Forest Policy and Economics 129 (2021) 102511

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Clearing forests to make way for a sustainable economy transition in Switzerland

David Troxler [a,b,*], Astrid Zabel [c]

[a] School of Agricultural, Forest and Food Sciences (HAFL), Bern University of Applied Sciences, Zollikofen, Switzerland
[b] Planning of Landscape and Urban Systems (PLUS), ETH Zürich, Zürich, Switzerland
[c] Centre for Development and Environment (CDE), University of Bern, Switzerland

ARTICLE INFO

Keywords:
Green economy
Bioeconomy
Forest clearances
Sustainable economy
Switzerland
Circular economy

ABSTRACT

While many countries around the world are advancing their efforts to transition to more sustainable economies, it is important to be aware of goal conflicts that can be induced by these transition processes. In this paper we focus on land use, especially forest clearances to provide space for transitions in other sectors. The key questions for our empirical case study in Switzerland are: 1) to what extent forests are being cleared to advance sustainability transitions in other sectors and 2) whether pressure on forest area is higher in the Central Plateau than in other parts of the country. We build a conceptual framework based on existing literature that allows us to identify overlaps and differences between three sustainable economy transition concepts (i.e. green, bio- and circular economy) and apply the framework to our data on forest clearances. Our analysis is the first empirical assessment of the Swiss national forest clearances database. In this paper, we included the records of all forest clearances in Switzerland from 2001 to 2017.

The analysis revealed that overall, 14.5% of the clearances in the database are attributable to the sustainable economy classes defined by our framework. 'Transportation', 'energy and lines', and 'waste disposal and recycling' are the three clearance categories that harbor most sustainable economy related clearances. Inspecting the data over time, we identified a trend towards more green economy related clearance reasons in the Plateau and in the Alps. Related to our second question, the data analyses revealed that the pressure, measured as absolute clearance area (definitive and temporary) as well as clearance area relative to the regions' forest area, is higher in the Plateau than in other regions. It was not possible to identify a trend in terms of clearance area over time. Our results should enable future discussions of forest clearances to be more nuanced, especially to take into account regional contributions to the sustainable economy transition.

1. Introduction

Global society is facing numerous environmental challenges and the state of the environment is continuing to deteriorate in many respects (Rockström et al., 2009; Steffen et al., 2018; UNEP, 2019). At the international level, the mode of responding to environmental problems has shifted from rather narrow, sector specific environmental agreements to wide-ranging inclusive frameworks for which prominent examples are the Sustainable Development Goals and the Paris Agreement (UNEP, 2019). This trend towards broader solutions is reflected in the cross-sectoral nature of many countries' ongoing efforts to advance in transitioning towards green, bio- and circular economies. Although these cross-sectoral sustainable economy approaches can benefit from synergies between sectors, there are also risks of unintended goal conflicts between sectors giving rise to unforeseen negative effects (DeBoer et al., 2020). The body of literature discussing the bioeconomy and its competition for agricultural land is substantial (Böcher et al., 2020; Dietz et al., 2018; Hertel et al., 2013; O'Brien et al., 2015). We expand the literature on goal conflicts by empirically investigating to which extent forests are cleared to make way for a sustainable economy transition, using data from Switzerland as a case study.

Forests are important elements of the green, bio- and circular economy approaches and can contribute to achieving transformational change in many ways. Forests sequester carbon, they provide construction material and biomass that can be used to substitute for less environmentally friendly building materials and fossil fuels, or as inputs

* Corresponding author at: School of Agricultural, Forest and Food Sciences, Bern University of Applied Sciences, Länggasse 85, 3052 Zollikofen, Switzerland.
E-mail address: david.troxler@bfh.ch (D. Troxler).

https://doi.org/10.1016/j.forpol.2021.102511
Received 19 June 2020; Received in revised form 8 April 2021; Accepted 9 May 2021
Available online 20 May 2021

to chemical processes (Ollikainen, 2014; Toppinen et al., 2020). However, there is a risk that forests are cleared to provide space for another sector's efforts to transition to a green, bio- or circular economy. Often these effects between sectors are indirect and empirically difficult to prove. While most of this literature relating to forests refers to developing countries (Andrade de Sá et al., 2013; Meyfroidt et al., 2013), an open question is to what extent forests in Europe are cleared to give way to sustainability projects in other sectors.

This paper contributes to the debate by empirically investigating which quantities of forest areas are removed to provide space for green, bio- and circular economy projects as well as their proportion in relation to other clearance projects. Apart from these numbers, we provide a more fine-grained analysis to assess differences between regions and the development over time. However, it is important to note that in Switzerland there is an obligation to compensate for most forest clearances so that the absolute forest area, which is increasing anyway, is not markedly reduced by clearances.

A subordinate question that we address relates to a hypothesis, which is being put forward by members of the Swiss civil society, stating that pressure on forests is increasing especially in the Central Plateau area of Switzerland (Bader, 2014; Baumgartner, 2011; Thönen, 2013). Using clearances as indicator for pressure, we investigate whether it is possible to empirically corroborate this hypothesis.

In this paper, we provide the first empirical assessment of the Swiss national forest clearances database which contains records of all clearances and their reasons in Switzerland from 2001 to 2017. Describing this data through the lens of the sustainable economy literature allows us to quantify the number of projects, spatial extent and distribution of forest clearance permits that were granted to advance sustainability projects in other sectors. A sound understanding of these sustainable economy goal conflicts in terms of trends and regional differences is expected to serve as basis for future policy developments in Switzerland, but also more generally for other countries with high competition for land. Thus, this paper seeks to raise awareness that efforts towards a sustainable economy can give rise to tangible land-use tradeoffs affecting forests and that it is therefore essential to quantify these impacts.

The remainder of the paper is organized as follows: the conceptual framework is presented in section 2, section 3 provides the background on the case study, section 4 describes methods and data, section 5 presents the results and finally section 6 discusses the results and offers conclusions.

2. Conceptual framework

Strategies supporting the transition to green, bio- or circular economies are on the rise throughout Europe, the Americas and several countries in Asia (Bugge et al., 2016; German Bioeconomy Council, 2018). Many advantages are attributed to these concepts including reducing carbon dioxide emissions and reliance on fossil fuels, job creation through new business opportunities and stimulated economic growth, fostering innovation and research, as well as an avenue for promoting the forest sector as component of a greener future (Dupont-Inglis and Borg, 2018; Hodge et al., 2017; Imbert et al., 2017; McCormick and Kautto, 2013). Apart from these advantages, potential risks have also been discussed in particular referring to competition between different resource use interests and over-use of natural resources to the detriment of non-marketed ecosystem services (Hodge et al., 2017; Imbert et al., 2017; Kleinschmit et al., 2014; Lindner and Suominen, 2017).

To build a framework for the classification of reasons for forest clearances, we discuss definitions of green, bio-, and circular economy concepts and highlight their distinctions and overlapping aspects. For the purpose of this paper, we build on previous comparisons of these concepts, e.g. D'Amato et al. (2017), and discuss them in light of the forest specific literature.

According to the definition by UNEP "a green economy is one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). A definition provided by the Swiss Federal Office for the Environment is "Switzerland understands a green economy as one that takes the scarcity of limited natural resources and the regeneration capacity of renewable resources into account, enhances resource efficiency, and hence boosts the overall performance of the economy and quality of life" (FOEN, 2016). Ollikainen (2014) argues that setting an efficient price for carbon is an encompassing element of the transition to a green economy that will bring about major changes for all sectors of the economy. Although the green economy concept is clearly broad, it premises that the transition to a trajectory of green growth will build on the three pillars of sustainability, namely economy, society and ecology.

The bioeconomy concept emphasizes the substitution of non-renewable resources with efficient, high-tech transformations of renewable resources in particular biomass, which ascribes an important role to forestry and agriculture as biomass suppliers (Kleinschmit et al., 2014; Ollikainen, 2014; Pelli et al., 2017). For example, Dupont-Inglis and Borg (2018) argue that there is potential to source 100,000 chemicals currently in production from renewable inputs.

