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European Union's Last Intact Forest Landscapes are at A Value Chain Crossroad between Multiple Use and Intensified Wood Production

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Received: 1 June 2019; Accepted: 2 July 2019; Published: 7 July 2019

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Abstract: *Research Highlights:* The European Union's last large intact forest landscapes along the Scandinavian Mountain range in Sweden offer unique opportunities for conservation of biodiversity, ecological integrity and resilience. However, these forests are at a crossroad between intensified wood production aimed at bio-economy, and rural development based on multi-functional forest landscapes for future-oriented forest value chains. *Background and Objectives:* We (1) estimate the area of near-natural forests potentially remaining for forest harvesting and wood production, or as green infrastructure for biodiversity conservation and human well-being in rural areas, (2) review how forest and conservation policies have so far succeeded to reduce the loss of mountain forests, and (3) discuss what economic, socio-cultural and ecological values that are at stake, as well as different governance and management solutions. *Materials and Methods:* First, we estimated the remaining amount of intact mountain forests using (1) the Swedish National Forest Inventory, (2) protected area statistics, (3) forest harvest permit applications and actually harvested forests, (4) remote sensing wall-to-wall data on forests not subject to clear-felling since the mid-1950s, (5) mapping of productive and non-productive forestland, and (6) estimates of mean annual final felling rate. Second, we review policy documents related to the emergence of land use regulation in north Sweden, including the mountain forest border, and illustrate this with an actual case that has had significant policy implementation importance. *Results:* There is a clear difference between the proportions of formally protected productive forestland above the mountain forest border (52.5%) and north Sweden in general (6.3%). A total of 300,000 ha of previously not clear-felled mountain forest outside protected areas remain, which can support novel value chains that are not achievable elsewhere. *Conclusions:* The mountain forests in Sweden provide unique conservation values in the European Union. Since the beginning of the 1990s, policy regulations have been successful in limiting forest harvesting. Currently, however, mountain forests are a battle ground regarding intensification of forest use, including logging of forests that have never been subject to clear-felling systems vs. nature conservation and wilderness as a base for rural development. The ability of mountain municipalities to encourage sustainable rural forest landscapes must be strengthened.

Keywords: green belt; amenity values; biodiversity conservation; continuous cover forestry; bioeconomy; rural development; forest policy; comprehensive planning; landscape stewardship; sustainability

1. Introduction

Remnant forest landscapes with a significant share of natural or near-natural forests with limited human influence are globally rare. Such intact forest areas and landscapes are not only crucial for the maintenance of viable populations of species and ecosystem functions that are sensitive to intensive forest management, e.g., [1,2], but also for securing ecological integrity [3] and resilience to changes on local to global levels, e.g., [4,5]. Intact areas also store large amounts of carbon in living trees, in dead and decaying wood, in field and bottom layers and in the soil [6,7]. Global mappings of large intact forest areas, nonetheless, show that they continue to decline [2,8–10]. On the European continent, large intact forest remnants are left primarily in hinterland areas at high latitudes and altitudes, e.g., [11–13], and thus represent "cool forests". In the Pan European boreal biome, large intact forests remain only in NW Russia and Fennoscandia. In the Russian Federation, these are located in remote areas of the subjects Komi and Arkhangelsk, on the Kola Peninsula, and in Russian Karelia along the border between Finland and Russia [14]. In a European Union perspective, however, large intact forest landscapes are found mainly in the foothills landscapes on the Swedish side of the Scandinavian mountain range [15].

Analyses of the spatial extent and connectivity of the Scandinavian mountains' intact forest landscapes in Sweden show that, by and large, they are currently not subject to short rotation, stand replacing and sustained yield forestry, which confirms their unique status as a key entity for biodiversity conservation, climate change resilience and wilderness in the European Union [16–18]. Hence, in this Scandinavian mountains' green belt [17], options still remain to support high biodiversity conservation ambitions, moving beyond protection of single habitat patches for individual species into also including the full range of natural processes and landscape level functional connectivity and resilience, e.g., [19,20].

