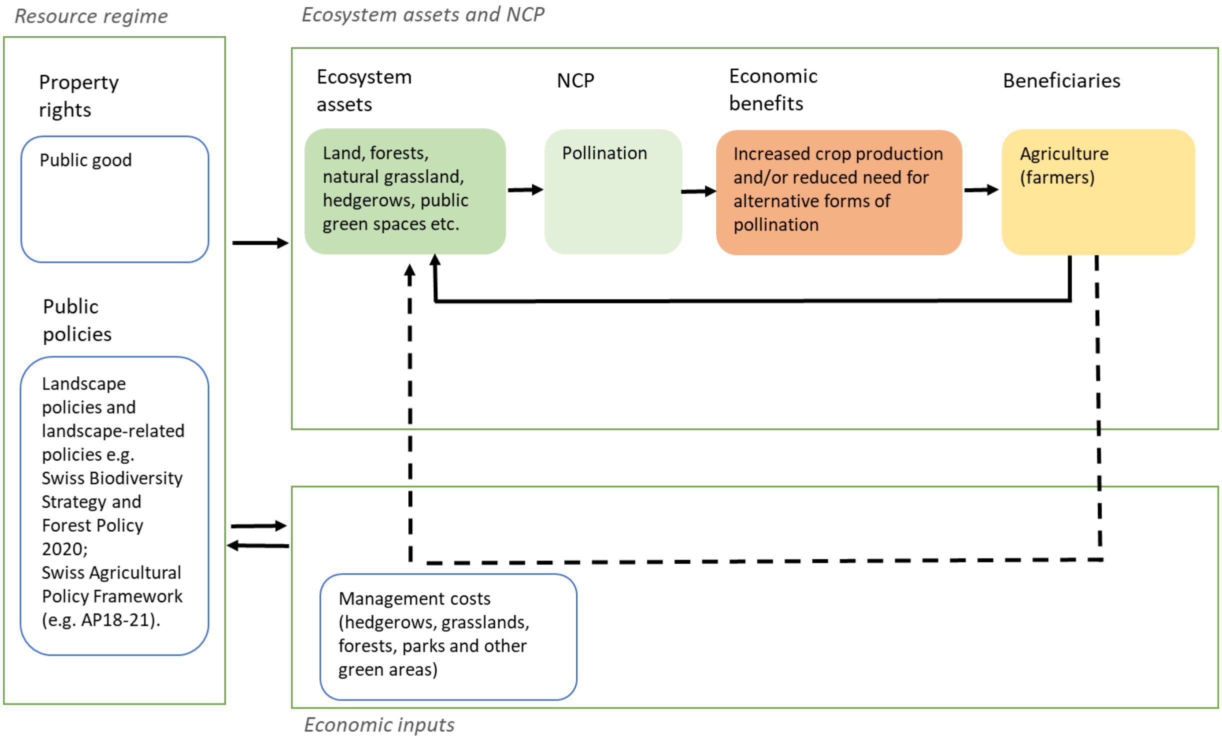

Figure 5: Monetary valuation framework of NCP Pollination, Source: authors´ presentation

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 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, pollinators 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. These higher costs and losses vary 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 from 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%, with the highest range obtained when pollination is combined with simulated pest control (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 pollinations, e.g. (Horlings et al. 2020a; Ecoplan / INFRAS 2014; INFRAS 2021). 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 2021). A study by INFRA (2021) applies this method in the context of Swiss agricultural production.

Choices related to the scope of this ecosystem service pertain to what agricultural products to include. Crops will be selected on the basis of the choices made in previous Swiss studies (INFRAS 2021; Sutter et al. 2017a) validating the list looking at area under production and monetary value per hectare.

We also suggest focusing on wild unmanaged pollinators. This choice is consistent with other European studies using the SEEA approach, e.g. Horlings et al. (2020b) 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).

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

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

(Hanley et al. 2015). Dependency ratios aim to calculate the portion of the production that can be lost in the absence of pollinators.

Sutter et al. (2021), Sutter et al. (2017b), and Sutter and Albrecht (2016) also provide 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 3: 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 4: 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 from 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 5). Although this is the categorization adopted in most of the studies conducting an economic valuation of the NCP Pollination, e.g. Horlings et al. (2020b) for The Netherland, 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 5: 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 estimate the value of the NCP we further need the production quantities for each selected crop, and the producers' price by crop. Monetary valuation at country level can be conducted using production and annual producers prices data (CHF/tonne) are sourced from FAOSTAT (www.fao.org/faostat/en/#data/PP), which in turn originate 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. Data on annual crop production and area under crop at cantonal level shall be also sourced from the Federal Statistical Office. These data would allow to obtain more spatially disaggregated results than those calculated in previous studies.

We suggest using the prices and production values for 2019, but also production volumes and their average for the period 2015-2019, to account for inter-annual variation in crop productivity and to produce sensitivity analysis to the use of a specific year.

Table 6 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 6: 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., 2017 (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 "large" following the categorization suggested by Klein et al., 2007.

If the date were available, this calculation could be done for Swiss municipalities using more disaggregated data.

7.3. Regulation of air quality

High levels of air pollution are a proven cause of disease and premature death. Depending on the pollutant, individual 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, it continues 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 was above the respective values for NO_2 and O_3, 270 and 350 deaths (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 mortality.

Resource regime

Air pollution reduction measures are stipulated in the Environmental Protection Act[20] and the implementing ordinances such as the Ordinance on Air Pollution Control.[21] 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 7 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 8.3).

[20] 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
[21] https://www.fedlex.admin.ch/eli/cc/1986/208_208_208/de

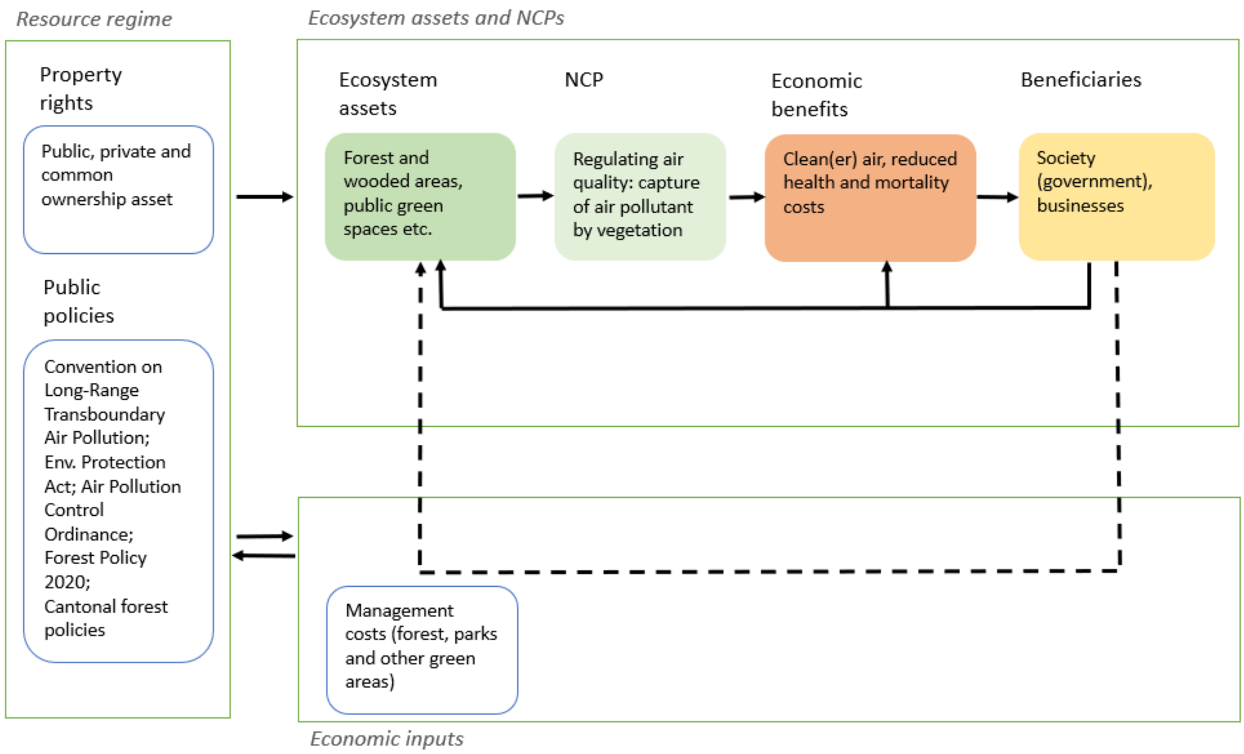

Figure 6: Monetary valuation framework of NCP Regulation of air quality. Source: authors´ presentation.

Table 7: Limits and status for selected air pollutants

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
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 humanity. 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 (DEFRA 2021).

Monetary valuation scope

Most studies estimating monetary value of the air filtration service apply the damage function approach (DEFRA 2021; Horlings et al. 2020b; 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 recommended by the WHO (2013) are used to determine health impacts associated with an increase in a specific pollutant, e.g. by 10 µg/ m^3. In the next step, a unit price is applied to the physical impact measure to convert it to monetary terms (Freeman 2014). This approach will be applied also for the economic valuation of the NCP Regulation of air quality in the ValPar.CH project. Specifically, we aim to quantify economic benefits due to a marginal reduction in air pollution as avoided morbidity and mortality damage costs.[22]

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. We will monetarize health benefits related to the NCP Regulation of air quality for Switzerland based on PM10 that is used for modelling PM removal through vegetation[23].

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.

[22] Initially, we planned 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; and it might require substantial efforts to address model prediction uncertainties when modelling O_3 pollution.

[23] 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 has not yet been completed, the co-lead of this project (Prof. Martin Röösli, personal communication on phone on 11.02.2022) recommends assessing the health costs of air pollution based on PM10. Furthermore, long time observations/estimates for corresponding pollutants are required modeling air pollution removal by vegetation. The estimates of spatial dispersion of PM2.5 are available so far for two years – 2015 and 2010 – only. 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).

Health benefits attributable to removing each excessive 10 µg/m^3 of PM10 will be calculated using the concentration-response functions applied in Switzerland to measure health costs associated with traffic-induced air pollution (Ecoplan and INFRAS 2014; WHO 2013), 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 will be then applied to relevant health impact categories using the methodology developed by (Ecoplan and INFRAS 2014) to measure avoided morbidity and mortality costs. Cost rates for the assessment of air-pollution related health and productivity loss costs [CHF/case] recommended by ARE (Ecoplan and INFRAS 2014) will be used after adjusting them to the situation in the reference year.