In the bioeconomy literature, innovation and technological progress are stated to be of key importance for economic growth, while social and ecological considerations often are of secondary importance (D'Amato et al., 2017; Pülzl et al., 2014). However, recently this is increasingly being criticized and suggestions are made to more prominently include environmental and social considerations to avoid losing societal support (Aguilar et al., 2018). For example, Bugge et al. (2016) develop the idea of a "bio-ecology vision", a version of the bioeconomy concept, which gives much weight to biodiversity and ecosystem conservation.

The circular economy in turn focuses largely on recycling and reducing the environmental impact of products' life cycles (D'Amato et al., 2017). In practice this can e.g. mean ending landfilling for paper and other recyclable biowaste, promoting cascading resource use and bio-degradability (Patermann and Aguilar, 2018; Sikkema et al., 2017).

The circular bioeconomy concept is a combination of the two former concepts. The relationship between them is viewed differently, either as overlap between the two concepts, as bioeconomy integrated into the circular economy or as something larger that is embracing the two concepts (D'Amato et al., 2020; Stegmann et al., 2020). In short, Stegmann et al. (2020) suggest the following definition: "The circular bioeconomy focuses on the sustainable, resource-efficient valorization of biomass in integrated, multi-output production chains (e.g. biorefineries) while also making use of residues and wastes and optimizing the value of biomass over time via cascading." Furthermore, they put forward that this optimization can or even ideally should build on the three pillars of sustainability. However, it is not a condition that the pillars of sustainability are considered in a balanced way. In the circular bioeconomy literature, indeed social aspects are less frequently referred to than economic and environmental aspects (D'Amato et al., 2020; Falcone et al., 2020; Stegmann et al., 2020). In the green economy concept, which harbors many aspects of the bio- and circular economy ideas, promoting or at least maintaining social and ecological safeguards is a precondition. Subsets of the bioeconomy, circular economy, and circular bioeconomy solutions that bear social or ecological trade-offs are thus not coherent with the green economy concept.

This leaves us with three distinct concepts – the 'green economy', the 'bioeconomy' and the 'circular economy', as well as four overlapping concept spaces – the 'circular bioeconomy', the 'green and bioeconomy', the 'green and circular economy' and the 'green and circular bioeconomy'.

For the empirical analysis of our Swiss case study, we apply this framework to classify the reasons for forest clearances. We add an eighth class 'none' to group all forest clearances that are not related to any of the individual or overlapping concepts of interest.

3. Case study

In Switzerland forests are strongly protected. Indeed, the Forest Act prohibits forest clearing (ForA; SR 921.0). This general ban on forest clearances dates back to 1876 for mountainous regions and was expanded to the entire country in 1902. Historically, it emerged from an immediate need to avert natural disasters (Mather and Fairbairn, 2000; Schulz and Lieberherr, 2020). Today the Forest Act stipulates that the forest is to be conserved in its area and spatial distribution. In its current version, it also emphasizes the need for sustainable management to ensure that the forest can fulfill its protective, social and economic functions.

3.1. Legal context

As there is generally no rule without exception, permission for forest clearances may be granted under well-defined conditions. For our empirical analysis below, it is important to understand the legal context of the exceptional clearances.

Forest clearing is defined as an either temporary or permanent change of use of forest land for non-forestry purposes. This change in land-use can be purely administrative, i.e. some forest clearances do not involve the clearing of a single tree (Keel and Zimmermann, 2009). The conditions under which permission can be granted are: (1) the reasons are important enough to outweigh the interest of forest conservation, (2) location-dependency, (3) spatial planning requirements must be fulfilled, and (4) the clearance poses no significant threat to the environment (ForA; SR 921.0). However, forestry-related buildings and facilities as well as non-forestry small buildings or facilities are exempted from the definition of forest clearances according to the Forest Ordinance (ForO; SR 921.01). The latter are instead considered as *detrimental uses* according to the ForA (Keel and Zimmermann, 2009). Moreover, clearances in the legal sense should not be confused with clear-cutting, which is also prohibited in Switzerland. Clear-cutting involves just a change in land cover and not a land-use change (ForA; SR 921.0). Apart from a few rare exceptions, cleared forest land must be compensated through afforestation in the same region (ForA).

3.2. Competition for land

The revision of the Federal Spatial Planning Act in 2013 strengthened the protection of agricultural land to, among other things, curtail the high rates of land conversion. In the Central Plateau area, 5.6% of former agricultural land was lost from 1985 to 1990 (FSO, 2015). With the ongoing population growth and changes in lifestyle, the demand for space to develop settlements and infrastructure remains high. There increasingly are voices that contest the strong protection of forests and call for more parity in the protection of agricultural and forest land, arguing that it is not reasonable for forest land to be better protected than agricultural land given that the net forest area is increasing while agricultural land is continuously being lost across the country (Baumgartner, 2011; Ettlin, 2018; Giuliani et al., 2002; Grêt-Regamey et al., 2018). Moreover, both the Federal Forest Act, which was amended in 2016, and the revised Federal Energy Act, which entered into force in 2018, greatly facilitate the granting of permission to construct and expand infrastructure for renewable energy generation in forests.

In parallel to these developments, concerns over an increasing pressure on forests have been raised. In particular, the forest area of the Swiss Central Plateau is often said to be under pressure (Bader, 2014; Baumgartner, 2011; Bugmann, 2014; Griffel, 2019; Griffel, 2012; Leugger-Eggimann, 2014; Pütz and Bernasconi, 2017; Rigling et al., 2015; Thönen, 2013; Ulber, 2013). National statistics indeed show that forest cover is expanding in the mountain regions of Switzerland while the forest area in the Central Plateau has remained fairly constant during the past two decades (see Fig. 1) (FSO, 2018). However, until now there is no empirical data to help understand the developments in the Central Plateau in detail. Our research addresses this gap by comparing whether values on indicators of pressure are higher in the Plateau than in other regions.

4. Method

The main data source for our analysis is the forest clearance database maintained by the Federal Office for the Environment (FOEN). It provides information, among other things, on: the year of authorization, project descriptions, and clearance reasons loosely divided into 60 subcategories. Given that clearance projects can include multiple clearance sites, the database also contains municipality names, clearance areas (temporary, definitive) as well as coordinates for every site. For roughly 35% of the clearance projects, there is some additional information available that helped to reveal projects that are in discord with nature and landscape conservation goals. The clearance projects in the database were all authorized, but not necessarily executed. For our analyses, we used the data from 2001 to 2017 with a total of 6108 projects.

4.1. Clearance categories

For reasons of tractability, we grouped the clearance projects into nine distinct categories. Table 1 provides details on their composition. Many projects are, of course, multidimensional and incorporate characteristics of more than one clearance category. For example, although

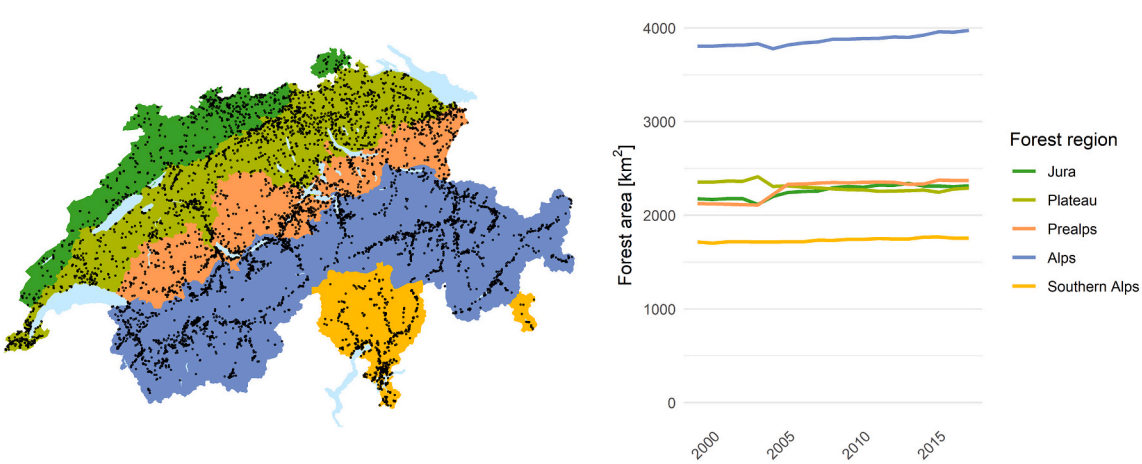

Fig. 1. Map of Switzerland with coordinates of the forest clearances between 2001 and 2017 partitioned into forest regions. On the right, a corresponding chart showing the development of forested area by region over time.