With respect to the future development of the Scandinavian mountain range green belt, two main and diverging trajectories in forest governance and management can be predicted. The first is an expanding focus on intensive wood and biomass production for provision of industrial raw material and implementation of so-called bio-economy, e.g., [21–23]. The second is an increased focus on conservation of the Swedish mountain forests as a "green belt" [24] and mainland for developing forest value chains based on multiple values linked to biodiversity, long-term carbon sequestration, wilderness, reindeer husbandry and amenity values. This latter trajectory is based on formal protection, voluntary set asides, and small-scale continuous cover forestry, and requires effective spatial and comprehensive landscape and land use planning, e.g., [25–28]. Given the severe rural development challenges in the hinterland forest and mountain municipalities [28,29] harboring the European Union's last intact forest landscapes, we argue in favor of holistic analyses of the landscape transformation consequences of these trajectories, see also [30–32].

The mountain region of north Sweden has been settled for millennia and is the "Sapmi" homeland of the indigenous Sami people. Historic land use included extensive use of both mountains and forests. This use was complex with a mix of hunting, fishing, and different forms of reindeer herding [33–35]). Non-Sami farmers settled in the region mainly from the late 1700s and utilized forestland for animal husbandry, forest grazing and collection of hay along streams and on mires, non-wood forest products, and to a limited extent small scale shifting cultivation. Tilled land was encouraged, but expanded only from the 19th century [33]. Starting in the mid-1800s, the first wave of selectively harvested large sized valuable timber for beams and saw logs commenced, e.g., [36]. Even-aged industrial forestry became dominant in the region after 1950 [37] and has since then caused severe forest fragmentation and loss across large areas in north Sweden [16,38]. Compared to lowland boreal forests at the same latitude, the mountain region has nevertheless escaped massive landscape change, and significant areas of natural and near-natural forests thus remain [8,16,39]. However, during the 1970s and the first half of 1980s forest harvesting in the mountain region increased dramatically [16,40]. This caused a rapid loss of intact mountain forests, which, in combination with an active environmental movement, led to a heated media and parliamentary debate, e.g., [34]. This resulted in defining the current "mountain forest border", based on the suggestion by von Sydow [41] to establish a nature conservation border, which was recognized in the 1991 Swedish Forestry Act. This legally-defined border delineated a forest area along the mountains with a more strict regulation of forest harvesting.

The Scandinavian mountain range green belt represents a last frontier and an intact forest landscape mainland of highly significant conservation value on global, EU, Pan-European and national scales [17]. With the ongoing expansion of intensified short rotation forestry into these old, natural and near-natural forests, sustaining their unique values calls for a holistic and comprehensive conservation strategy development in line with EU and Pan-European sustainability objectives, national green infrastructure policies [42], Aichi targets [30] and IPBES [32,43] statements. Furthermore, the 15 municipalities covering the Swedish mountain region are populated by ca 140,000 residents [44] with forest landscapes and other natural resources as key assets. Rural residents' needs, the access to land rights of the Sami people, and other societal foundations need to be simultaneously addressed. Thus, to promote sustainable rural development, continued wood production and other forms of land use must be balanced with additional formal protection, voluntary set-asides and subsidized conservation agreements.

Consequently, innovative value chains based on developing stakeholder knowledge and capacity has to be built and recognized in territorial strategic and operational planning. To support conservation and rural development simultaneously, there is an urgent need to provide quantitative information relevant to the future trajectory of the Scandinavian mountains forest green belt as a social-ecological system. How much forest area is remaining and available for industrial forestry, or as green infrastructure for biodiversity conservation, maintenance of ecological integrity and resilience, or for a combination of these different directions? How can evidence-based knowledge be used in landscape and regional stewardship?

In this paper we (1) estimate the area of near-natural forests potentially remaining for forestry aimed at effective wood production, or as green infrastructure for biodiversity conservation and human well-being in rural areas, (2) review how past forest and conservation policy regulation succeeded to reduce pressure on mountain forests, and (3) discuss what economic, socio-cultural and ecological values that are currently at stake, and the pros and cons of different governance and management solutions.