The avoided mortality costs will be 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).[24] 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 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 our analysis of the value-added of ecological infrastructure in Switzerland.[25]

7.4. 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.[26] 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

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

[25] 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. Furthermore, similar to the procedure proposed by INRAS and ecoplan (2019), we will incorporate in our valuation in addition to the average VLYL estimate also estimates accounting for ±50% variation in VOLY to account for prediction uncertainty associated with this measure.

[26] 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).

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, was revised. The revised CO_2 Act was approved by the Swiss Parliament in autumn 2020 but rejected in a national referendum on June 13, 2021. Currently, a new CO_2 Act amendment is prepared that should enable Switzerland to halve its emissions by 2030 compared to 1990.

The CO_2 levy introduced in Switzerland in 2008 has been a key policy instrument to achieve the country CO_2 emissions targets. It is imposed on fossil combustible fuels, such as heating oil and natural gas.[27] 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). Since 2018, the CO_2 levy has been set at CHF 96 per ton of CO_2. From January 1 2022, the CO_2 levy will automatically raise to 120 CHF per ton of CO_2, as the CO_2 emissions from fuels such as heating oil or natural gas emissions were reduced by less than 33% by 2020 (the target level for 2020 according to the current CO_2 Act) compared to their 1990 level.[28]

Soils and forests are important sinks of carbon.[29] 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 fulfill 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 8.3) and NCP Food and feed (section 8.2).

[27] Transportation is exempt from the CO2 levy and other policies to reduce GHG emissions in Switzerland.
[28] https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-84335.html
[29] 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.

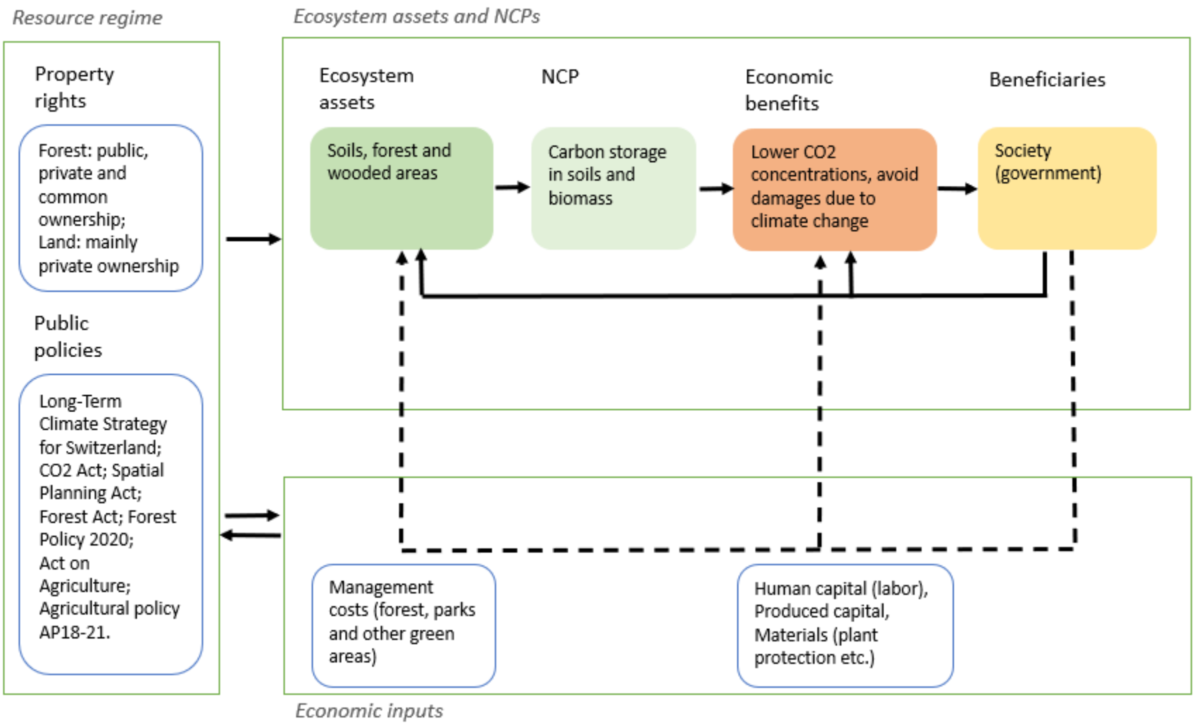

Figure 7: Monetary valuation framework for NCP Regulation of climate. Source: authors´ presentation.

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. Both the SCC and the MAC are measures of avoided damage cost.

The carbon price assessed using the MAC approach[30] was used in the UK National Ecosystem Assessment (Bateman et al. 2014) and also more recently in the Scottish natural capital accounts (2020), 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.

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

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 individual 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[31]. 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%[32]. 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 2º-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 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)[33] 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 yields 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.

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)[34], 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 SDR, 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

[31] 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).

[32] 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.

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

[34] 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).

by the IPCC.[35] 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 **310.6 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[36]. Accordingly, the proposed monetary values for measuring the NCP Regulation of climate for 2019 are **669.1** CHF (reference price estimate) and **1140.0** CHF (precautious price estimate), each in CHF of 2019 per 1 ton of carbon (**Table 1**).

Table 8: CO_2eq. and carbon price estimates for 2019, CHF 2019/t.

Indicator	CO_2 price CHF 2019/t CO_2	Carbon price CHF 2019/t carbon
MAC-based estimate	182.3	669.1
SCC-based estimate	310.6	1140.0

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

7.5. 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 (60km^3/year) and an influx from other countries (13km^3/year). More than two-thirds of this water leaves the country as runoff (53km^3/year) while the rest evaporates (20km^3/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.[37] At the federal level, several laws and ordinances regulate water use.[38] 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.

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[35] 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.
[36] i.e. 1 ton of carbon is equivalent to 3.67 ton of CO_2.
[37] A detailed discussion on property can be found in Leimbacher and Perler 2000.
[38] 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).

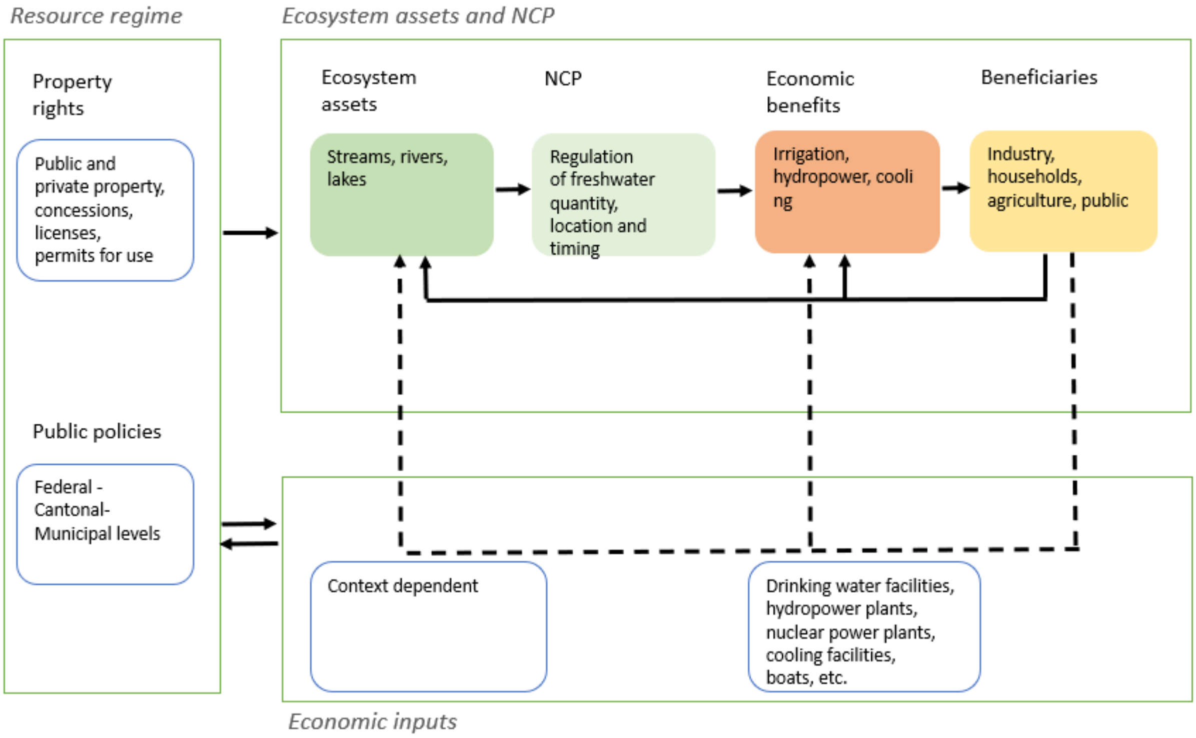

Figure 8: Monetary valuation framework for NCP Regulation of freshwater quantity, location and timing. Source: authors´ presentation.

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 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 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 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 will be modelled as water yield per raster cell. This indicator refers mostly to surface water. We thus propose to monetize the modelled water quantity per raster cell with the price for surface water of the canton, that the raster cell is situated in.

We propose to scrutinize the water legislation for all 26 cantons and to list their different types of water-related concession, permit and license fees, especially those related to surface water. For the parks, we suggest to additionally check at the municipal level if there are any deviances or additions to the cantonal regulations

We will list the cantonal and park-level data as raw data in an excel file including links to the information sources. Building on this data we can average the surface water prices (provided there are several) in each canton. This table of raw data will also allow to transparently compute weighted averages of surface water prices, if there is reason to do so, e.g. because one water consumption category is known to be quantitatively far more important than another. Table 9 provides an example for concession price information from Solothurn.