Table 1
The composition of the nine main categories of clearance reasons.

Clearance categories	Clearance subcategory titles
Water supply	Reservoirs; water pipelines
Water construction	Hydro-engineering measures; bedload collection sites; water renaturalizations; storm-water runoff; stream and lake regulation
Quarry sites	Quarries for extracting gravel, sand and stone; gravel extraction from waterbodies
Waste disposal and recycling	Landfills for inert matter; wastewater treatment plants; sewer pipes; waste incineration plants; waste sorting sites; residue landfills; landfills for reactor waste; interim storage sites for hazardous waste
Energy and lines	Hydropower plants; power lines; long-distance heat pipelines; fiber optic cables; gas and petroleum pipelines; facilities for geothermal energy; woodchip / pellet heating facilities; facilities for the exploitation of petroleum, gas and charcoal; gas plants; storage sites for gas and petroleum; thermal powerplants; other lines, cables and pipes
Transportation	Main roads with federal support; other main roads; national roads; other roads; new railway lines; railway sidings; other railway constructions and -extensions; airports; helicopter airfields; airfields; public transportation harbor; boat harbors; other traffic facilities
Constructions	Private construction zones; larger public constructions; industrial businesses; facilities for livestock; sports stadiums; shopping centers; parking houses and parking lots; permanent and mobile antenna installations; cargo handling facilities/ distribution centers
Sport and Tourism	Ski slopes; ski lifts and aerial cableways; artificial snow systems; golf courses; fun parks; motorsports tracks; other sports facilities
Miscellaneous	Biotope ameliorations; biotope renaturalizations; land ameliorations and agricultural land; forest land consolidation and forest development; 300 m shooting ranges; military artillery ranges; military airfields; military vehicle fleets; other military facilities; other

some hydroelectric power plants have certain 'water construction' features, they clearly belong to the 'energy and lines' category. Another example in the 'water supply' category is a clearance for a water pipe with an associated drinking-water power plant that could also be categorized as 'energy and lines'. However, the vast majority of drinking-water pipelines are built for drinking water supplies, where their slopes might also be used for energy production only as a by-product. In such cases, the predominant use was decisive for categorizing.

For the spatial comparison, we refer to Switzerland's five forest regions: Jura, Central Plateau, Prealps, Alps and Southern Alps. For the visualization of the data, we apply a seriation algorithm based on Principal Component Analysis to automatically arrange the order of the variables in our plots with unordered categorical data both on the x and y axis (Hahsler et al., 2008).

4.2. Application of the conceptual framework

In a second step, the authorized clearance applications were classified according to our definitions of the green, bio- and circular economy concepts and their overlapping spaces (see section 2). Hence, there are seven possible classes ('green economy', 'bioeconomy', 'circular economy', 'circular bioeconomy' 'green and bioeconomy', 'green and circular economy', 'green and circular bioeconomy') and a class termed 'none' comprising all other clearance projects that do not fit into one of the other classes (see Table 2 for a list of these classes and short definitions). We assigned each clearance project in the database to one of these classes by scrutinizing the project descriptions and further research in ambiguous cases.

By default, we assumed that clearance projects which correspond to our framework (i.e. those not in the 'none' class) are compliant with social and environmental goals and either fall into the green economy class or overlap with it. This assumption is plausible because, in

Table 2
A comparison of our sustainable economy classes.

Sustainable economy class	Short description
Green economy	• Stands for renewable resource use, improved resource efficiency or the reduction of (carbon) emissions • Builds on the three pillars of sustainability; economy, society and ecology • Align with environmental and social goals Examples: forest clearances related to railway, geothermal energy, wind- and waterpower, district heating, slow traffic (e.g. foot and bicycle) or public transportation projects
Bioeconomy	• Emphasizes the substitution of non-renewable resources with (efficient, high-tech transformations of) renewable resources in particular biomass • Allows for trade-offs with environmental or social aspects
Circular economy	• Stands for recycling, cascading and reducing the environmental impact of products' life cycles • Allows for trade-offs with environmental or social aspects Examples: wastewater treatment plants that conflict with nature conservation objectives
Circular bioeconomy	• Combines the circular economy and the bioeconomy concept • Allows for trade-offs with environmental or social aspects
Green and bioeconomy	• Combines the green economy and the bioeconomy concept • Related to the use of biomass to substitute for non-renewable resources • Align with environmental and social goals Examples: clearance reasons related to wood energy, biogas or wood processing
Green and circular economy	• Combines the green economy and the circular economy concepts • Align with environmental and social goals Examples: Clearance reasons related to recycling (e.g. waste, heat and steam), projects to end landfilling, wastewater treatment, waste sorting or incineration plants as well as drinking-water power plants
Green and circular bioeconomy	• Combines the green economy and the circular bioeconomy concept • Align with environmental and social goals Example: a furnace with a drying facility for wood by-products of a sawmill
None	• Forest clearance projects that are not related to any of the individual or overlapping sustainable economy concepts

Switzerland, larger construction and infrastructure projects need to pass an ex-ante environmental impact assessment that checks projects' conformity with environmental regulations. On the one hand, this is a concretization of the precautionary principle and, on the other hand, it enables holistic and comprehensive consideration of potentially environmentally damaging projects (Griffel, 2019). Moreover, people who are directly affected by a construction project, have legal possibilities to raise objection against the building permit application. In case the database provided information on a social or environmental conflict related to a clearance project, we negated an overlap with or the placement in the green economy class.

In more detail, clearance projects related to renewable resource use, improved resource efficiency or the reduction of (carbon) emissions were classified as 'green economy', provided they align with environmental and social goals. In case of trade-offs, the projects were put in the 'none' class. For example, clearances related to railway, geothermal energy, wind- and waterpower, district heating, slow traffic (e.g. foot and bicycle) or public transportation projects were put into the 'green economy' class. Clearance reasons related to the use of biomass to substitute for non-renewable resources were put into the 'green and bioeconomy' class. However, if a trade-off with environmental or social goals was noted in the database, the clearance project was put into the

'bioeconomy' class because it was not compliant with the sustainability constraints of the green economy concept. For example, clearances related to wood energy, biogas or wood processing were put into the 'green and bioeconomy' class.

Clearance reasons related to recycling (e.g. waste, heat and steam), projects to end landfilling, wastewater treatment, waste sorting or incineration plants as well as drinking-water power plants were put into the 'green and circular economy' class, again under the condition that other environmental or social goals were not compromised. In case of a noted conflict, the clearance project was put into the 'circular economy' class.

Finally, the 'circular bioeconomy' class comprises clearance projects that meet both the criteria for the circular and bioeconomy class. Given that the literature recommends but does not strictly require compliance with the three pillars of sustainability, we do not see an overlap of this class with the green economy class. Hence, we propose a distinct 'green and circular bioeconomy' class especially emphasizing sustainability. The only example in that class is a furnace with a drying facility for wood by-products of a sawmill.

All clearance projects that did not fit into any of these classes were put into the class 'none'. For validity, the exercise of assigning the clearance projects into the sustainable economy classes was done by both authors independently, and discrepancies were discussed. Analyzing this data allows us to assess the scope of the green, bio- and circular economy projects in terms of their absolute numbers as well as their proportion relative to the numbers of other clearance reasons. Moreover, we can assess differences between regions and the development of project numbers over time.

4.3. Indicators for pressure on forests

Several indicators have been applied in previous research to quantify pressure on ecosystems. For example, the Human Footprint is an indicator applicable at the global scale that combines eight dimensions of human pressures (Sanderson et al., 2002; Venter et al., 2016). An alternative increasingly popular approach is to use forest cover as an indicator, based on the assumption that it responds to human pressure (Allan et al., 2017).