2. Materials and Methods

2.1. Study Area

Coniferous (*Picea abies* (L.) H. Karst. and *Pinus sylvestris* L.), and mixed coniferous-deciduous (i.e., also with *Betula spp.* L., *Populus tremula* L.) forests dominate the Swedish mountain forest region, with *Betula pubescens ssp. czerepanovii* (N. I. Orlova) Hämet-Ahti at higher tree-line altitudes. The definition of forestland in Sweden follows the Food and Agriculture Organization of the United Nation's (FAO) definition [45] but is by tradition separated into productive forests annually producing >1 m^3 wood volume per hectare and non-productive forest producing <1 m^3 per hectare. The main natural disturbance regime is small scale gap dynamics, resulting in long-term tree continuity at stand and landscape scales [46–48]. Although forest fires did historically occur in the mountain forests, they were not as frequent there as at lower altitudes to the east of the mountain forest border, especially on dry sites dominated by *Pinus sylvestris* [39]. We contrast conditions in forests above the mountain forest border with the forests in the 15 mountain municipalities of NW Sweden, as well as with the remaining boreal forests in the five northernmost counties in Sweden (Figure 1), collectively known as "Norrland"; hereafter termed north Sweden. In total, this area represents about 57% of the Swedish productive forestland.

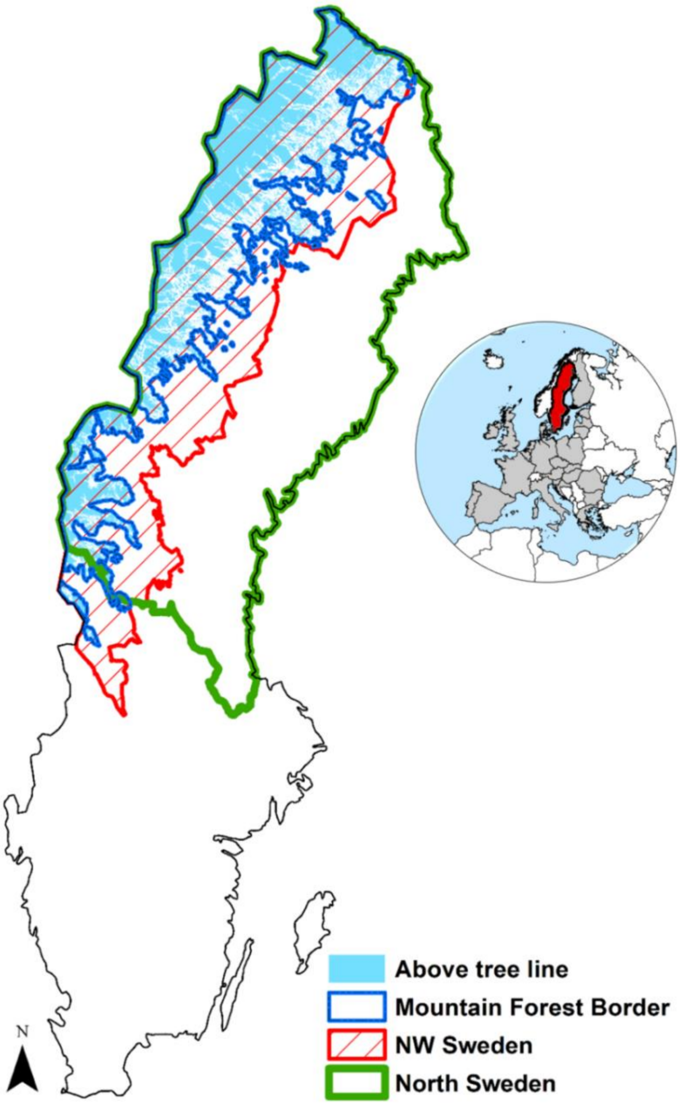

Figure 1. Our study covers four spatial extents: (1) forests below the tree line west of the mountain forest border, (2) NW Sweden defined as the 15 municipalities hosting mountain forest (hatched), (3) the five counties in north Sweden forming the informal region north Sweden ("Norrland"), and (4) entire Sweden with its policies. The inset map shows the location of Sweden in the European Union.

2.2. Forest Data Sources

To estimate the remaining amount of intact mountain forests, and to compare their characteristics with the rest of the forests in north Sweden, we used openly available data sources. (1) The Swedish National Forest Inventory, which annually samples a large range of forest variables based on permanent and temporary field sample plots, including the area above the mountain forest border if trees are present for details, see reference [49]. For the current study, we have utilized average values for the sampling period 2012–2016 as presented in Claesson [40] with data separately reported for forests above the mountain forest border. (2) Official statistics on protected areas in Sweden updated to December 2018 [50]. (3) Forest harvest permit applications and actually harvested forests with their spatial location and areal extent from the Swedish Forest Agency statistical database 1995 to 2018 [51]. (4) Remote sensing wall-to-wall data by Metria on forests not subject to harvesting since the mid-1950s [52]. (5) Data from the new (2019) National Land Cover mapping of productive and non-productive forestland and woodlands [53], and (6) data on estimates of mean annual final felling rate from 2000 to 2018 based on existing data on global land cover changes [54,55].