Table 9: Exchange values for water in Solothurn

Category	CHF/m^3	CHF/m^2	CHF /(MJ/h)
Entnahme von Oberflächenwasser	0.007		
Entnahme von Grund- und Quellwasser. Kategorie A: private Nutzung als Trinkwasser	0.020		
Entnahme von Grund- und Quellwasser. Kategorie B: öffentliche Nutzung als Trinkwasser	0.015		
Entnahme von Grund- und Quellwasser. Kategorie C: Nutzung für industrielle und gewerbliche Zwecke	0.020		
Entnahme von Grund- und Quellwasser. Kategorie D: Nutzung für Wärmepumpe (heizen oder kühlen) bei Wiederversickerung	0.005		
Entnahme von Grund- und Quellwasser. Kategorie E: Nutzung zur Bewässerung von landwirtschaftlichen Kulturen	0.020		
Betrieb von Wärmepumpenanlagen durch Oberflächenwasser			1.00
Entnahme von Wasser zur Kühlung von Kernkraftwerken pro m³ verdunstetes Wasser (Differenz zwischen Wasserentnahme und Wasserrückgabe)	0.220		
Schiffshäuser und andere Bauten pro m² beanspruchte Wasserfläche (jährlich)		12.00	
Schiffsstege pro m² beanspruchte Wasserfläche (jährlich)		6.00	

Source: BGS 615.11 – Gebührentarif (GT), Art. 105 https://bgs.so.ch/app/de/texts_of_law/615.11

The information on the concession fees provides a current snapshot of the exchange values. However, as mentioned in the introduction, local water shortages are expected due to climate change. We suggest to conduct expert interviews with staff in 4-5 cantonal administrations to better understand (i) how the concession fees are determined, (ii) how often they change, and (iii) if they are expected to change provided water shortages become more pronounced in the future.

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. Our suggested approach of using 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. We will try to validate, i.e. better understand the advantages and disadvantages related to our approach through a series of expert interviews.

7.6. 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."

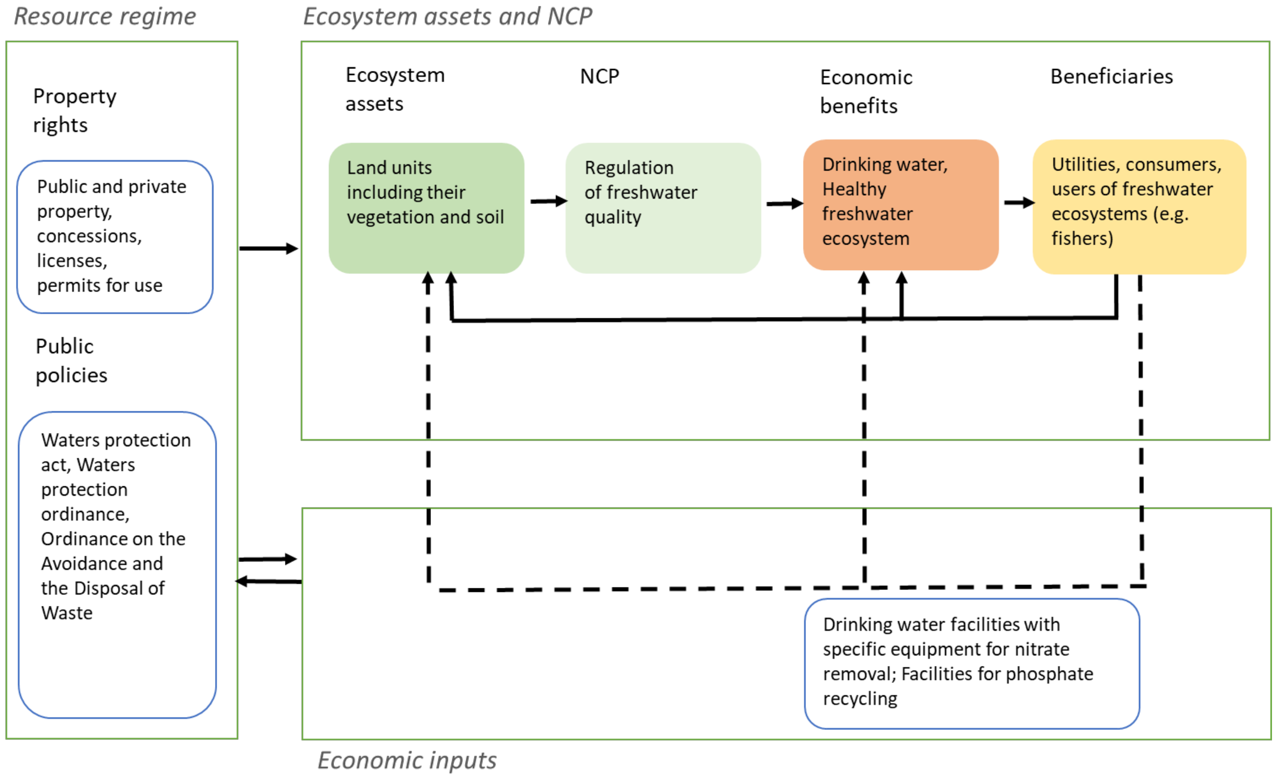

Figure 9: Monetary valuation framework for NCP Regulation of freshwater quality. Source: authors´ presentation

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 thus 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

According to the SEEA-EEA guidelines, avoided damage cost is an appropriate monetary valuation method especially for regulating NCPs that are impaired by human-caused pollution (UN DESA 2019). Essentially, the method estimates the monetary value of a NCP based on the costs that would have been incurred if the NCP was absent (Remme et al. 2015). Applied to our context, this means that we compute the cost for water utilities of removing a unit of nitrate. This cost of nitrate removal can then be used to monetarily value the nitrogen retention capacity per unit of land.

We will conduct interviews with producers of technical equipment for water utilities to understand the spectrum of options available to remove nitrate from water. In a second step, we will send a survey to a sample of water utilities in regions with too high nitrate contents in groundwater to ask what removal technology they use, how much nitrate they remove and how much they estimate it costs.

For phosphorus, we will use existing estimates on the cost of extracting phosphorus from wastewater (Kanton St. Gallen 2019) and market prices for phosphate to monetarily value the phosphorus retention capacity per unit of land.

Our approach focuses on nitrogen and phosphorus and is thus more specific than the approach used by Remme et al. (2015) who for the Netherlands compute the cost of cleaning surface water also from other polluting substances as a substitute for groundwater. However, our approach of using avoided damage costs is consistent with the SEEA-EEA guidelines.

7.7. 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 measure 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 fulfill 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.

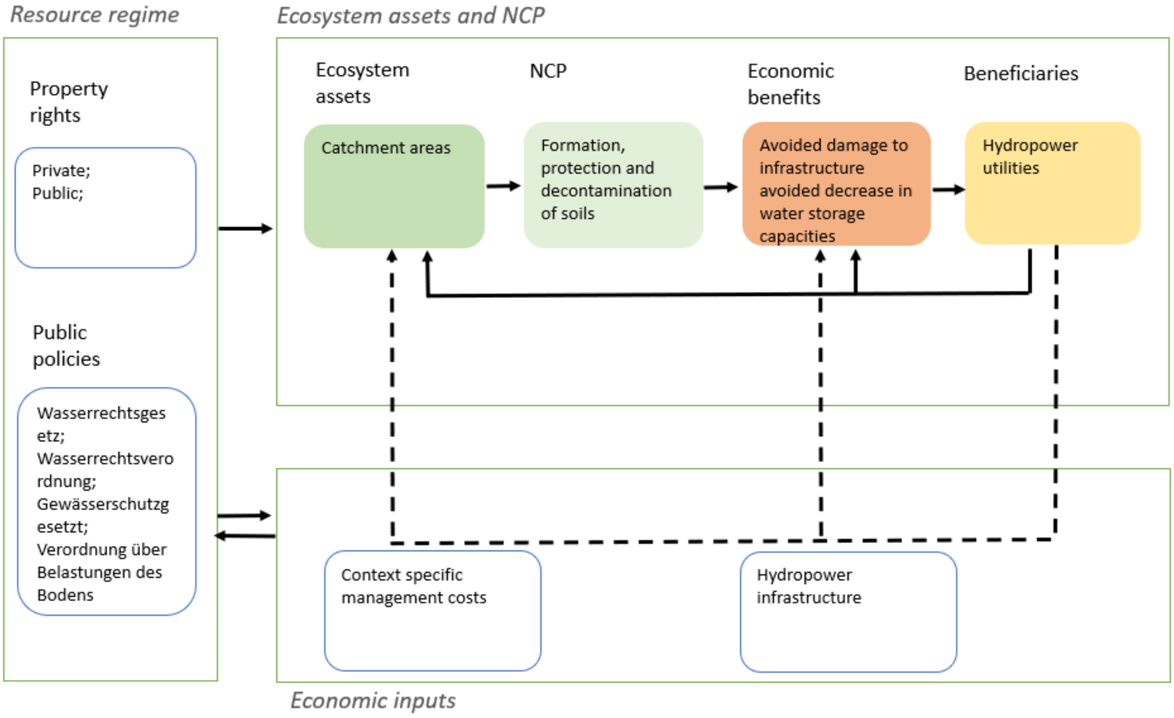

Figure 10: Monetary valuation framework for NCP Formation, protection and decontamination of soils. Source: authors´ presentation.

Management of sediments is a complex and costly task. The cost of sediment management appears to be particularly high in the Swiss hydropower sector (Boes, personal communication 23.09.2021). Hydropower is the most important source of energy in Switzerland (Ehrbar et al. 2019). It covers 57% of the country's energy production. The importance of hydropower is expected to further increase in the upcoming decades. Following the Fukushima nuclear disaster in March 2011, the Federal Council and Parliament decided to augment its energy policy and to gradually phase out nuclear energy in Switzerland. Successively, the Act on energy adopted in 2017 specified the objective of increasing electricity production from hydropower by 2050. In particular, average annual production of hydropower energy should increase by to 38,600 GWh, i.e. by around 23,000 GWh. Accordingly, 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).

Method and data

We propose to 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 exist on that subject, we intend to collect these data by surveying hydropower enterprises. To this end, we will establish a typology of hydropower facilities considering important characteristics such as the facility type (run-of-the-river power plants and storage power plants), size/capacities including storage capacities, types of sediment management, relevant features of their location (e.g. altitude and steepness) etc. Successively, up to three facilities will be selected from each identified category and surveyed to assess their costs of sediment control and management.

7.8. 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 defined 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. Depending on data availability, we intend to also cover floodplains as a second indicator for this NCP. 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 fulfill 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.