For our case study analysis, we thus use the absolute clearance area as well as the clearance area relative to the regions' forest area as indicators to compare pressure between the regions. Moreover, for this analysis we differentiate between temporary and definitive clearances and depict the data over time. It is important to note that these indicators only consider forest clearances (and not e.g. forest degradation). As discussed above, clearances in Switzerland are usually compensated for, resulting in little change in the absolute forest cover over time, at least until now. This differentiates our indicators from other research that uses net changes in forest cover as indicator for pressure (Allan et al., 2017).

5. Results

Fig. 1 shows a map of Switzerland depicting the forest regions used in the analysis together with the coordinates of the forest clearances between 2001 and 2017. The forest area of Jura, Plateau and Prealps is approximately the same. While the forest area of the Alps is larger (170%), it is a bit smaller in the Southern Alps (70%). Overall, between 2001 and 2017 the forest area was increasing over time, most of all in the Alps (FSO, 2018). The Plateau region is an exception with a slight net loss of forested area. Between 2001 and 2017, The Swiss Federal Office for the Environment (FOEN) registered 6108 forest clearance applications.

5.1. Clearance categories by region

In terms of the number of authorized clearance applications, Fig. 2

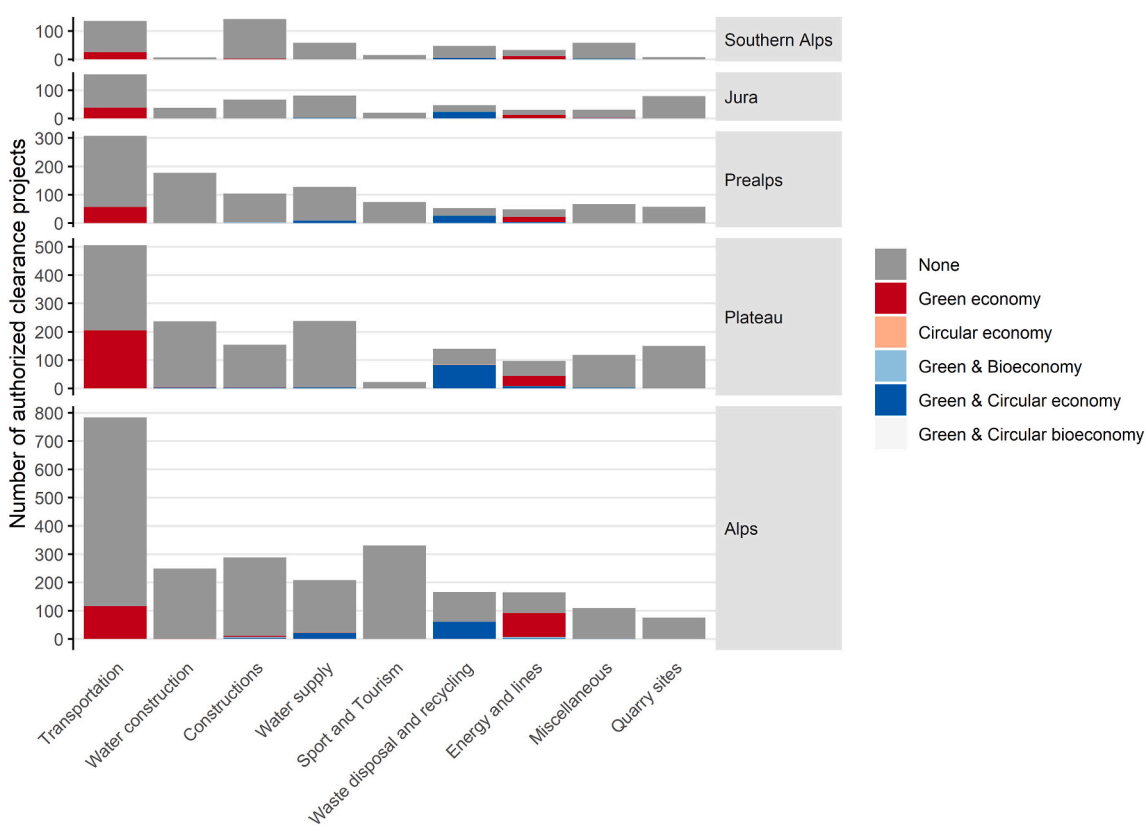

Fig. 2. Numbers of authorized clearance applications per forest region and category of clearance reasons, from 2001 to 2017, with a color-coded subdivision into our sustainable economy classes.

reveals that transport related reasons have been by far the most important contributors to clearances in Switzerland between 2001 and 2017, followed by constructions, water supply and water construction related reasons. Particularly in the Alps, it is striking how much more transport related clearance projects there are compared to the other regions. Only in the Southern Alps, construction related clearances are slightly more important than the transportation related ones. Water construction and quarry sites play just a marginal role in the Southern Alps and the category of 'sport and tourism' is an important contributor to clearances only in the Alps. The majority of quarry sites and 'energy and lines' related clearance projects lay in the Plateau region and the Alps, respectively.

5.2. Scope of green, bio- and circular economy clearance classes

Overall, there are 615 'green economy', 250 'green and circular economy', 15 'green and bioeconomy', 3 pure 'circular economy' and finally 1 'green and circular bioeconomy' related clearances. Together, they make up for about 14.5% of all clearance projects in the database. Note that none of the clearances were classified as circular bioeconomy and none as only bioeconomy related.

In Fig. 2, the classes of the green, bio- and circular economy concepts are highlighted in color. Fairly large proportions of green economy related clearance projects are only apparent in the categories transportation and in 'energy and lines' (Fig. 2). In the green economy fraction of the transportation category, the forest was cleared to make space for public transportation (e.g. railway) or non-motorized traffic projects such as cycle paths and sidewalks. Especially in the Plateau region, the green economy proportion in the transportation category is remarkably high at around 40%.

In the 'energy and lines' category, across all regions the green economy share makes up for just a little less than half of the cases. In the Alps, where most energy projects are being carried out, the proportion is even higher. The green economy part in the 'energy and lines' category is mainly composed of hydroelectric or wind power plants and district heating networks. In the Plateau region, there is a small share of 'green and circular economy' related projects that consist of district heating and steam pipelines (Fig. 2). They are in this class because they use energy that is generated as a result of industrial processes, in the sense of a byproduct, where the primarily production purpose was not the generation of energy. In the Alps, there is a small share of 'green and bioeconomy' related clearance projects in the 'energy and lines' category. In these cases, the forest was removed to make space for wood chip/pellet or biogas facilities and wood related district heating. Accordingly, energy related 'green and bioeconomy' clearances are presently confined to the Alps.

The 'green and circular economy' class within the 'waste disposal and recycling' category consists of wastewater treatment plants and pipelines as well as of waste sorting and incineration plants. Apparently, its proportion is more than half only in the Plateau region, while it is very small in the Southern Alps. Overall, there are only three clearance projects in the pure circular economy class. They are related to wastewater treatment plants and hence are categorized as 'waste disposal and recycling'. However, information provided in the database reveals that they conflict with nature conservation objectives. This is in discord with the constraints of the green economy definition, so that these three cases represent only the circular economy class.

In the water supply category, especially in the Alps and Prealps, there are some 'green and circular economy' related clearance projects. These are drinking-water power plants and wastewater pipes, which have also been laid during work on drinking water infrastructure. Thus, the spatial occurrence patterns of the more frequent case of drinking-water power plants can possibly be explained just by the necessary slope.

5.3. Clearances over time

Fig. 3 shows the number of authorized clearance applications per forest area over time segmented into the five forest regions. The spatial subdivision reveals that in the Plateau region, the total number of clearance projects per forest area is the largest compared to the other regions and it is increasing over time, disregarding the outlier in 2015, during which only a few clearance projects are listed. Further, the density of green economy as well as 'green and circular economy' related clearance projects are highest in the Plateau region. The green economy class is increasing over time especially in the Alps and the Plateau region. The density of 'green and circular economy' related clearance projects, on the other hand, does not seem to follow a clear trend.