2.3. Evolution of the Mountain Forest Border Policy

There is a > 300-year history of attempts by governments to regulate the types and intensity of use of the Swedish mountain forest landscapes. The emergence and consequences of the mountain forest border, and its predecessors, is a factor that has contributed to low harvest rates in mountain forests since the 1990s. First, we review this development with a focus on the emergence of regulation and deregulation of forestry with conservation motives in the mountain forests. This review illustrates key aspects in the social system, which interact with the ecological system as represented by the biophysical data and analyses described above, and form a social-ecological system referred to as landscapes [56]. Second, using a concrete example of policy implementation (the "Änok" case) we illustrate the complexity of different stakeholders' views, political directions and judicial decisions towards sustained yield forestry vs. conservation of values linked to intact forest landscapes.

3. Results

3.1. Forests, Forest Landscapes and Forest Harvesting

Forests in north Sweden are dominated by productive forestland (83%), although the fraction of non-productive forests above the mountain forest border (MFB) is relatively high (46%; Table 1). Forests above the MFB are in general old with 61% of the forests older than 120 years, in strong contrast to the rest of north Sweden where 69% of all forests are younger than 80 years (Figure 2). Also within NW Sweden young forests dominate, with 53% being less than 80 years and 32% being older than 120 years. The fraction of old forest above the MFB corresponds well to the estimate that about 66% of the forests above the MFB has not been clear felled since the 1960s when this practice first became widespread [52], thus confirming the existence of larger components of natural and near-natural forests with significant forest continuity values.

Table 1. Total and productive forestland area, and the proportion (%) formally protected and voluntary set aside area according to NFI (2012–2016, 5-year average) (*), and total and productive forestland area, and the proportion formally protected area according to SCB [50] (**), presented for north Sweden, northwest (NW) Sweden, and the region within NW Sweden above the mountain forest border (MFB) in 1000 ha.

	North Sweden		NW Sweden		Above MFB (2012–2016) *		Above MFB (2018) **	
	kha	%	kha	%	kha	%	kha	%
Total forestland	15,880		7340		2224		2579	
formally protected	1445	9.1	1340	18.3	1072	48.2	1444	56.3
voluntary set aside	469	3.0	293	4.0	93	4.2		
Productive forestland	13,129		5482		1188		1232	
formally protected	830	6.3	714	13.0	513	43.1	641	52.5
voluntary set aside	424	3.2	260	4.7	81	6.8		

* NFI data, representing the situation 2012–2016, with formally protected forest areas including national parks, nature reserves, biotope protection areas, nature conservation agreements, and with these areas non-overlapping Natura 2000 habitats. Voluntary set aside areas are forests set aside by forest owners to fulfill forest certification standards. ** SCB data, representing the situation in December 2018 and based on forestland estimates in NMD [53], with formally protected forest including also areas formally agreed with other State organization (7000 ha), and areas in formal process towards protection (72,100 ha).

Also outside protected areas, the forest age structure clearly differs between north Sweden and the area above the MFB (Figure 3). While the young forests regenerated after clear-felling have increased during the last 60 years in north Sweden and currently constitute 35% of the forested land, the area above the MFB has a high proportion of old forests (43% > 120 years) and only 17% of the forestland contains forests <40 years of age (Figure 3). The increase in young forests above the MFB during the 1970s and 1980s mirrors the patterns of forest harvest in the region (see below). Yet, the large fraction of old forest above the MFB strongly suggest that also the forestland outside protected areas host large contiguous forest cover, temporal continuity and other old forest attributes and values. The decreasing trend of forests aged 81–120 years above the MFB is evident. This indicates a loss in recruitment of forests into older age classes. The long-term distribution of younger and older age classes is more stable.