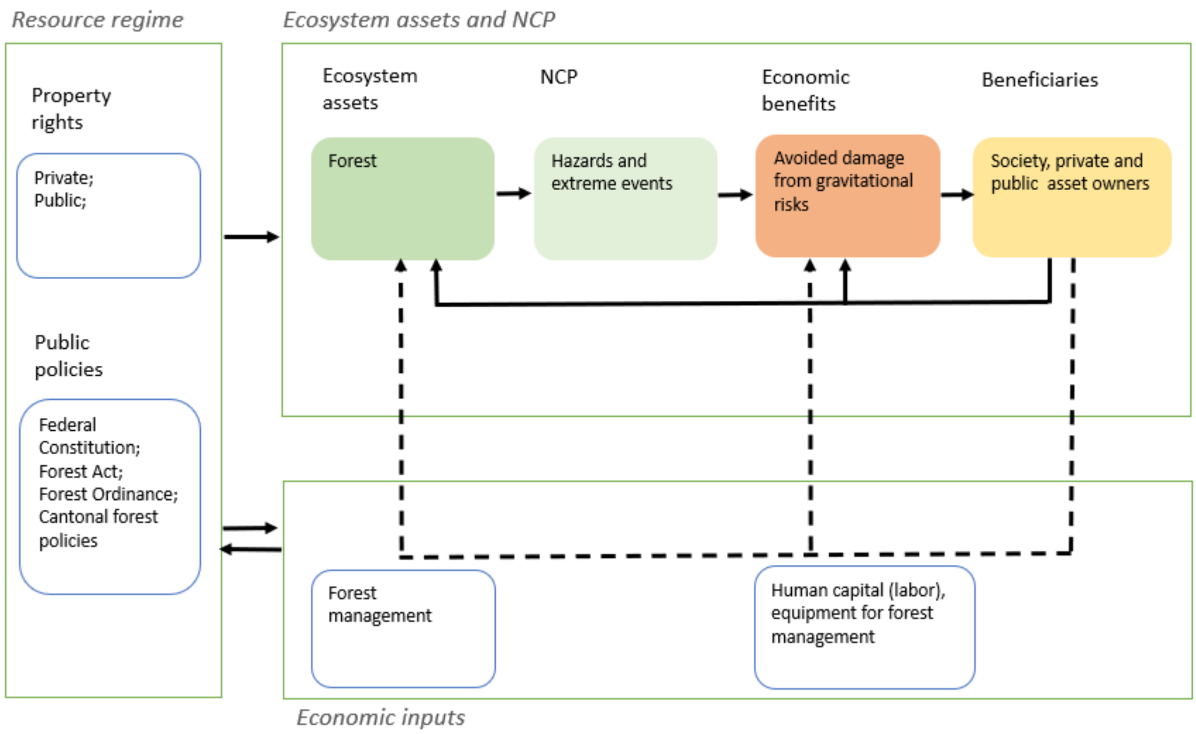

Figure 11: Monetary valuation framework for NCP Regulation of hazards and extreme events. Source: authors´ presentation

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. 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. 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 200/ha or CHF 20'000/ha).

We propose to use this value for broad-brushed NCP valuation studies, although 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. However, values derived in this way reflect risk, i.e. the consequences from a natural hazard, rather than a hazard itself. In addition, we will contact large insurance companies in Switzerland to explore whether they have readily usable monetary values for protection forests. If so, the monetary values will be reported as a range.

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.

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 propose to use cost data from NFA-funded projects on water way restorations that were conducted with a main objective of decreasing flood hazards and ecological restoration as side objective. A request for this data has been sent to BAFU. Ideally, this data will allow us to compute an exchange value for floodplains per m^2.

7.9. 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 will determine its scope. In ValPar.CH, we will value common vole biocontrol by avian raptor species in agricultural landscapes. The common vole appears to be already well controlled by avian raptors such as kestrels in the Swiss central plateau (Fay et al. 2020; Stutz 5/30/2022). Accordingly, valuation of common vole biocontrol services will be based on the results of a controlled trial conducted using the increased predation pressure of avian raptors for biocontrol of common vole outbreaks by Machar et al. (2017).

Resource regime

An option for farmers whose crops and orchards are damaged by vole populations is try to combat this pest with rodenticides – chemicals inhibiting blood clotting in voles. However, as prey affected by rodenticides´ treatments can be eaten by their antagonists such as different raptor species and small mammals, e.g. short-tailed weasel (Mustela erminea), rodents´ predator species can be also affected by anticoagulant rodenticides.

As the valuation of this NCP will be done using as an example rodent biocontrol in agriculture, the relevant ecosystem is land used for agricultural production. Accordingly, the resource regime described for the NCP Food and feed in section 8.2 concerns also 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 7.1. 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 is more widespread in the country.

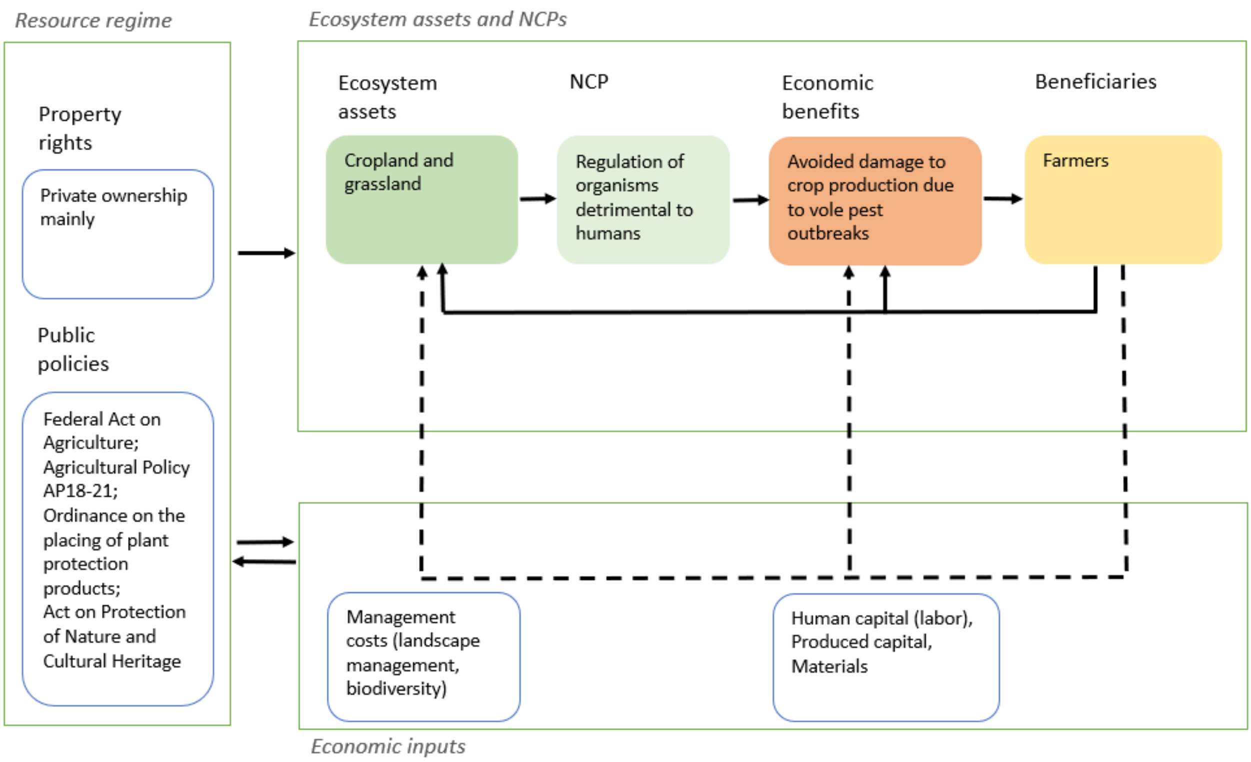

Figure 12: Monetary valuation framework for NCP Regulation of organisms detrimental to humans. Source: authors´ presentation.

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 raptors may be a lower cost alternative compared to rodent control through rodenticides´ application. Two main methods of controlling rodent populations are: (i) installing huma-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 (http://www.bff-spb.ch/fileadmin/pdfs/DE/Direktzahlungen_BFF.pdf).

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.

In ValPar.CH, we propose to assess economic benefits of raptors´ regulation services using agricultural production as an example. Accordingly, the beneficiaries of this NCP are farmers. The economic benefit to be assessed is avoided damage costs to crops or plants in conventional agriculture due to vole outbreaks. This measure of the NCP Regulation of organisms detrimental to humans´ benefit 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 analyzing 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[39] 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 Swiss agricultural landscapes, we will use results of the study by Machar et al. (2017) to 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.

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 this 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 labor costs (in Swiss agriculture) that will proxy farmers´ avoided damage costs in case of a common vole outbreak. Considering that vole outbreaks occur not each year, we will multiply this estimate of avoided damage by an estimate of probability of vole outbreaks to assess expected avoided damage per year (independently of that whether it was a year with outbreak or not). Although rodenticides are currently not used in Swiss agriculture for the control of the common vole (but for the control of the European water vole), we assume that in the absence of an effective avian 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 pest control.

Successively, we will deduct from this estimate farmers´ costs for building and installing perches (5 perches/ha) adjusted to account for perches useful life (up to 20 years) and the probability of vole population outbreak. This monetary value will be then divided by the number of buzzard and kestrel individuals required to provide effective vole control on one hectare of cropland according to the experiment results by Machar et al. (2017). This value per 1 raptor individual will present the monetary value of vole regulation by two considered raptor species.[40]

The probability of common vole outbreaks can be assessed using an index of vole abundance estimated based on data collected by the Swiss Ornithological Institute (Vogelwarte) from a total of 6,187 kestrel broods between 2008 and 2018 on the Swiss central plateau (Kleijn et al. 2015; Fay et al. 2020) or observations of the Swiss Information Center on Species (Infospecies) on common vole populations. As both mentioned indicators have been measured for different spatial units/locations, it is possible to measure the value of this NCP for single spatial locations covered in corresponding data sets. Should the probability of common vole outbreaks in Switzerland be very low (due to an effective biocontrol by avian raptors), it can be assumed to be similar to that for other vole species such as e.g. the water vole or from the study by Machar et al. (2017), i.e. in the absence of an effective avian predator pest control.

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[39] 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.

[40] We will discuss with ornithology experts the need for considering potential differences in dietary requirements or vole hunting efficiency between two raptor species in our analysis and, if necessary, adjust our procedure to account for these differences.