In the Alps, the green economy class seems to be steadily increasing while the overall numbers of forest clearance projects vary strongly between years. Hence, in the Alps, at least by visual inspection of the data, the growth of the green economy class may not be explained by the overall change in the number of clearance projects in the region.

5.4. Pressure on forest area

Our first indicator for pressure on forests is the area of clearances per region. As can be seen from Table 3, the aggregated area of temporary clearances was highest in the Plateau. The definitive clearances are second highest in the Plateau. By far the most definitive clearance areas are located in the Alps. Data on our second indicator, the area cleared relative to the regions' forest area reveals that the Plateau has the highest values both for temporary and definitive clearances (see Table 3).

Fig. 4 and Fig. 5 add further detail to these findings. Fig. 4 shows the area of temporary and definitive clearances per forest region and category of clearance reason whereas Fig. 5 shows the development of temporarily and definitively cleared area per forest area over time. Despite the small number of clearance projects (Fig. 2), quarry sites are by far the biggest contributors to temporarily cleared area, especially in the Plateau region (Fig. 4). When it comes to definitive area, however, they are no longer conspicuous. In the Plateau, temporary clearances are clearly highest compared to the other regions in the categories quarry sites, water construction and 'waste disposal and recycling' (Fig. 4). Fig. 5 reveals that the Plateau has by far the most temporary clearance areas per forest area.

As expected due to the high number of clearance projects (Fig. 2), transportation is a major contributor to the definitively cleared area (Fig. 4). Especially in the Alps, transportation is the biggest contributor to both temporarily and definitively cleared forest area. 'Energy and lines' as well as 'sport and tourism' are only relevant in terms of area in the Alps. Water construction plays a role only in the Alps, Prealps and the Plateau.

Despite the considerable amount of clearance projects (Fig. 2), the 'green and circular economy' related clearance areas in the 'waste disposal and recycling' category seem not to play an important role in terms of area, except maybe in the Plateau (Fig. 4). The fraction of green economy related clearances within the 'energy and lines' category, especially in the Alps, is very high (Fig. 4). Within the transportation category however, the fraction of green economy related clearance areas is comparatively high most of all in the Southern Alps and in the Plateau region but only for temporary areas (Fig. 4).

What is striking in Fig. 5 is an unusually large temporarily cleared green economy area in 2016 in the Alps. This is due to a single project, the Lagobianco pumped-storage power plant in Val Poschiavo. A second remarkable outlier is to be found 2006 in the Southern Alps (Fig. 5). This huge temporarily cleared area was caused by the AlpTransit railway project in Monteceneri.

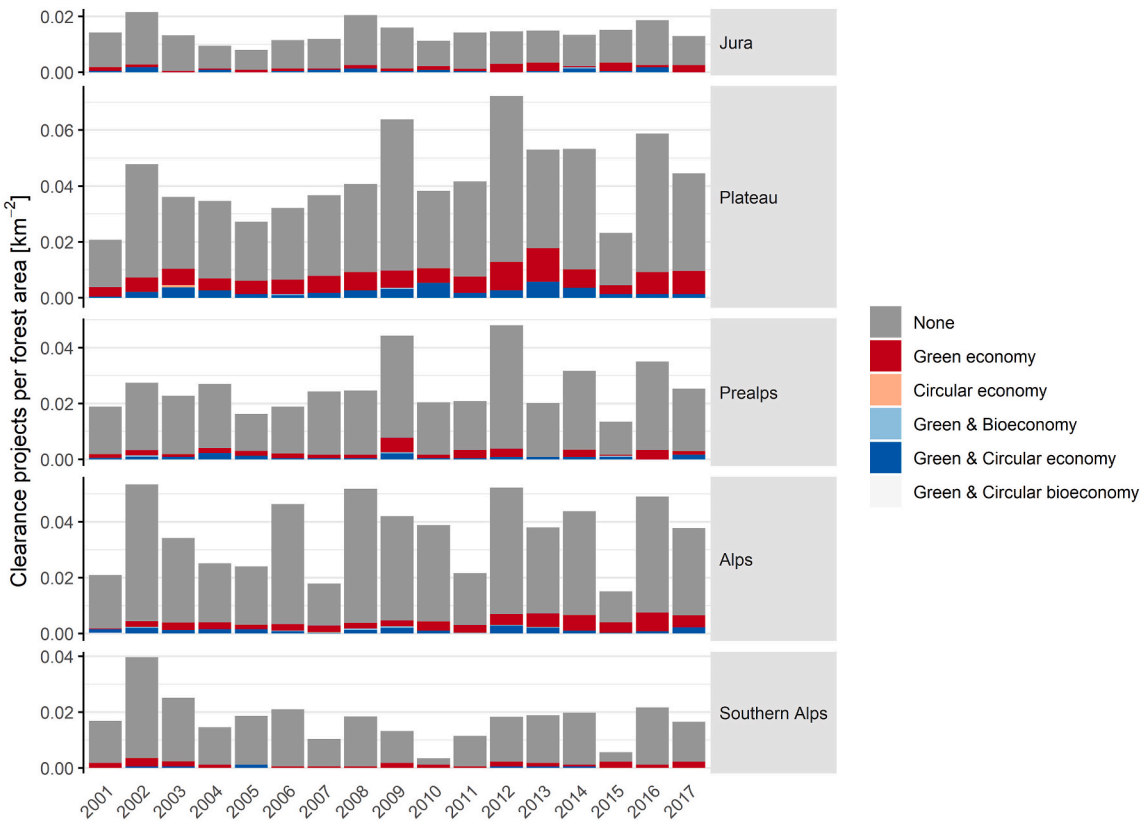

Fig. 3. Numbers of authorized clearance projects per forest area in the five forest regions over time, with a color-coded subdivision into the sustainable economy concepts.

Table 3
Numbers of clearance projects and temporary and definitive clearance area aggregated for the years 2001 to 2017 as well as total forest areas (2017) of the Swiss forest regions. Based on this information, the temporary and definitive clearance area per forest area have been calculated.

	Total forest area [ha]	Number of projects	Temporary clearance area [ha]	Deffnitive clearance area [ha]	Temporary area as share of forest area	Deffnitive area as share of forest area
Jura	231′412	549	371.5	103.7	0.16%	0.04%
Plateau	229′056	1′661	966.5	212.6	0.42%	0.09%
Prealps	237′127	1′013	259.0	111.6	0.11%	0.05%
Alps	397′529	2′376	596.2	335.4	0.15%	0.08%
Southern Alps	175′466	509	129.3	47.1	0.07%	0.03%
Total	1′270′590	6′108	2′322.5	810.4	0.18%	0.06%

6. Discussion and conclusion

While many countries around the world are advancing their efforts to transition to more sustainable economies, it is important to be aware of trade-offs that can be induced by these transition processes. In this paper, we focus on aspects of land use, especially forest clearances to provide space for transitions in other sectors. However, it is important to acknowledge that land use conflicts are only one dimension within a larger spectrum of issues related to sustainability transitions that, for example, also includes concerns over justice and the societal distribution of costs and benefits (Ciplet and Harrison, 2020; Williams and Doyon, 2019).

The key question for our empirical case study in Switzerland was to what extent forests are being cleared to advance sustainability transitions in other sectors. As a subordinate question we also investigated whether pressure on forests is higher in the Central Plateau area than in other parts of the country. We presented a general conceptual framework that allows us to identify overlaps and differences between three sustainable economy transition concepts and applied the framework to our empirical data on forest clearances.

The analysis revealed that overall, 14.5% of the clearance projects in the database are attributable to the sustainable economy classes defined by our framework. At least visually, we could identify a trend towards more green economy related clearance reasons in the Plateau and in the Alps. It is also the Plateau region that harbors most clearance projects per forest area, sustainable economy related as well as regarding total numbers. Among the sustainable economy clearances, green economy projects dominate in numbers and size over bio and circular economy related clearances. Several reasons are possible for this finding. The first is that the green economy class is broadest, allowing for a wider range of projects being included. A second reason may be that the green economy class harbors many clearances of the transportation and ‘energy and lines’ categories, which by virtue of their purpose of transporting people, goods or energy from A to B require a lot of space and their high demand might help to get clearance permissions more easily.