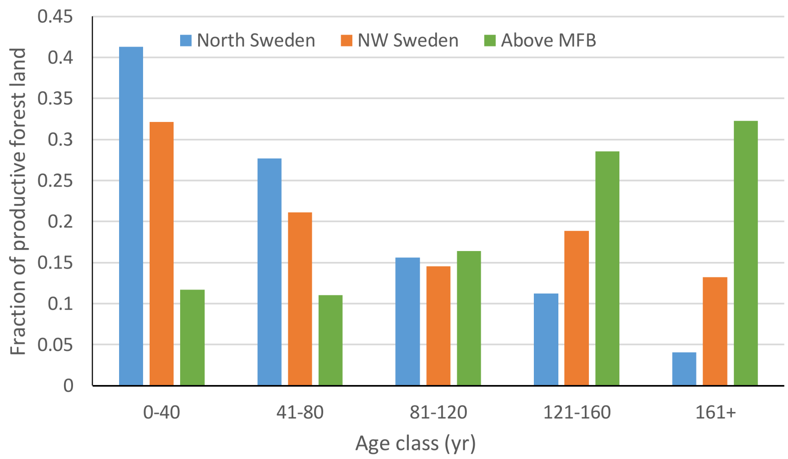

Figure 2. Age distribution of all productive forests (including protected forests) based on the Swedish National Forest Inventory (2012–2016, 5-year average) in north Sweden, NW Sweden (the 15 mountain municipalities) and above the mountain forest border (see Figure 1).

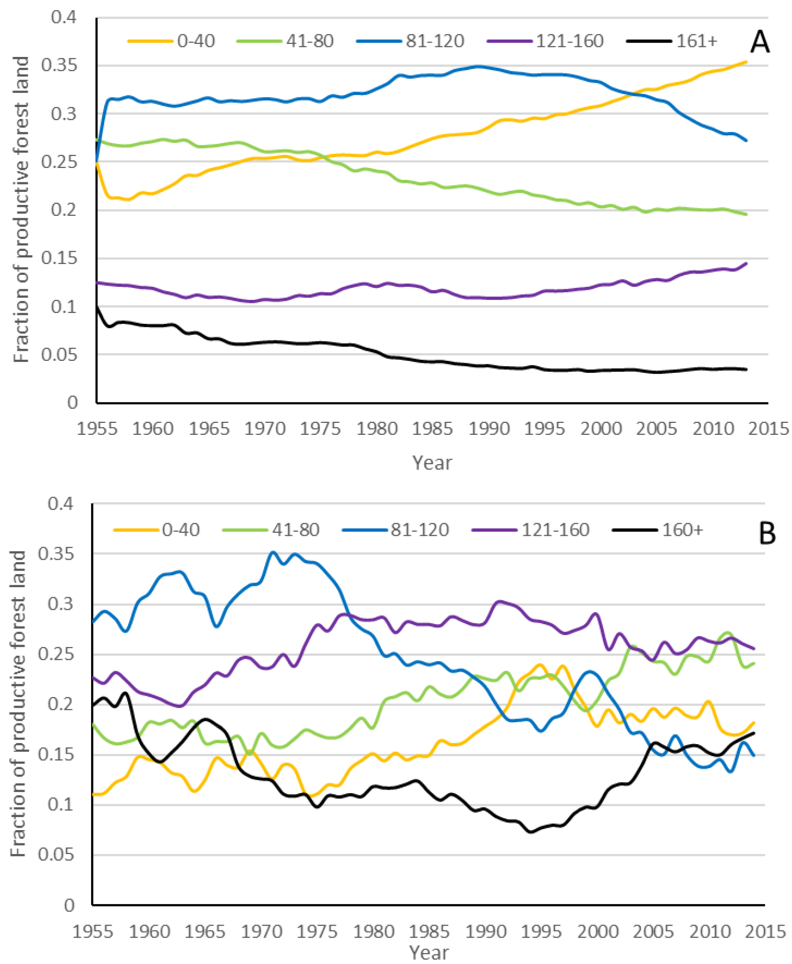

Figure 3. Change in forest age distribution (running 5-year average) based on data from 1955 to 2015 outside protected areas for (**A**) north Sweden and (**B**) the area above the mountain forest border (MFB); data from the Swedish National Forest Inventory (NFI). Data from the area above the MFB are based on fewer field sample points in the NFI and hence show larger statistical variation.

Despite the strong dominance of old forests above the MFB, the total standing volume per hectare is still lower than in north Sweden and similar to NW Sweden below the MFB. Tree species composition shifts from pine to spruce dominance above the MFB (Figure 4). The difference in natural disturbance regime (low frequency of fires above the MFB), together with topographic and edaphic factors, is the main reason for a larger share of spruce forests above the MFB.