8. Material NCPs

8.1. 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 8.3 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 will use stumpage prices 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.

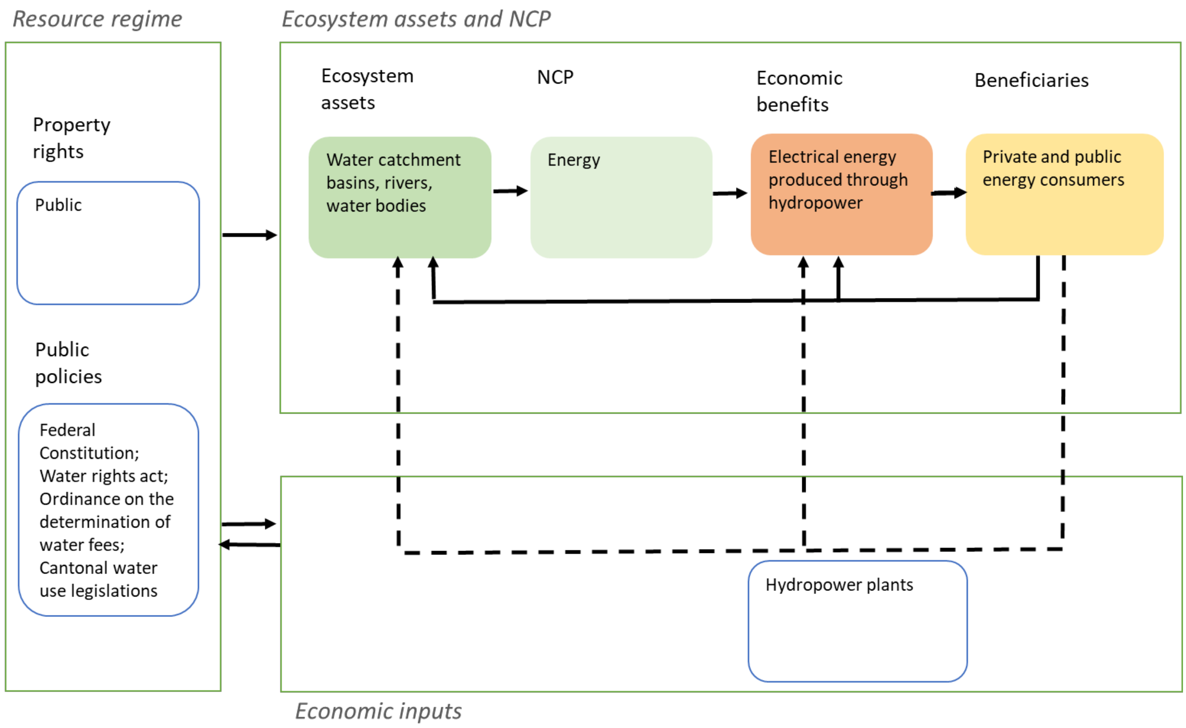

Figure 13: Monetary valuation framework for the hydropower indicator for the NCP Energy. Source: authors´ presentation

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 will compute a monetary value (CHF/m^3) of water that is usable for the generation of hydropower in plants that have a gross capacity above 2 megawatt. Hydropower plants with a capacity of less than 1 megawatt do not have to pay concession fees. Based on data availability, we will include plants with a capacity between 1 and 2 megawatt. These intermediate plants can benefit from reduced fees.

Method and data

Annual data on hydropower production is publicly available as "Statistik der Wasserkraftanlagen der Schweiz" (BFE 2022). These datasets include information on the installed turbine power per plant, which is a good indicator for gross capacity. However, gross capacity tends to be lower than the installed turbine power. Interviews will be conducted with cantonal administrations (Valais and Grisons) to determine valid correction factors. Furthermore, we will screen the cantonal legislations on water use to compile information on deviations from the federal price ceiling. (Synergies will be used in screening the cantonal legislations for the NCP Energy and the NCP Water quantity). By multiplying the cantonal prices with gross capacity, we will obtain an estimate of the total annual sum paid by the power plant for water. Data on the volume of water used per second is available, which allows to compute the price per cubic meter of water.

8.2. 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.[41] Food produced from livestock production is not considered as an NCP indicator, as it is produced using feed which itself already captures the Nature´s contribution to food production.

Resource regime

Agricultural production in most industrialized countries strongly determined by national agricultural policy frameworks 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 decentralized 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 are provided to Swiss farmers under the current agricultural policy framework – AP18-21[42]: (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 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.[43] Implementation of such policy measures could considerably influence the magnitude of agricultural production in Switzerland, its structure as well as the spatial distribution of production. 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, the propose to value the NCP Food and feed in ValPar.CH considering the current agricultural policy framework including border protection measures. Accordingly, no adjustments to the value added from agriculture measured in producer prices will be done to account for price differentials that exist for certain categories of products compared to border prices.

[41] 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.

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

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

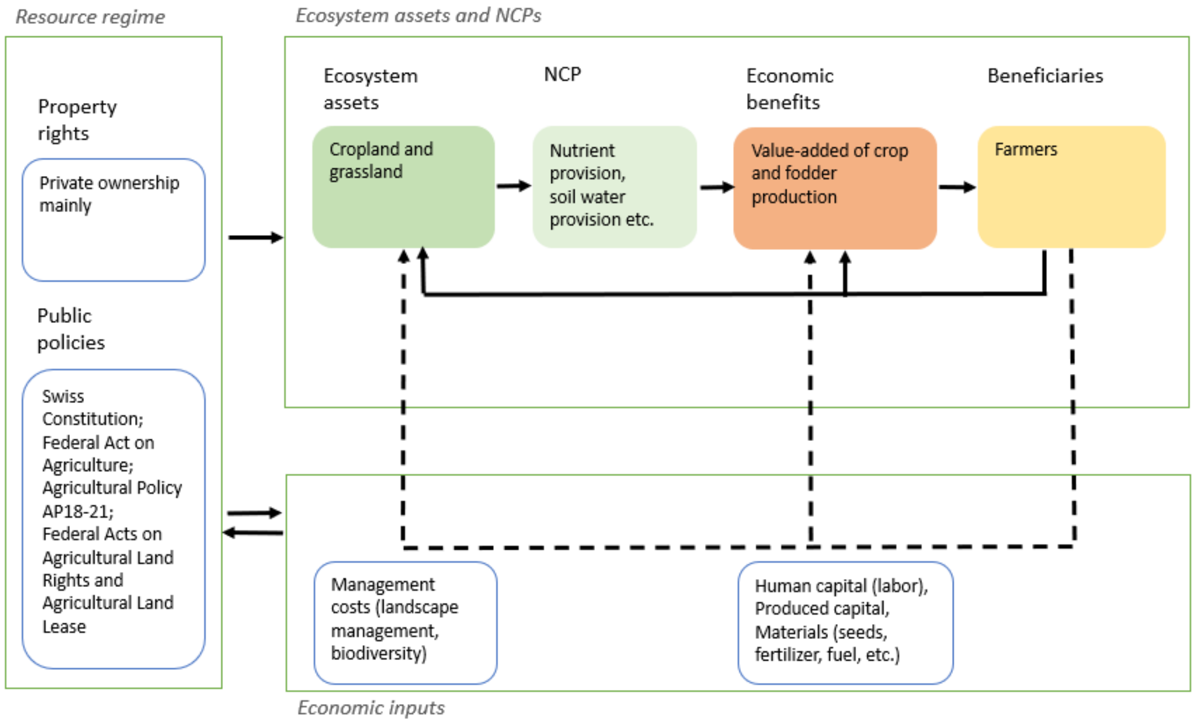

Figure 14: Monetary valuation framework for the NCP Food and feed. Source: authors´ presentation.

The two important legal acts regulating agricultural land use are the Federal Act on Agricultural Land Rights ("Bundesgesetz über das bäuerliche Bodenrecht, BGBB"[44]) and the Federal Act on Agricultural Land Lease ("Bundesgesetz über die landwirtschaftliche Pacht, LPG"[45]). 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 Pacht-zinses"[46]) and the Guidance on the Estimation of the Agricultural Yield Value ("Anleitung zur Schätzung des landwirtschaftlichen Ertragswertes"[47]) 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 contribution of land to agricultural output (marginal product of this factor) should coincide with rents paid for corresponding land parcels.

[44] https://www.fedlex.admin.ch/eli/cc/1993/1410_1410_1410/de
[45] https://www.fedlex.admin.ch/eli/cc/1986/926_926_926/de
[46] https://www.fedlex.admin.ch/eli/cc/1987/406_406_406/de
[47]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

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 gods 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 utilized agricultural land. In addition, we intend to utilize, wherever available, information on observed rental prices, to validate our land marginal product estimates obtained using the production function approach.

Method and data

Production function method: The application of this method enables deriving 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 behavior, 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.

We intend to estimate production functions for Swiss crop and dairy farms[48] using the FADN data 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 analysis.[49]

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

[48] 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.

[49] 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.

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.

We will specify a production function model which should enable us to test for differences in agricultural land productivity between farms situated in different climatic zones as well as zones of different soil quality as captured in the FOAG maps of climate suitability and soil suitability[50]. We also intend to test model formulations allowing to distinguish between productivity of cropland and grassland. Additionally, alternative farm output specifications to get robust estimates of marginal land productivity will be employed. Given statistical significance of corresponding model parameter estimates, we intend to approximate land marginal productivity by applying our model estimates to data for individual regions; in particular the data on the agriculture gross product, cropland and grassland area, and information on shares of specific climatic and soil quality zones in each region. This procedure should allow accounting for spatial differences in agricultural land productivity and thus enable drawing more disaggregated monetary values for the NCP than it would have been possible by applying the resource rent approach[51].

Rental price method: 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.

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. Both types of prices are, however, collected by Agroscope for the Swiss FADN farm sample. Accordingly, based on these data, it should be possible to calculate average rental prices at the national level and potentially also at lower aggregation levels such as climatic zones and soil zones (here we refer to actual rental prices only). These average prices would present relatively coarse approximation of actual rental prices of land. However, they potentially could be used to validate land marginal product estimates from the production function method. In particular, we expect that that land marginal product estimates derived accounting for spatial differences in climate and soils should show similar magnitudes as rents paid for land of approximately similar quality and location.