Given the lack of comparable studies in other countries, it is difficult to normatively assess whether these values are high or low. However, it is important to keep in mind that the results are framed by our

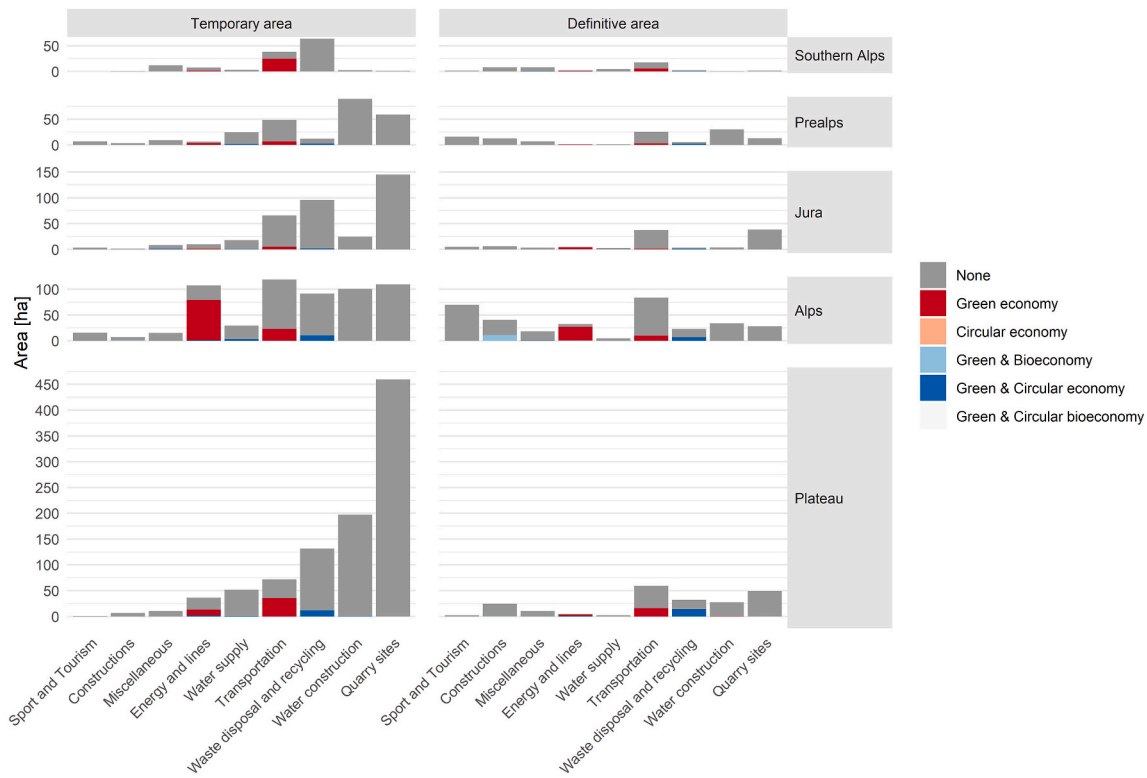

Fig. 4. Areas of temporary and definitive clearances per forest region and category of clearance reason, from 2001 to 2017, with a color-coded subdivision into our sustainable economy concepts.

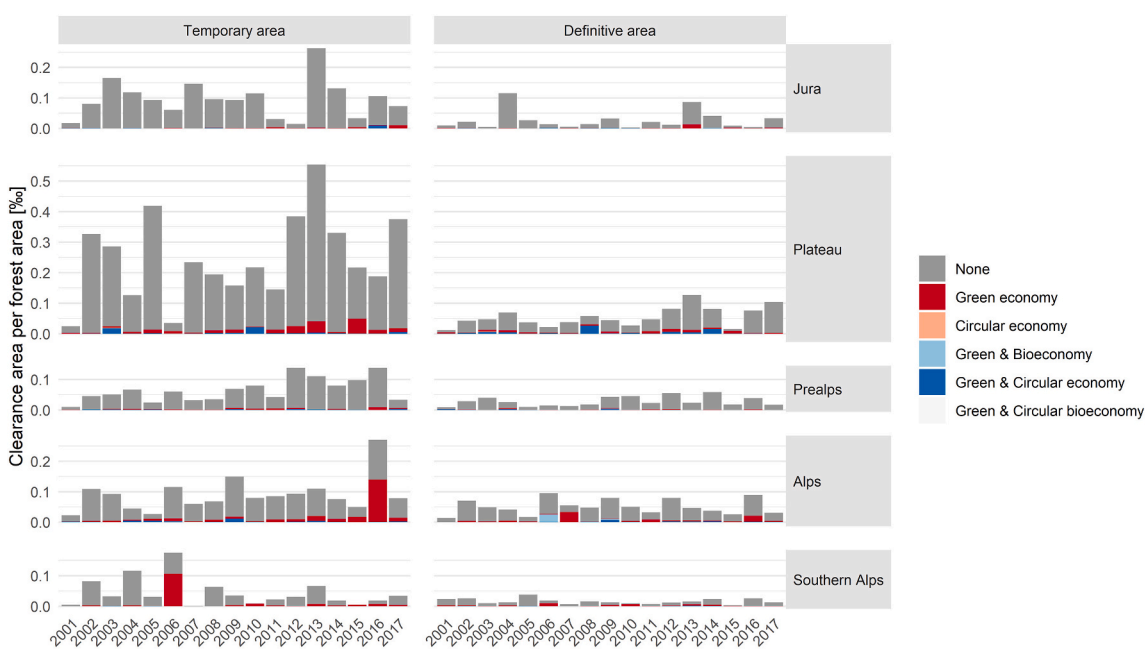

Fig. 5. Fractions of temporary and definitive clearances on forest area per region over time [‰], with a color-coded subdivision into our sustainable economy concepts.

application of sustainable economy concepts to the empirical data. By default, we assumed that circular and bioeconomy projects overlap with the green economy concept. We only placed a circular economy (or theoretically a bioeconomy) project in the non-overlapping class if information in the database indicated a conflict with the sustainability constraint of the green economy concept. There is of course a risk that information on such constraints may not have been consistently reported, resulting in a bias towards the overlapping classes. An alternative application of the framework to the data, e.g. requiring evidence of an active pursuit of all three dimensions of sustainability for the green economy class would have possibly resulted in very different results, simply because such information is not available in the database. Moreover, the framework builds on academic literature. A more interdisciplinary approach in which the categorization and construction of

the framework had been co-created with stakeholders would have possibly produced deviating results.

In the framework of our categorization, overall the results point out that the sustainable economy transition is indeed claiming forest land. This calls for a political discussion on how society wants to weigh the need for a transition against the benefits provided by the forest. While the permits for forest clearances are granted only very restrictively in Switzerland, our results suggest that there is need to discuss whether the sustainable economy transition could be implemented in a more land sparring manner. This question is likely to be relevant also in other densely populated countries with high competition for land and regions with increasing demand for infrastructure.

Related to our subordinate question, the data analyses revealed that the pressure, measured as absolute clearance area as well as clearance area relative to the regions' forest area, is higher in the Plateau than in the other regions. This finding is not surprising, since both the quantity and the demand for infrastructure are greatest in the Central Plateau. However, these forests are also used most heavily for recreational purposes (Rigling and Schaffer, 2015). Thus, it is likely that opposition to forest clearance-related infrastructure projects in the regions will increase in the future.

It was not possible to identify a trend in terms of clearance area over time. We argue that the random impact of clearance projects regarding area can lead to an over- or underestimation of possible trends over time. Especially due to the small sample size, outliers can overshadow the essential aspects. Aggregated clearance areas are thus not a robust measure for estimation or analysis of progression over time. But nevertheless, it is an informative and reliable metric for the actual impact of the clearance projects.

