Deriving monetary values of Nature's Contributions to People: an extended conceptual framework with an application to Switzerland.
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Abstract

This paper builds upon the economic valuation suggested in the United Nations System of Environmental Economic Accounting – Ecosystem Accounting (SEEA EA). In particular, we present the conceptual and methodological framework that can be applied in countries with highly regulated use of and access to natural resources. We apply this framework for deriving monetary values for a number of NCPs in the Swiss context and present a selection of estimates

Keywords Monetary valuation, exchange values, SEEA, Switzerland

JEL code Q51 Valuation of Environmental Effects

1. Introduction

During the past decades, different branches of literature on economic valuation of ecosystem services (ES), or nature's contributions to people (NCPs), emerged that seek to communicate the value of biodiversity and natural capital into mainstream political processes (Gómez-Baggethun und Ruiz-Pérez 2011). A comparatively recent approach used in the valuation literature to measure NCP's economic benefits is the derivation of exchange values. This approach is mostly being developed and applied in the framework of the United Nations System of Environmental Economic Accounting (SEEA). Recent applications include Horlings et al. (2020b), Scottish government (2020) and many more as reviewed in Hein et al. (2020). Exchange values serve to include NCP values into countries' systems of national accounts to compute adapted forms of gross domestic product (GDP). Including monetary NCP values into GDP is a step toward measuring 'inclusive wealth', which will allow to assess the sustainability of economic development (Dasgupta 2021).

In countries with highly regulated access to natural resources, the observable market prices or exchange value estimates for NCPs may often be distorted or even negative (Edens und Graveland 2014). If not addressed, there is risk that distorted and/or negative values are not included in national SEEA accounts concealing the NCPs' contributions to GDP. In this paper, we distinguish between different reasons for such distortions and propose an expanded framework to identify distortions and to correct for them in the estimation of exchange values.

Previous literature on exchange values relates to ES whereas we use the NCP terminology which is better apt to include diverse worldviews (Kadykalo et al. 2019). The Millennium Ecosystem Assessment defined Ecosystem Services as "the benefits people derive from ecosystems". Since the release of this assessment, ES have been used to characterize a rather broad range of contributions to human wellbeing directly or indirectly through the conditions and processes of natural or semi-natural ecosystem-functioning (Kadykalo et al. 2019). NCPs are a related concept introduced in 2017 by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The IPBES defines NCPs as 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).

When estimating exchange values for the purpose of expanding the scope of GDP measurement, the valuation methods for NCPs need to be aligned with the GDP concept. This means that market prices should be used whenever possible (SEEA 2021). When they are not available, as often is the case for NCPs, so-called exchange value estimates that conceptually come close to market prices can be used. Under free market conditions, market prices or exchange value estimates reflect NCPs' contributions to the economy.

The concept of exchange values refers to the theoretical notion of an exchange happening for an NCP 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). However, exchange values are restricted because they do not provide a broad monetary value including all direct and indirect benefits received from ecosystems including their non-use values. Non-use values arise directly from the existence of natural systems and species even in the absence of current and/or future direct use or consumption (Turner et al. 2003). Use values refer instead to current or future (option) uses and can be both direct and indirect. Indirect use values capture the ways that people benefit from something without necessarily directly seeking it out (e.g. flood protection) (Pascual et al. 2017). Thus, this approach does not provide a *comprehensive* monetary value of well-being (SEEA 2021).

We contribute to the debate by expanding the exchange value framework developed by Horlings et al. (2020) to include elements of the Institutional Resource Regime (IRR) (Gerber et al. 2009; Lieberherr et al. 2019). In particular, we propose to expand on any public policies governing the ecosystems and NCPs under consideration and the prevailing allocation of property rights. This has two advantages. Firstly, it allows to identify the reasons for any distortions to market prices or exchange value estimates. This can considerably help disentangle overlapping resource regimes that can give rise to double counting issues. Secondly, it provides guidance on how to correct for monetary valuations of distorted and negative NCP values.

We demonstrate the application of our expanded framework to the monetary valuation of three NCPs in Switzerland: pollination, ‘food and feed’, and ‘material and assistance’. In Switzerland, the Federal Statistical Office will soon start developing its SEEA accounting methodology, which makes a case for using Switzerland as a study country. Moreover, market distortion limiting competition is an issue in Switzerland, that is not least due to public ownership (OECD 2019).