8.3. Material and assistance

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

[51] The resource rent approach requires the use of the national accounts data. As these data/similar data structures are not available at regional levels, it cannot produce resource rent estimates for subnational aggregation levels.

In this section, we present our approach for valuing NCPs using as an example the NCP 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 propose using 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).

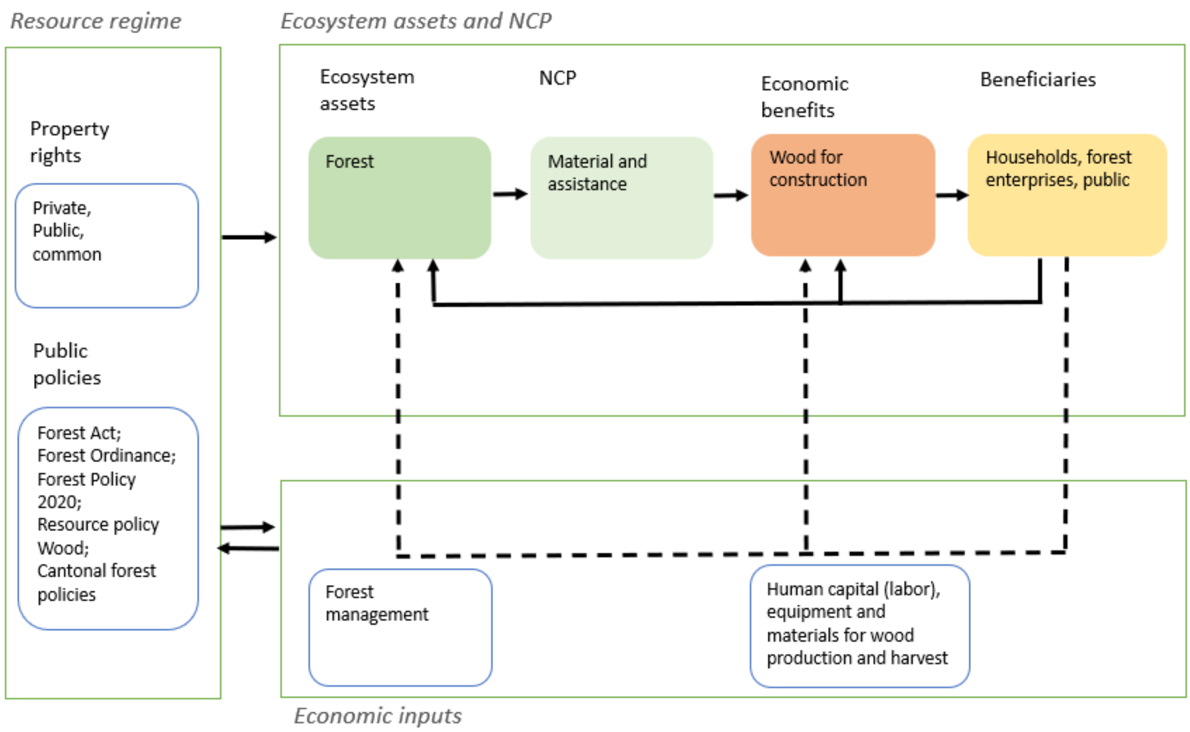

Figure 15: Monetary valuation framework for NCP Regulation of freshwater quantity, location and timing. Source: authors´ presentation

Forest provides 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).

Method and data

The FSO applies the residual value method to compute stumpage prices for each National Forest Inventory (NFI) sample plot. The volume of the (standing) wood assortments on each sample plot is multiplied with the respective market prices to obtain the potential proceeds. In the next step, the stumpage price is estimated as the difference between the potential proceeds and the operational costs (per m^3) related to the logging, cutting and transporting of timber (Murbach 2016). Given that the operational costs often exceed the potential proceeds, the stumpage price per sample plot is often negative. The FSO refers to the NFI sample plots with positive stumpage prices as 'economic plots' and the sample plots with negative stumpage prices as 'non-economic plots'. Only the economic plots are used for further upscaling (Murbach 2016). **Figure 16** presents the corresponding data aggregated to the national level.

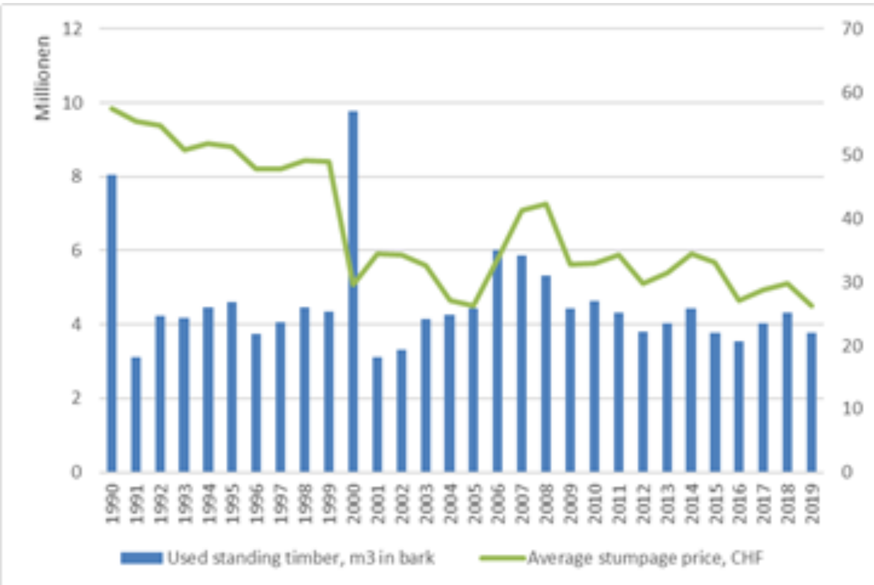

Figure 16: Standing timber used and its average stumpage price. Source: FSO 2021 Forstwirtschaftliche Gesamtrechnung (FGR), stehende Holzvorräte (Bilanz)

To value wood produced for construction, we propose to follow the FSO approach and to distinguish between economic and non-economic NFI sample plots. Accordingly, economic plots will be treated as forest plots used primarily for production of wood, while non-economic plots will be treated as forest areas used primarily for other purposes such as e.g. natural hazard protection, habitats for wild species, recreation, etc. The monetary value of construction wood will be computed as an average stumpage price (excluding energy wood) for the sample of economic NFI plots at the national and cantonal levels as well as at the park level whenever park forest areas are represented in the NFI sample. These monetary values will reflect the value of the non-energy wood assortments at the point in time when they transition from the ecosystem to the economy.

Due to market failures, the stumpage prices computed using wood market prices may underestimate the real social benefits of wood production under sustainable forest management practices. As mentioned in the discussion of the forest institutional resource regime, Swiss forest enterprises have to comply with sustainable forest management practices. However, these aspects of wood production may not be reflected in the wood selling prices which follow price developments in international markets. To address this methodological issue, we propose to derive an alternative estimate of the exchange value for construction wood. In particular, we suggest adjusting the stumpage prices for the volume of public policy support provided to forest enterprises through such measures as "Optimale Bewirtschaftungstrukturen und Prozesse"; "Walderschliessung ausserhalb des Schutzwaldes"; "Forstliche Planungsgrundlagen"; "Jungwaldpflege"; "Praktische Ausbildung" within the program objective "Waldbewirtschaftung" of the "Neuer Finanzausgleich" program agreement. The final list of policy support measures to be accounted for will be established involving FOEN experts in forest management.

8.4. 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.

In the context of the Swiss economy, there are records of Cantons supporting the production of a variety of medicinal plants for commercial purposes since the early 1980s (e.g. Valais). There has been an increasing popularity and economic opportunities of selling plants such as sage, arnica, mint and edelweiss following growing businesses of companies such as of Ricola, the well-known Swiss company that makes sweets, A. Vogel AG, Max Zeller Söhne AG, and Swiss Alpine Herbs Alpenkräuter AG.

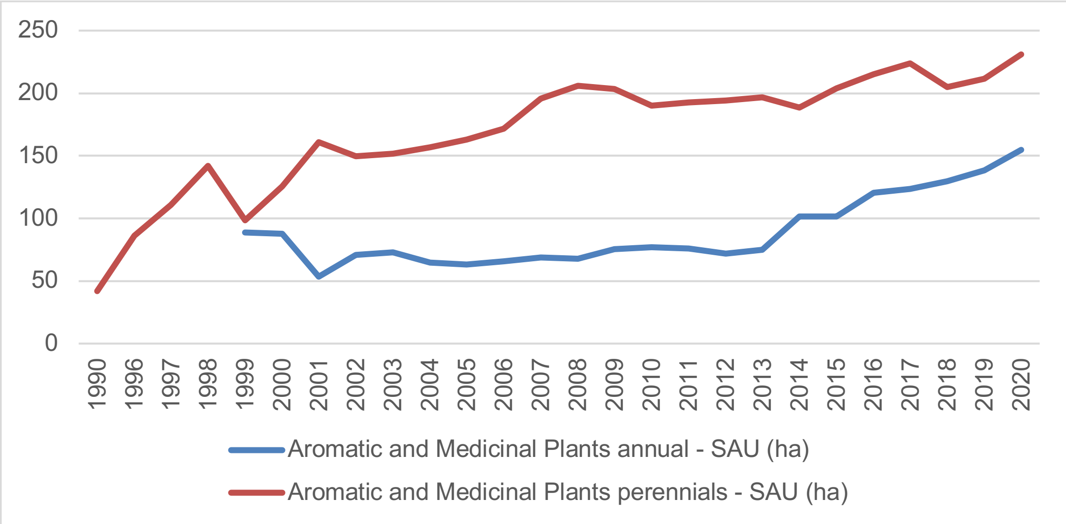

Figure 17: Agricultural land under production (in ha), aromatic and medicinal plants (Switzerland). Source: Authors based on data FSO – Relevé des structures agricoles, Section Structure et analyses économiques

The area under production of aromatic and medicinal plants in Switzerland was about 350 ha in 2019, of which about 60% were perennials (e.g. Sage, Thyme and Mint) and 40% annuals plants (e.g. Basil, Marjoram and Coriander). Unfortunately, disaggregate statistics for aromatic and medicinal plants, as well as for specific plants, are not available.