We expect that our findings will improve the foundation for the currently rather fuzzy debate on pressure on forests in different regions of Switzerland. Rather than calling for a more balanced spread of clearances across regions, we argue that there is need for a larger debate on arable and forest land use change as a consequence of ceaseless demand for economic growth. This is all the more important as Switzerland's rather restrictive quantitative forest conservation policy is increasingly being contested. It is important that this debate includes members of the sectors that are pushing into the forest. Although they may be very concerned about the sustainability of their products and services, it is questionable to what extent they include forest clearances related to their business in their own sustainability assessments. Our analysis focuses on categories of clearance reasons but it does not allow for an assessment of the sustainability of the new land uses, which will largely depend on their modes of implementation. However, addressing the sustainability of different new land uses on former forest land could be an avenue for future research. Furthermore, from a spatial planning perspective, forests are currently considered as homogeneous areas. Possibilities to include the heterogeneity of forests with their various functional areas into spatial planning could be explored more in the future. This includes investigating compensation for forest clearances, diffusion processes and local drivers of forest clearances. Examining clearance areas using remote sensing as alternative or complement to our current data set could provide additional insights.

A limitation of the study relates to the short time span for which data is available, which limits the possibilities of testing for any statistically significant trends. However, an early investigation has the advantage of being able to detect patterns that may require closer monitoring in the future.

At the beginning of 2017, some amendments to the ForA and ForO came into force, which are likely to affect the number and type of clearance applications. Now static forest boundaries may be established outside the building zone. After its implementation, it is possible to clear newly forested areas outside the boundaries without filing a clearance application. Furthermore, while forest conservation previously was favored over the construction of infrastructure for the use of renewable energy when balancing land use interests, the legal reforms now give equal weight to both (Zabel et al., 2018). It is likely that, in the future, this will lead to more clearance applications for energy purposes being authorized.

Based on the empirical results presented above, we conclude that there are structural differences in the Plateau area clearances. Whether they are interpreted negatively as pressure or more positively as the region's contribution to the transition to a sustainable economy is left to the discretion of the individual.

Many countries in Europe are developing bioeconomy strategies with important roles for the forest sector (Dietz et al., 2018). It is likely that this debate will emerge more prominently in Switzerland but also in the EU with its ambitious Green Deal in the near future which will further increase the need for a sound understanding of natural resource demands and the reasons of forest and agricultural land-use change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We gratefully thank Prof. Dr. Adrienne Grêt-Regamey, Dr. Tobias Schulz, Dr. Tamaki Ohmura and two anonymous reviewers for their valuable feedback and suggestions to further improve the manuscript and the forest division of the Federal Office for the Environment (FOEN), especially Roberto Bolgè, for the clearance data and technical advice.

This research is part of the project "Analyzing TRade-offs in forests between sustainable Economy and Environmental objectives" (ATREE), supported by the Swiss National Science Foundation (SNSF) within the framework of the National Research Programme "Sustainable Economy: resource-friendly, future-oriented, innovative" (NRP 73) Grant-N° 407340_172388.

References

Aguilar, A., Wohlgemuth, R., Twardowski, T., 2018. Perspectives on bioeconomy. New Biotechnol. 40 (Pt a), 184. https://doi.org/10.1016/j.nbt.2017.06.012.

Allan, J.R., Venter, O., Maxwell, S., Bertzky, B., Jones, K., Shi, Y., Watson, J.E.M., 2017. Recent increases in human pressure and forest loss threaten many natural world heritage sites. Conserving complexity: Global change and community-scale interactions Tropical forest biodiversity in a human-modified world: a multi-region assessment, 206, pp. 47–55. https://doi.org/10.1016/j.biocon.2016.12.011.

Andrade de Sá, S., Palmer, C., Di Falco, S., 2013. Dynamics of indirect land-use change: empirical evidence from Brazil. J. Environ. Econ. Manag. 65 (3), 377–393. https://doi.org/10.1016/j.jeem.2013.01.001.

Bader, P., 2014. Wald roden für die Energiewende? Umwelt 1, 24–25.

Baumgartner, H., 2011. Druck auf den Wald in Siedlungsnähe. Umwelt 2, 50–53.

Böcher, M., Töller, A.E., Perbandt, D., Beer, K., Vogelpohl, T., 2020. Research trends: bioeconomy politics and governance. Forest Policy Econ. 118, 102219. https://doi.org/10.1016/j.forpol.2020.102219.

Bugge, M., Hansen, T., Klitkou, A., 2016. What is the bioeconomy? A review of the literature. Sustainability 8 (7), 691. https://doi.org/10.3390/su8070691.

Bugmann, H., 2014. Warum nicht endlich Wald roden? ETH-Zürich. https://www.ethz.ch/de/news-und-veranstaltungen/eth-news/news/2014/12/warum-nicht-endlich-wald-roden.html. (Accessed 27 February 2019).

Ciplet, D., Harrison, J.L., 2020. Transition tensions: mapping conflicts in movements for a just and sustainable transition. Environ. Politics 29 (3), 435–456. https://doi.org/10.1080/09644016.2019.1595883.

D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lähtinen, K., Korhonen, J., Leskinen, P., Matthies, B.D., Toppinen, A., 2017. Green, circular, bio economy: a comparative analysis of sustainability avenues. J. Clean. Prod. 168, 716–734. https://doi.org/10.1016/j.jclepro.2017.09.053.

D'Amato, D., Veijonaho, S., Toppinen, A., 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. Forest Policy Econ. 110, 101848. https://doi.org/10.1016/j.forpol.2018.12.004.

DeBoer, J., Panwar, R., Kozak, R., Cashore, B., 2020. Squaring the circle: refining the competitiveness logic for the circular bioeconomy. Forest Policy Econ. 110, 101858. https://doi.org/10.1016/j.forpol.2019.01.003.

Dietz, T., Börner, J., Förster, J., von Braun, J., 2018. Governance of the bioeconomy: a global comparative study of National Bioeconomy Strategies. Sustainability 10 (9), 3190. https://doi.org/10.3390/su10093190.