In the following section, we present our suggestion for an extended exchange value framework. In sections three and four we present methods compatible with the exchange value approach and the results of our empirical application of the framework to the monetary valuation of three NCPs in Switzerland.

2. Extended framework

The backbone of the ecosystem accounting framework presented in UN DESA (2019) and depicted in Horlings et al. (2020b) is given by the chain of links between ecosystem assets, NCPs, economic benefits and beneficiaries that make use of these benefits. The top right box in Figure 1 contains this chain. Understanding these relations is important because NCPs can be valued using economic valuation methods at the point when they start to benefit society and the economy.

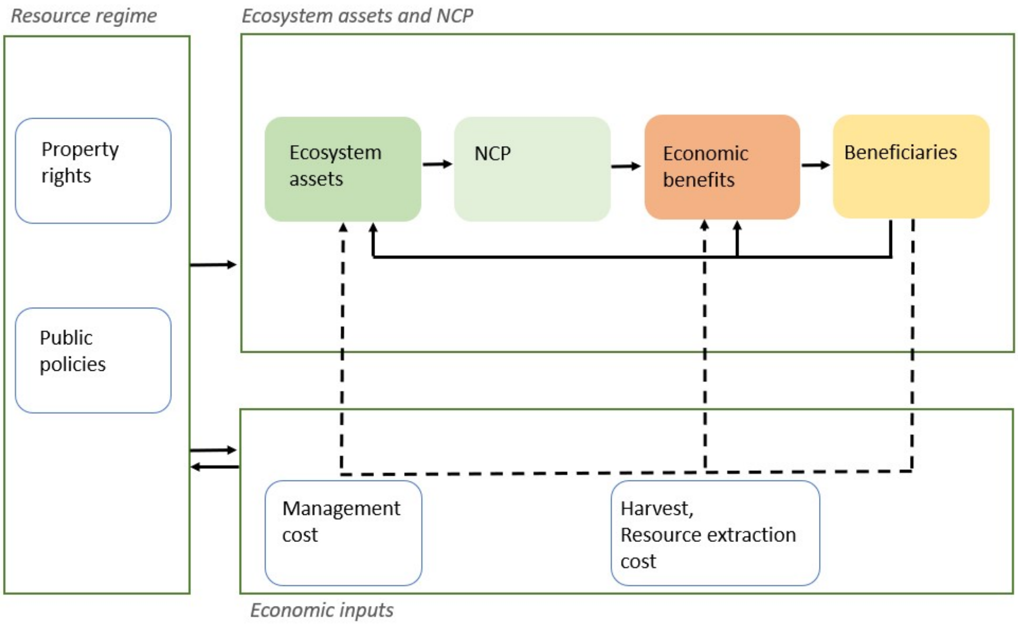

Figure 1. NCP economic valuation framework. Source: authors´ elaboration building on UN DESA (2019), Horlings et al. (2020), Gerber et al. (2009) and Lieberherr et al. (2019).

Economic inputs e.g. some forms of human or material capital are often required for both managing ecosystem assets as well as generating economic benefits from NCPs. 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 1, 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'.

We suggest extending this framework with a consideration of the prevailing resource regime, as depicted by the box on the left side of Figure 1. The modes of managing ecosystems, generating economic benefits from NCPs and distributing benefits among beneficiaries, are often shaped by formal institutions and property rights. This is particularly relevant in highly regulated contexts. 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).

The analysis of property rights and public policies can help detect overlaps of resource regimes for several NCPs. This is particularly relevant when governmental payments, e.g. direct payments in agriculture, form a part of, or all of, the exchange value of an NCP. To avoid double counting, it needs to clearly be laid out how much of the payment is attributed to which NCP.

Moreover, an analysis of the IRR helps detect distortions. Distortions can for example arise from border protection which can push prices up or down, depending on the political intention. Goods and services subject to border protection then display a national market price that is higher or lower than the global market price. Beyond this, there is a second type of distortion in the sense of a policy-induced discrepancy between national and global market prices. It can arise when products placed on the global market are produced unsustainably with negative externalities that are not reflected in the products' prices whereas national legislation stipulates sustainable production methods that result in higher production costs. If there is no separate market for the sustainably produced products, major discrepancies in profitability arise that can result in negative exchange values. Often these discrepancies are cushioned by countermeasures such as e.g. subsidies, trade restrictions and tariffs. We argue that corresponding residual value estimates in the computation of exchange values can and should be adjusted for the value of relevant public spending per unit of resource under consideration.