Given a rapid increase in demands for plant-based medicinal and other products, swiss-based processing companies and retailers have been increasingly looking for commercially oriented producers of medicinal plants. This development induced a substantial increase in the area under aromatic and medicinal plants in Switzerland over the past 20 years (Figure 17)

Resource regime

Medicinal plants are often included in processed products registered as food supplements, rather than as medicines. When a plant is used as a "*Botanicals*", i.e. as medicine, to give flavor to a drink, or as food supplements, their handling, processing and production should comply with regulations such as the "*Verordnung des EDI vom 16. Dezember 2016 über Lebensmittel pflanzlicher Herkunft, Pilze und Speisesalz (VLpH) (SR 817.022.17)*" and the "*Verordnung des EDI über Nahrungsergänzungsmittel (VNem) (SR 817.022.14)*". When medicinal plants enter the food production process they also have to respect all regulations in term of food safety standards, such as the "*Bundesgesetz über Lebensmittel und Gebrauchsgegenstände".*

It is often complicated to identify whether medicinal plants enter the commercial value chain as a "medicament", "food" or an "ingredient/ input for other uses (e.g. in cosmetics)". However, this is an important distinction because it affects which regulation applies to the production process and sales of the products containing medicinal plants. For this reason, the Swiss Agency for Therapeutic Products (Swissmedic), the Bundesamt für Lebensmittelsicherheit und Veterinärwesen (BLV) and the Bundesamt für Gesundheit (BAG) elaborated criteria for the demarcation of therapeutic products from food, when these are destined to oral consumption ("Kriterien für die Abgrenzung zwischen Medikamenten, Lebensmitteln und Gebrauchsgegenständen"), as well as criteria for the demarcation of cosmetic products from therapeutic products and biocidal products ("Abgrenzungskriterien der kosmetischen Mittel zu den Heilmitteln und Biozidprodukten"). These criteria take into consideration laws and juridical praxis of both the EU and Switzerland.

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.[52] These include monograph for medicinal plants and their components, such as sage leaves from *Salvia officinalis*.

In this analysis we focus on medicinal plants cultivated commercially, hence agricultural policies are a relevant component of the resource regime for this NCP too.[53] Other important policy instruments such as the Swiss Biodiversity Strategy may impact public and private funding to R&D and technology sites that promote the commercial exploitation of natural ingredients.

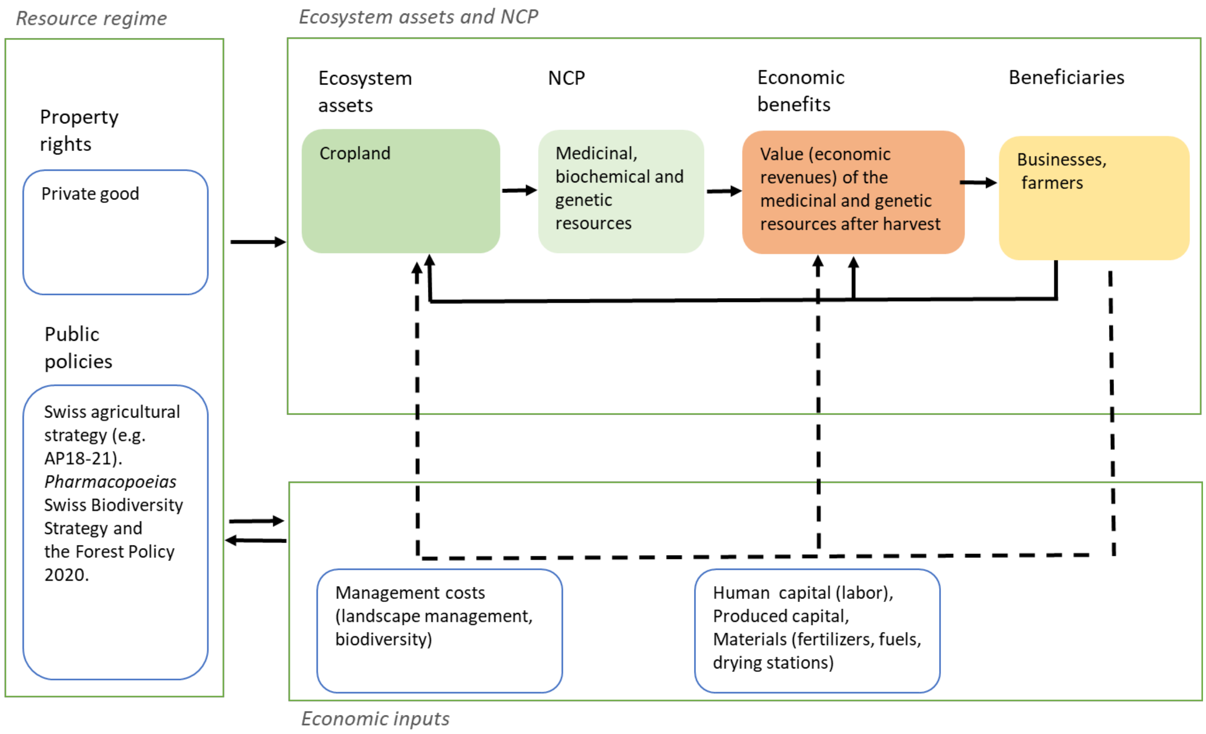

Figure 18: Monetary valuation framework for NCP Medicinal, biochemical and genetic resources. Source: authors´ presentation

Economic benefits and beneficiaries

Natural Medicinal Products (NMPs) constitute one of the most common human uses of biodiversity (species and related habitats) that contributes 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). Some medicinal biochemical and genetic resources are also used in agriculture as biological pesticides.[54] The main economic benefit of medicinal, biochemical and genetic resources are farmers' revenues derived selling medicinal plants to processing companies or directly to the end consumers. The main beneficiaries are the farmers, who often organize in cooperatives in this type of production.[55] Further beneficiaries of this NCP are companies using medicinal plants in their trading, processing

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

[53] Because some medicinal plants commercially sold can be harvested in the wild, policies designed to preserve, protect and restore forestland could also matter in maintaining the supply of this NCP.

[54] Source: semi-structured interviews with experts of the ZHAW School of Life Sciences and Facility Management Section Natural Product Chemistry and Phytopharmacy.

[55] For example in Valais, most of the medicinal plant growers have formed cooperatives to better respond to the increasing demand. See e.g. Valpantes http://www.valplantes.ch (last accessed 1/11/2021). There have been also records of cooperatives established in the 1990s and early 2000s that did not succeed in becoming economically viable and cease to exist a few years after the attempts to establish them. An example is the cooperative COFIT in Canton Ticino.

and production activities. The three major companies in Switzerland producing and using in their production medicinal plants are: Max Zeller Söhne AG, A. Vogel AG (former Bioforce) and Ricola. The most important local raw material supplier for the herbal medicinal industry is Dixa AG.

Monetary valuation scope

For the monetary valuation of commercially sold medicinal plants as indicator for the NCP Material and assistance, we need to determine a list of the most important plants used in Switzerland for this purpose, and then determine the annual monetary value of selected medicinal and officinal plants and herbs (CHF per ha).

Medicinal, biochemical and genetic resources provide by nature in the wild as NCP can also be perceived as a cultural service through the recreational components of the activity (e.g. berry picking) or even contributing to the cultural identity of the local communities (Tardío et al. 2007; Tardío and Pardo-De-Santayana 2008; Vári et al. 2020). Notably, 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. In this analysis we do not consider these aspects. Instead, we focus on the value of this NCP when it enters the economy as inputs, that is, the economic value capturing the revenues derived from seedlings and medicinal plants sales.

Method and data

As there exist markets for medicinal seedlings, plants and herbs we suggest using a resource rent method, where prices for selected medicinal plants are collected at the point in time when it transitions from the ecosystem to the economy. The data will be requested to companies, such as Ricola. To facilitate the data collection and knowledge exchange, the research team plans to discuss, data and other aspects included in the research related to this NCP with relevant research units at the ZHAW School of Life Sciences and Facility Management, particularly with the Section Natural Product Chemistry and Phytopharmacy, and with relevant Swiss private sector companies. Data related to the resource rent can be used together with, where available, (e.g. by Agroscope) data pertaining Swiss production of such plant species. We suggest focussing the analysis on a sub-sample of wild edible and officinal plants and herbs, identified through experts' consultations and desk research as particularly relevant in the Swiss context.

9. Non-material NCPs

9.1. 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.

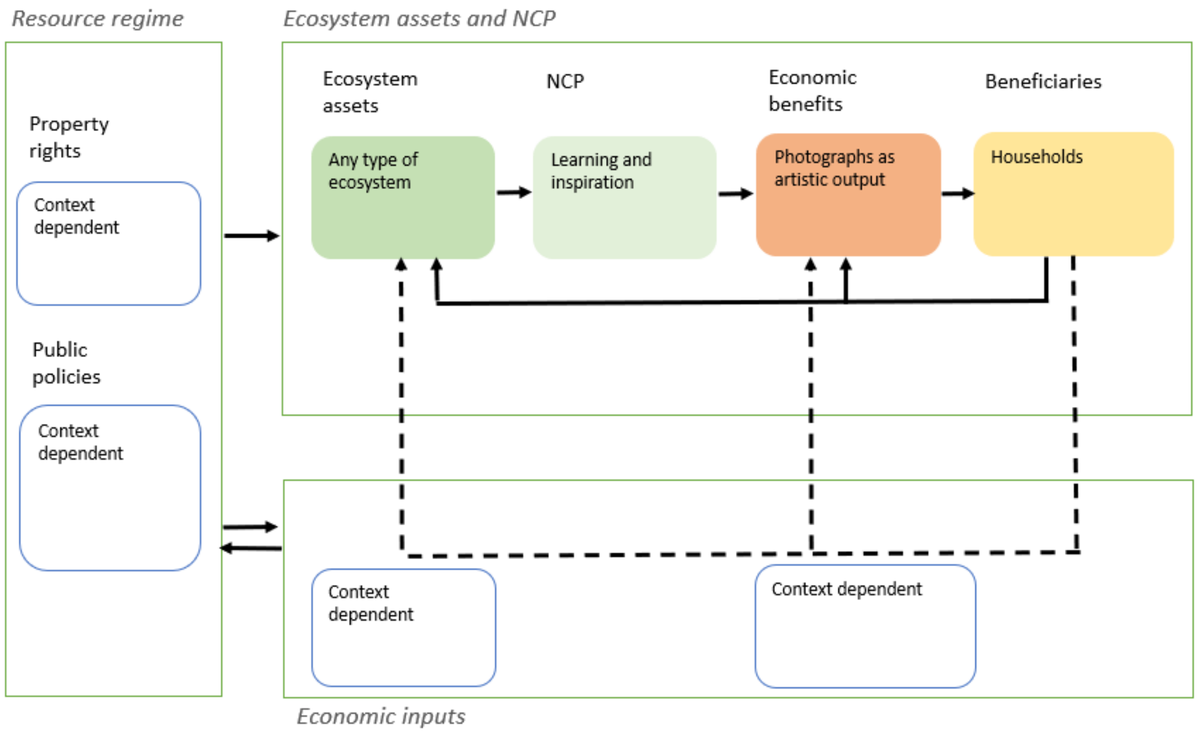

Figure 19: Monetary valuation framework for NCP Learning and inspiration. Source: authors´ presentation

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 (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. Unfortunately, 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.