Dupont-Inglis, J., Borg, A., 2018. Destination bioeconomy - the path towards a smarter, more sustainable future. New Biotechnol. 40 (Pt a), 140–143. https://doi.org/10.1016/j.nbt.2017.05.010.
Ettlin, E., 2018. Kulturland und Wald sind gleichwertig. Stopp dem Kulturlandverlust zugunsten der Waldflächenausdehnung. Motion 18 (3869). https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20183869.
Falcone, P.M., Tani, A., Tartiu, V.E., Imbriani, C., 2020. Towards a sustainable forest-based bioeconomy in Italy: findings from a SWOT analysis. Forest Policy Econ. 110, 101910. https://doi.org/10.1016/j.forpol.2019.04.014.
FOEN, 2016. What is understood by the term "green economy"? Federal Office for the Environment. https://www.bafu.admin.ch/bafu/en/home/topics/economy-consumption/info-specialists/green-economy/what-is-understood-by-the-term-green-economy-.html. (Accessed 3 April 2019).
FSO, 2015. Die Bodennutzung in der Schweiz: Resultate der Arealstatistik. Neuchâtel, 24 Seiten.
FSO, 2018. Swiss Forestry Statistics: Waldfläche und Holzernte. FSO number: je-d-07.03.03.01. Federal Statistical Office. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.5708652.html (accessed 7 March 2019).
German Bioeconomy Council, 2018. Bioeconomy Policy (Part III) Update Report of National Strategies around the World. Office of the Bioeconomy Council, Berlin.
Giuliani, G., Abdulai, A., Rieder, P., 2002. Landwirtschaftlicher Bodenmarkt und landwirtschaftliche Bodenpolitik in der Schweiz: Eine theoretische und empirische agrarökonomische Analyse anhand von Daten über Handelsfälle von Landwirtschaftsland in den Kantonen Aargau, Graubünden und Zürich. Diss., Technische Wissenschaften ETH Zürich, Nr. 14781. Shaker Verlag, Aachen.
Grêt-Regamey, A., Kool, S., Bühlmann, L., Kissling, S., 2018. Eine Bodenagenda für die Raumplanung: Thematische Synthese TS3 des Nationalen Forschungsprogramms. In: «Nachhaltige Nutzung der Ressource Boden» (NFP 68). Schweizer Nationalfonds, Bern, 91 Seiten.
Griffel, A., 2012. Wald und Recht (Essay). Schweizerische Zeitschrift fur Forstwesen 163 (8), 304–306. https://doi.org/10.3188/szf.2012.0304.
Griffel, A., 2019. Umweltrecht: In a Nutshell, 2nd ed. Dike, Zürich. (285 pp).
Hahsler, M., Hornik, K., Buchta, C., 2008. Getting things in order: an introduction to the R package seriation. J. Stat. Softw. 25 (3) https://doi.org/10.18637/jss.v025.i03.
Hertel, T., Steinbuks, J., Baldos, U., 2013. Competition for land in the global bioeconomy. Agric. Econ. 44 (s1), 129–138. https://doi.org/10.1111/agec.12057.
Hodge, D., Brukas, V., Giurca, A., 2017. Forests in a bioeconomy: bridge, boundary or divide? Scand. J. For. Res. 32 (7), 582–587. https://doi.org/10.1080/02827581.2017.1315833.
Imbert, E., Ladu, L., Morone, P., Quitzow, R., 2017. Comparing policy strategies for a transition to a bioeconomy in Europe: the case of Italy and Germany. Energy Res. Soc. Sci. 33, 70–81. https://doi.org/10.1016/j.erss.2017.08.006.
Keel, A., Zimmermann, W., 2009. Der Wald im Lichte der neueren bundesgerichtlichen Rechtsprechung | Forest legislation in the recent jurisdiction of the Federal Supreme Court. Swiss Forestry J. 160 (9), 263–274. https://doi.org/10.3188/szf.2009.0263.
Kleinschmit, D., Lindstad, B.H., Thorsen, B.J., Toppinen, A., Roos, A., Baardsen, S., 2014. Shades of green: a social scientific view on bioeconomy in the forest sector. Scand. J. For. Res. 29 (4), 402–410.
Leugger-Eggimann, U., 2014. Ein beliebter Alleskönner steht unter Druck (Essay). Schweizerische Zeitschrift fur Forstwesen 165 (8), 220–223. https://doi.org/10.3188/szf.2014.0220.
Lindner, M., Suominen, T., 2017. Towards a sustainable bioeconomy. Scand. J. For. Res. 32 (7), 549–550. https://doi.org/10.1080/02827581.2017.1357329.
Mather, A.S., Fairbairn, J., 2000. From floods to reforestation: the Forest transition in Switzerland. Environ. Hist. 6 (4), 399–421. https://doi.org/10.3197/096734000129342352.
McCormick, K., Kautto, N., 2013. The bioeconomy in Europe: an overview. Sustainability 5 (6), 2589–2608. https://doi.org/10.3390/su5062589.
Meyfroidt, P., Lambin, E.F., Erb, K.-H., Hertel, T.W., 2013. Globalization of land use: distant drivers of land change and geographic displacement of land use. Curr. Opin. Environ. Sustain. 5 (5), 438–444. https://doi.org/10.1016/j.cosust.2013.04.003.
O'Brien, M., Schütz, H., Bringezu, S., 2015. The land footprint of the EU bioeconomy: monitoring tools, gaps and needs. Land Use Policy 47, 235–246. https://doi.org/10.1016/j.landusepol.2015.04.012.
Ollikainen, M., 2014. Forestry in bioeconomy – smart green growth for the humankind. Scand. J. For. Res. 29 (4), 360–366. https://doi.org/10.1080/02827581.2014.926392.
Patermann, C., Aguilar, A., 2018. The origins of the bioeconomy in the European Union. New Biotechnol. 40 (Pt a), 20–24. https://doi.org/10.1016/j.nbt.2017.04.002.
Pelli, P., Haapala, A., Pykäläinen, J., 2017. Services in the forest-based bioeconomy – analysis of European strategies. Scand. J. For. Res. 32 (7), 559–567. https://doi.org/10.1080/02827581.2017.1288826.
Pülzl, H., Kleinschmit, D., Arts, B., 2014. Bioeconomy – an emerging meta-discourse affecting forest discourses? Scand. J. For. Res. 29 (4), 386–393. https://doi.org/10.1080/02827581.2014.920044.
Pütz, M., Bernasconi, A., 2017. Urban Forestry in der Schweiz: fünf Herausforderungen für Wissenschaft und Praxis (Essay). Schweiz. Z. Forstwes. 168 (5), 246–251. https://doi.org/10.3188/szf.2017.0246.
Rigling, A., Schaffer, H.P. (Eds.), 2015. Waldbericht 2015: Zustand und Nutzung des Schweizer Waldes. Bern und Birmensdorf.
Rigling, A., Landolt, D., Manser, R., 2015. Wald im Wandel. In: Rigling, A., Schaffer, H.P. (Eds.), Waldbericht 2015: Zustand und Nutzung des Schweizer Waldes. Bern und Birmensdorf, pp. 9–22.
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecol. Soc. 14 (2).
Sanderson, E.W., JAITEH, M., Levy, M.A., Redford, K.H., WANNEBO, A.V., WOOLMER, G., 2002. The human footprint and the last of the wild. Conserv. Biol. 52 (10), 891. https://doi.org/10.1641/0006-3568(2002)052[0891:THFATL]2.0.CO;2.
Schulz, T., Lieberherr, E., 2020. Regulierungen im Waldbereich im Wandel: Gefahrenabwehr, Multifunktionalität und Koordination. Schweizerische Zeitschrift fur Forstwesen 171 (1), 3–10. https://doi.org/10.3188/szf.2020.0003.
Sikkema, R., Dallemand, J.F., Matos, C.T., van der Velde, M., San-Miguel-Ayanz, J., 2017. How can the ambitious goals for the EU's future bioeconomy be supported by sustainable and efficient wood sourcing practices? Scand. J. For. Res. 32 (7), 551–558. https://doi.org/10.1080/02827581.2016.1240228.
Steffen, W., Rockström, J., Richardson, K., Lenton, T.M., Folke, C., Liverman, D., Summerhayes, C.P., Barnosky, A.D., Cornell, S.E., Crucifix, M., Donges, J.F., Fetzer, I., Lade, S.J., Scheffer, M., Winkelmann, R., Schellnhuber, H.J., 2018. Trajectories of the earth system in the Anthropocene. Proc. Natl. Acad. Sci. U. S. A. 115 (33), 8252–8259. https://doi.org/10.1073/pnas.1810141115.
Stegmann, P., Londo, M., Junginger, M., 2020. The circular bioeconomy: its elements and role in European bioeconomy clusters. Resour. Conserv. Recycling X 6, 100029. https://doi.org/10.1016/j.rcrx.2019.100029.
Thönen, S., 2013. Wer im Mittelland rodet, hat Mühe. Ersatzwald zu pflanzen, Der Bund.
Toppinen, A., D'Amato, D., Stern, T., 2020. Forest-based circular bioeconomy: matching sustainability challenges and novel business opportunities? Forest Policy Econ. 110, 102041. https://doi.org/10.1016/j.forpol.2019.102041.
Ulber, M., 2013. Der Einfluss von Naturschutzorganisationen auf Rechtsetzung und Vollzug. Schweizerische Zeitschrift fur Forstwesen 164 (3), 65–69. https://doi.org/10.3188/szf.2013.0065.
UNEP, 2011. Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication - a Synthesis for Policy Makers.
UNEP, 2019. Global Environment Outlook – GEO-6: Healthy Planet, Healthy People. Cambridge University Press.
Venter, O., Sanderson, E.W., Magrach, A., Allan, J.R., Beher, J., Jones, K.R., Possingham, H.P., Laurance, W.F., Wood, P., Fekete, B.M., Levy, M.A., Watson, J.E.M., 2016. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nat. Commun. 7, 12558. https://doi.org/10.1038/ncomms12558.
Williams, S., Doyon, A., 2019. Justice in energy transitions. Environ. Innov. So. Trans. 31, 144–153. https://doi.org/10.1016/j.eist.2018.12.001.
Zabel, A., Schulz, T., Lieberherr, E., 2018. Grüne Wirtschaft: Eine Annäherung an mögliche Zielkonflikte und Synergien im Wald. Schweiz. Z. Forstwes. 169 (3), 143–149. https://doi.org/10.3188/szf.2018.0143.