3. Methods (to be shortened)

We present in this section the application of the expanded framework to three selected NCPs (food and feed, pollination and material and assistance), and discuss the adjustments needed to derive the exchange value given the resource regime framework.

3.1. Food and feed

In many industrialized countries, agriculture is a highly subsidized sector. Agricultural producers´ support typically forms a large share of gross farm income. For example, according to the OECD Agricultural policy monitoring and evaluation 2021´s report (OECD, 2021), this share is around 50% in Switzerland, that means that almost one of every two francs of Swiss farms´ gross receipts originate from public policies.[1] Consequently, as long as agricultural producer´s support presents an important source of farm income, it cannot be excluded that farmers´ revenues from marketed products will be covering farms production costs. Under these circumstances, it can happen that applying the resource rent approach or the residual value approach for deriving monetary value of the NCP Food and feed may result in negative estimates.

Resource regime

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. Within this policy setting, the following seven types of direct payments

[1] Although direct market price support has steadily reduced in many OECD countries during the last two decades, it still plays an important role in a number of them.

are provided to Swiss farmers under the current agricultural policy framework – AP18-21 : (i) Payments for ensuring food supply, (ii) Contributions for open landscapes, (iii) Biodiversity payments, (iv) Contributions to landscape quality, (v) Contributions for organic and extensive production systems, (vi) Contributions for efficient use of resources and (vii) Transitionary payments.

An evaluation of the relevance of the current border protection regime for agriculture in Switzerland (Gray et al. 2017) has shown that border protection is a relatively inefficient and expensive policy instrument because it does not specifically promote services that are demanded by the society (such as e.g. environmental services, animal welfare, decentralized settlement). Consequently, the OECD (Gray et al. 2017) recommends several alternative policy measures that may provide more targeted contributions to achieving the constitutional goals. 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, currently it is not foreseeable, whether and when policies proposed by the OECD or other significant reforms in agriculture will be adopted and implemented in Switzerland. Additionally, assessing the impact of a potential abolition of the border price adjustments´ mechanism on domestic producers´ prices and the country´s GDP would require applying a general equilibrium modelling framework. In this context, we suggest to conduct the economic valuation of the NCP Food and feed taking into account the current agricultural policy framework and within a partial equilibrium context that does not account for price differentials that exist for certain food and feed products compared to respective border prices.