Method and data

We suggest using Flickr's Application Programming Interface (API) to obtain the number of pictures on the Flickr platform that are geotagged within the parks. For the price information, we will report on prices per picture that can be obtained on sales platforms such as shutterstock, istockphoto, getty-images etc. and will report a price range that a hobby photographer can realistically expect to obtain.

A visitation index based on Flickr data was applied by Alemu I et al. (2021) to project a continuous surface of the probability (0–1) of plant photograph occurrence across a specified area. For a given raster cell, multiplying the probability of photograph occurrence with the price of photographs reveals the expected value of photographs from that raster cell.

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 our valuation exercise, it will be important to closely investigate the available meta-data attached to the pictures and to further develop a method for testing of the representativeness of the sample of people who upload pictures, to the extent that this is possible.

9.2. 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.

The tourism industry in Switzerland is driven by the country's landscapes and nature. Many recreationnal activities that enhance the physical and psychological wellbeing of people are performed outdoor, in the 'natural' environment. The website of the Swiss confederation[56] posits "lakes, forests, mountains and clean air" as Switzerland's most prominent touristic offers to tourists and visitors. The federal statistical office includes both trips without overnight stay, and with overnight stays, when it provides tourism statistics (see e.g. Strauss et al. (2020) and STF (2020)).

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)
- Cablecars 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.

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

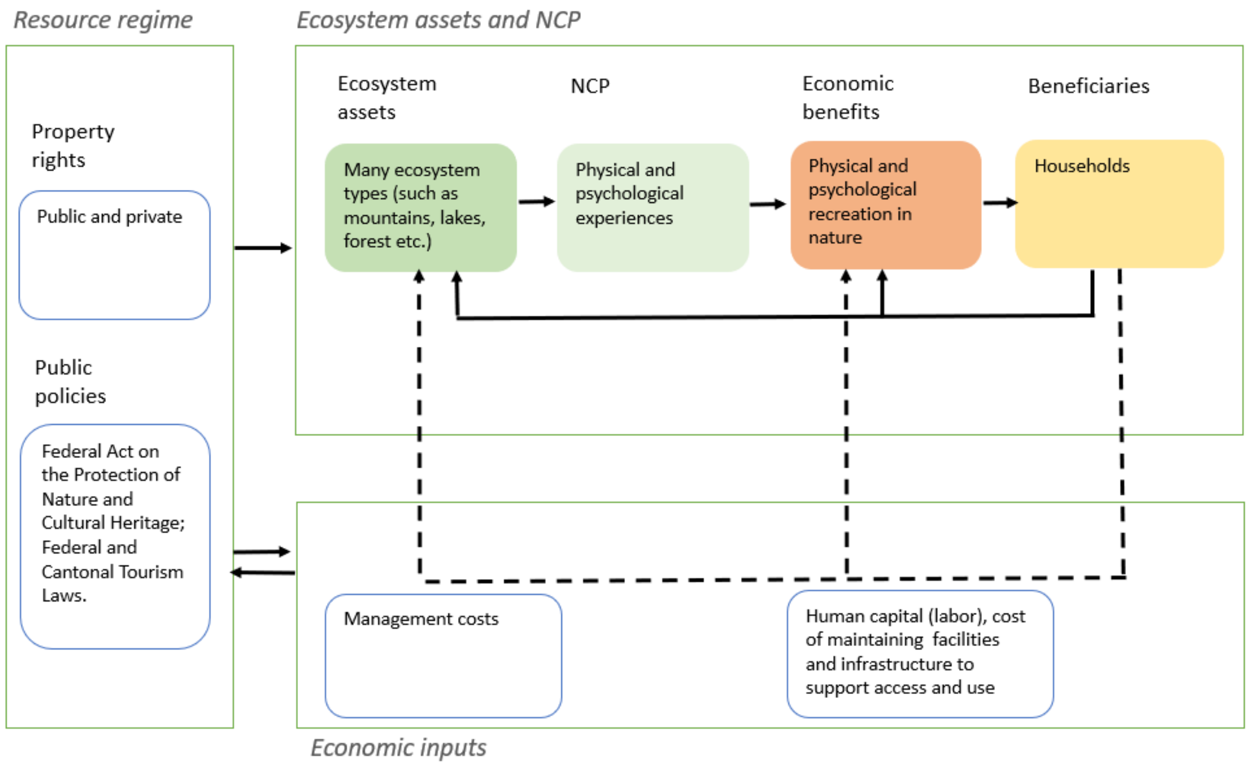

Figure 20: Monetary valuation framework for NCP Physical and psychological experience. Source: authors´ presentation

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.[57]

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 Netherland).

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 transport services generate the largest share (over 25%) of the total revenues accrued by the tourism sector in Switzerland (STF 2020) (**Figure 21**). Transport services include travel to the recreational site by car, train or other means, which involves costs.

[57] 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.

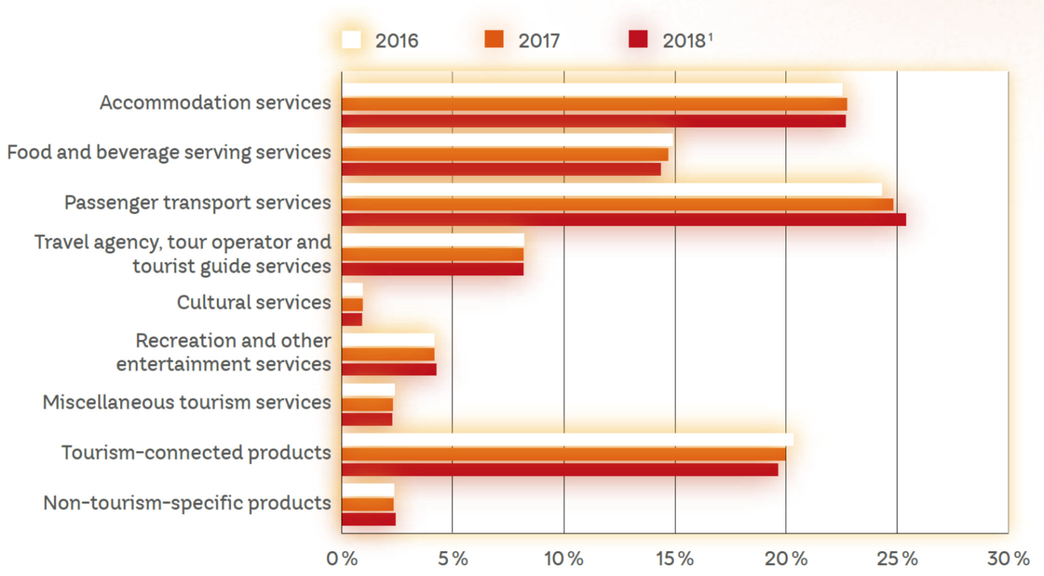

Figure 21: Share of tourism gross value added according to products, 2016–2018. Source: STF (2020)

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). The demand-oriented approach has already been applied in national ecosystem assessments in other countries, such as the UK and The Netherland (ONS 2020; van Berkel et al. 2021). It was also applied in studies analyzing this NCP for Swiss parks [Knaus (2018); Knaus and Backhaus (2014), Backhaus et al (2013); Knaus (2012); Küpfer (2000)].

One way to apply this 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 (e.g. regional parks, as in the case of the mentioned studies). This data collection process would be too costly and time consuming given the scope of the research mandate, hence we suggest relying on secondary data from the latest Swiss National Mobility and Transport Microcensus (2015) (FSO and ARE 2017) and complement this with data from the Swiss Federal Statistical Office, the Swiss Tourism Federation and Swisstopo.[58]

The Swiss National Mobility and Transport Microcensus (2015) is a continuous survey, conducted at equal frequency all throughout the year across the country. This dataset captures information from approximately one percent of the Swiss population about their daily travel behaviour. 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).[59] Of particular interest for our analysis are a sub-set of questions regarding the itinerary and purpose of the trip. We plan to retrieve information about the starting and destination point of the trip and type of recreational activities for which the daily trip is undertaken (e.g. biking, hiking, and other outdoor activities). The level of spatial resolution in this data (for the destination point) allows to calculate transport costs to the municipalities within and nearby the ValPar.CH study parks (Tier 2). The travel costs obtained from the analysis of this dataset will be adjusted for inflation, to proxy the values corresponding to the year 2019. As it is possible to obtain

[58] 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). Since the exact reduction of healthcare costs of various recreational activities are difficult to quantify, they will be not considered.

[59] These are domestic trips only as the Swiss National Mobility and Transport Microcensus does not include information on international trips made to Switzerland by people living in other countries.

data about the kilometers of hiking trails at given locations (e.g. from Swisstopo), we can divide the travel costs by such physical variables at the administrative level of interest (Willibald et al. 2019).

For robustness analysis, this Tier 2 information will be compared to detailed surveys of visitor's expenses for four Swiss Natural Parks in 2017 and 2018: Binntal, Parc Ela, Gantrisch and Jura Vaudois Knaus (2018). The values obtained in this 2018 study will be adjusted for inflation, to proxy the values corresponding to the year 2019 and applied to the ValPar.CH study parks using "benefit transfer" (Plummer 2009). The basic goal of the "benefit transfer" approach is to estimate benefits for a location interest by adapting estimates generated for comparable sites. There are different ways on how the original values can be adapted. For example, existing values for other parks can be adjusted based on expert judgement, or by averaging estimates from existing studies.

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