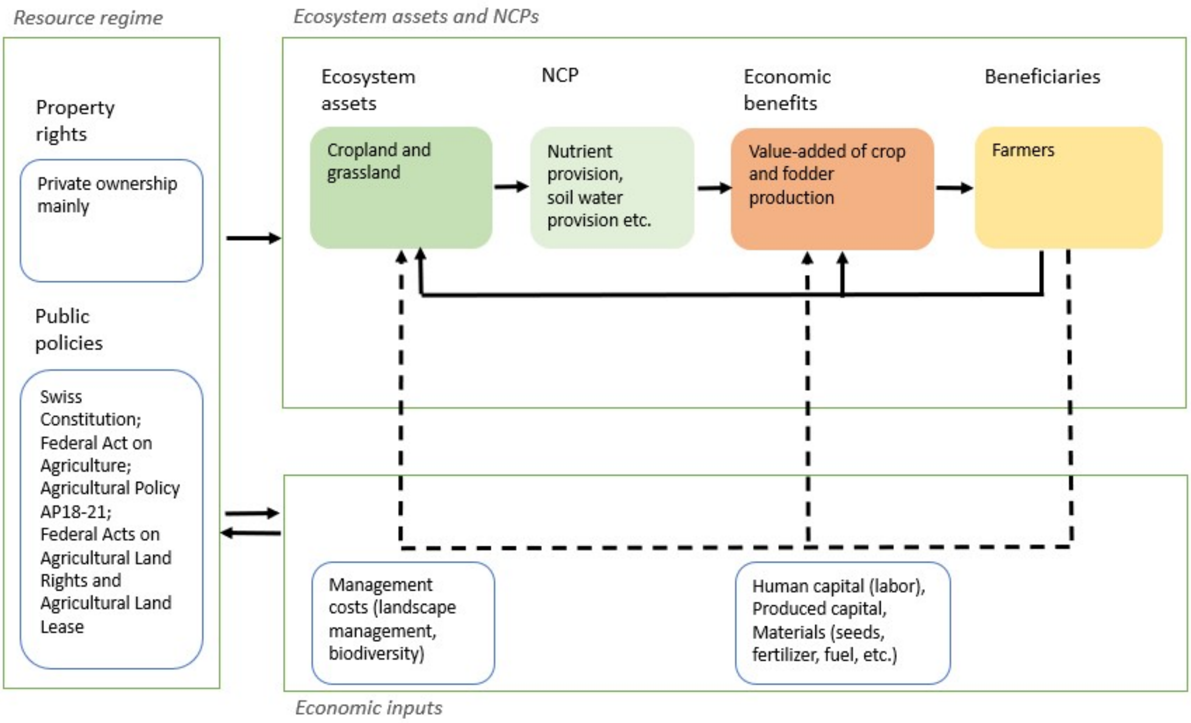

Figure 2: Monetary valuation framework for the NCP Food and feed. Source: authors´ presentation.

The two important legal acts regulating agricultural land use are the Federal Act on Agricultural Land Rights and the Federal Act on Agricultural Land Lease. To prevent overshooting of rental prices, agricultural land rental prices are capped in Switzerland. The Ordinance on the Agricultural Rent Assessment and the Guidance on the Estimation of the Agricultural Yield Value 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 farmland of similar quality. Under a competitive rental land market, marginal contribution of land to agricultural output (marginal product of this production factor) should coincide with rents paid for corresponding land parcels.

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

Monetary valuation scope

Due to market failures and also policy interventions aimed at addressing the earlier, land and other production factors´ prices may deviate considerably from their marginal productivity. Under these circumstances, production factor prices such as rental prices for agricultural land might be inadequate measures of factors´ marginal contributions to final 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, Horlings et al. (2020) suggest using the rental price method and accordingly to proxy the farmland contribution to production of food and feed by farmland rent prices. However, as shown by a number of theoretical and empirical studies (Gardner 1983; Breustedt und Habermann 2011; Ciaian und Kancs 2012; Ciaian et al. 2018) agricultural subsidies can be capitalized in land prices and significantly increase farmland prices. That fact suggests that farmland rental prices may not necessarily reflect adequately marginal land productivity. Taking into account the two aspects discussed above, we propose to value the NCP Food and feed using the production function method that should allow us to derive marginal products for all factors used in the production including farmland.

Method and data

The application of the production function method enables deriving marginal product for production factors under consideration. 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 specific production factors can be considered as implicit or shadow prices for respective factors applied by farmers when making their production decisions. Furthermore, 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 using the FADN data at farm-level, 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 in 2015 and accordingly are less suited for a statistical analysis.

The ecological cross-compliance regulations in Switzerland put constraints on production practices used by Swiss farms and hence also on (short-run) agricultural land productivity. In this context, direct payments and border protection measures may present not necessary most efficient but nevertheless important instruments aimed at overcoming market failures. In particular, by compensating farmers for the efforts/costs that might be not paid by consumers/markets in the presence of market failures, they incentivize farmers to adopt/use more sustainable production practices. Although subsidies and market price support measures may overpay farmers for complying with regulations, it might be still reasonable to take into account 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 Swiss Federal Office for Agriculture (FOAG) maps of climate suitability and soil suitability. 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 were possible by applying the resource rent approach.

3.2. Pollination and dispersal of seeds

The IPBES (Brauman et al. 2019) defines "Pollination and dispersal of seeds and other propagules" 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. It is important to consider this aspect when conducting the monetary valuation of several NCPs. For example, the role of pollination and dispersal of seeds in the production of agricultural products could lead to double counting issues, if this was included in both the monetary evaluation of the NCP pollination and dispersal of seeds as well as one of the inputs in the production function of the NCP Food and feed.

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 strongly regulated and 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. The resource regime relevant to forests is also of importance for this NCP.

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.).[2] 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

[2] 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).

significantly higher pollinator community compared to farms without ecological compensation areas (Albrecht et al. 2007).

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

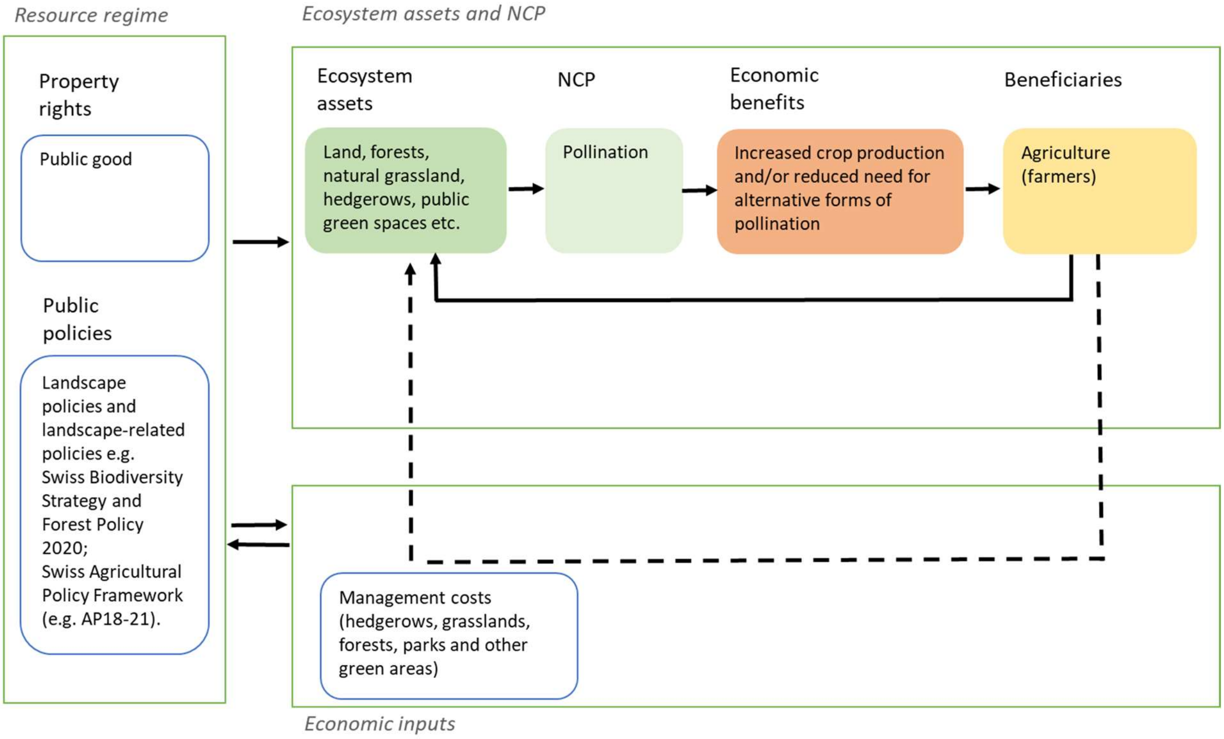

Figure 3: Monetary valuation framework of NCP Pollination, Source: authors´ presentation

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.[3] 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.

[3] 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.

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 wild 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 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). Again, these aspects should be considered when deriving the monetary values of both the NCP pollination and dispersal of seeds and the NCP food and feed as they may lead to double counting issues. 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 und Albrecht 2016).[4]

Monetary valuation scope

The literature estimating the monetary value of pollination and dispersal of seeds 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 etc.). Therefore, the production function approach is one of the most used valuation method for this NCP (Freeman 2014; Hein 2009; Ricketts et al. 2004).

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 to focus on wild 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, wild 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

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

meteorological conditions than honey bees (e.g. with moderate rainfall). This is an important aspect considering the climate and topological conditions in Switzerland. Also, there are crops for which wild pollinators cannot be replaced by honey bees, 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).

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 recent study by INFRA (2021) applies this method in the context of Swiss agricultural production. If these alternative ways to obtain the same benefit were highly subsidized, such interventions could distort the results of monetary valuation methods based on these replacement costs.

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 (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 und 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). The results will then be validated/discussed in light of the forthcoming results (monetary ranges) by INFRAS (2021).

Table 1: 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	Captures benefits across different crops; Captures producer welfare; Applicable at all scales; Minimal	Estimates only producer benefits; might generalise across crops; Does not account of other inputs to crop	Klein et al. (2007); Sutter et al. (2017a)

	there would be no pollination)	data requirements; Comparability with previous studies conducted for Switzerland	production, hence it may overestimate benefits; based on global assessments stemming from literature reviews and expert consultations	

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

Table 2: 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	Large	1004	231343	150.97
Colza	Modest	752	93945	17.66
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 to assign to crops produced in Switzerland the five classes of pollination dependence, based on the categories defined by Klein et al. (2007). In their study, Klein et al, (2007) determine the dependence of crops for pollination on the basis of the expected yield losses in absence of wild pollinators. Pollination by honey bees is not considered. 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. large, iii. modest or iv. low, to crops that v. do not depend at all on pollination (Table 3). 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 wild 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 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 3: 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. Large	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.

In order to estimate the value of the NCP we further need the production quantities for each selected crop, and the producers' price by crop. As explained above and in the description of the NCP food and feed, these prices may be affected by policies. In turn, these may distort the analysis and final monetary results obtained for the evaluation of this NCP. 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 to use 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 4 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 4: 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	Large: 65%	1,066	189,726 (50.78)	131.46	35,188	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.

3.3. Material and assistance

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

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).

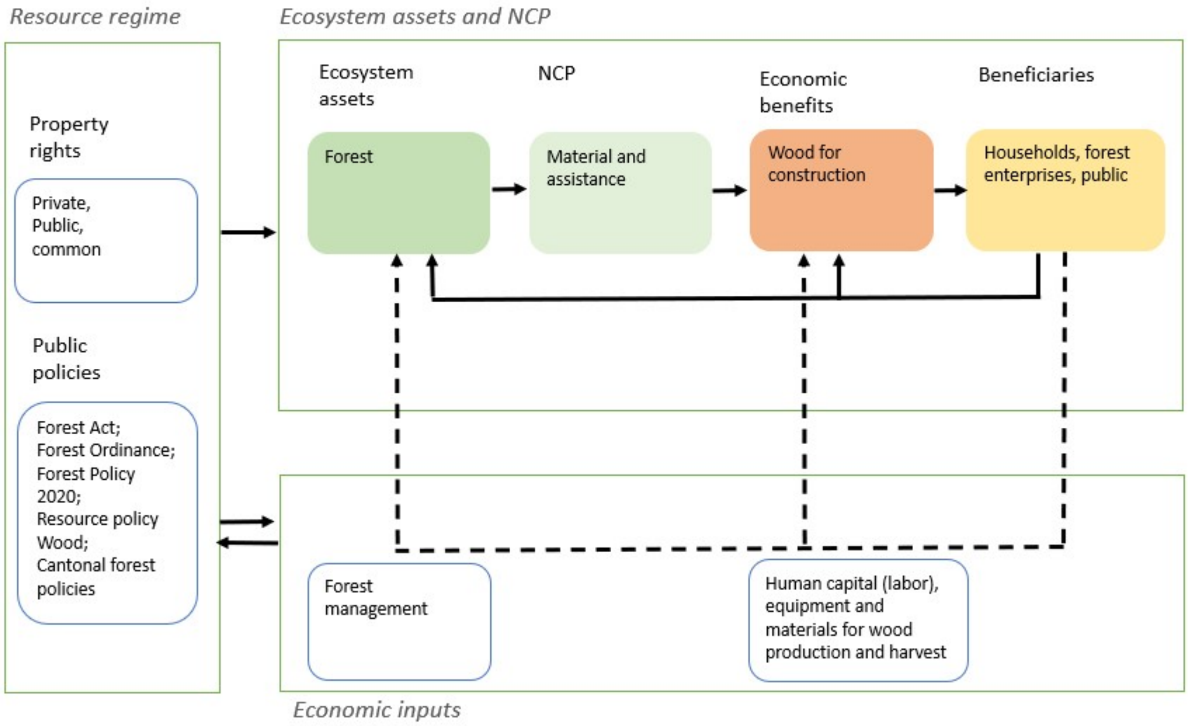

Figure 4: Monetary valuation framework for NCP Regulation of freshwater quantity, location and timing. Source: authors´ presentation

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. Considering the fact that 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 (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 m3) 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).

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 issue, we propose to derive an alternative estimate of the exchange value for construction wood. In particular, we suggest to adjust 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.

4. Results

5. Discussion

6. Conclusion

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