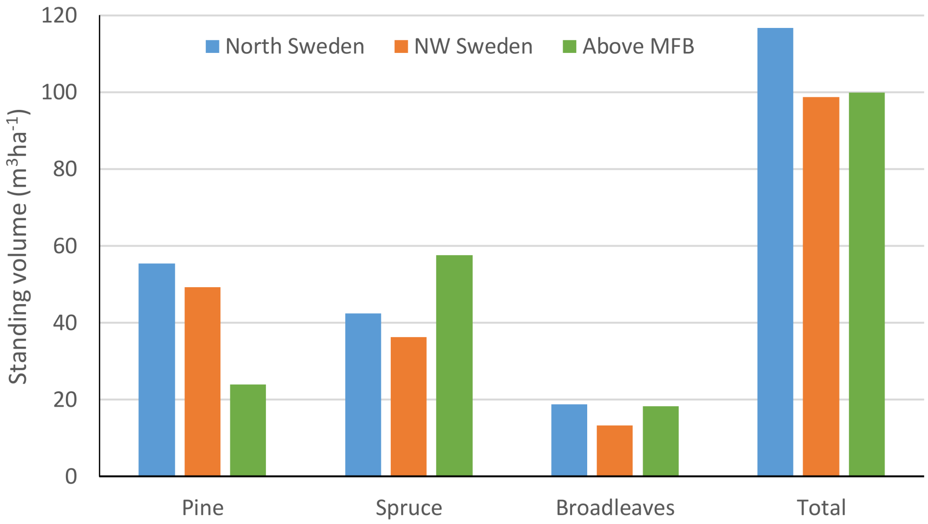

Figure 4. Standing volume of living trees per hectare based on the Swedish National Forest Inventory (5-year average) for all forests in north Sweden, mountain municipalities (NW Sweden) and the area above the mountain forest border. Only forests outside protected areas included.

Of the productive forestland, 24% is owned by non-industrial private forest (NIPF) landowners, 11% by private forest companies and the remaining 65% are owned by other owners, out of which the Swedish State owns the vast majority. As a large fraction of the State forestland is formally protected (Figure 5), the remaining unprotected productive forests are mostly owned by non-industrial private landowners (53%), whereas 14 % are owned by private forest companies and 33% by other owners, mainly by the State [50]. Compared with north Sweden and NW Sweden below the MFB, the ownership situation and allocation of protected areas are quite different in the region above MFB. For example, only 0.5% of all formally protected productive forests in NW Sweden below the MFB is on private company land, another 0.5% on non-industrial private land, and 3.6% on public ownership. The corresponding proportions for all forestland (i.e., both productive and non-productive) are very similar (0.6%, 0.6% and 4.1%, respectively).

Based on the NFI data (2012–2016), 9.1% of the total forestland and 6.3% of productive forest in north Sweden is formally protected. However, there is a clear difference between the proportions of formally protected forest above the MFB (48% of all forestland and 43% of productive forests; Table 1) and below it (3.1% and 2.8%, respectively). The updated protected area statistics [50] show that, additionally, more than 400,000 ha of forestland including 145,000 productive forestland is protected, resulting in 56% and 53% being protected and set-aside areas above the MFB, respectively. However, the figures from NFI and SCB (see Table 1) are not fully comparable because the latter figure also includes State forests in the process of being protected. It should be noted that in some of these protected forests, forestry operations are allowed. This fraction is quite low, about 1000 ha out of 516,000 ha located in national parks and nature reserves above MFB, but can be assumed to be higher in nature conservation agreements covering about 13,000 ha productive forest and 20,000 ha total forest area above the MFB [50]. In addition to formal protection, certain areas are also voluntarily protected by landowners, ranging from 3% of all forestland in north Sweden to 7% above the MFB (Table 1).

The mountain forests border regulation has had a clear effect on limiting forest harvesting in the mountain forests compared to the rest of Sweden. This is evident from the gradual decrease of this estimate of the annual final felling rate in forests west of the mountain border (mean 0.11%, based on 84 grid cells sized 25 × 25 km) compared into the rest of NW Sweden (0.64%, based on 126 grid cells sized 25 × 25 km) and in, north Sweden outside NW Sweden (mean 0.91%, based on 226 grid cells sized 25 × 25 km) and southern Sweden (0.90 % based on 352 grid cells sized 25 × 25 km (see also Figure 6). Regulation through the mountain forest border has thus supported the conservation of mountain forest landscape values.

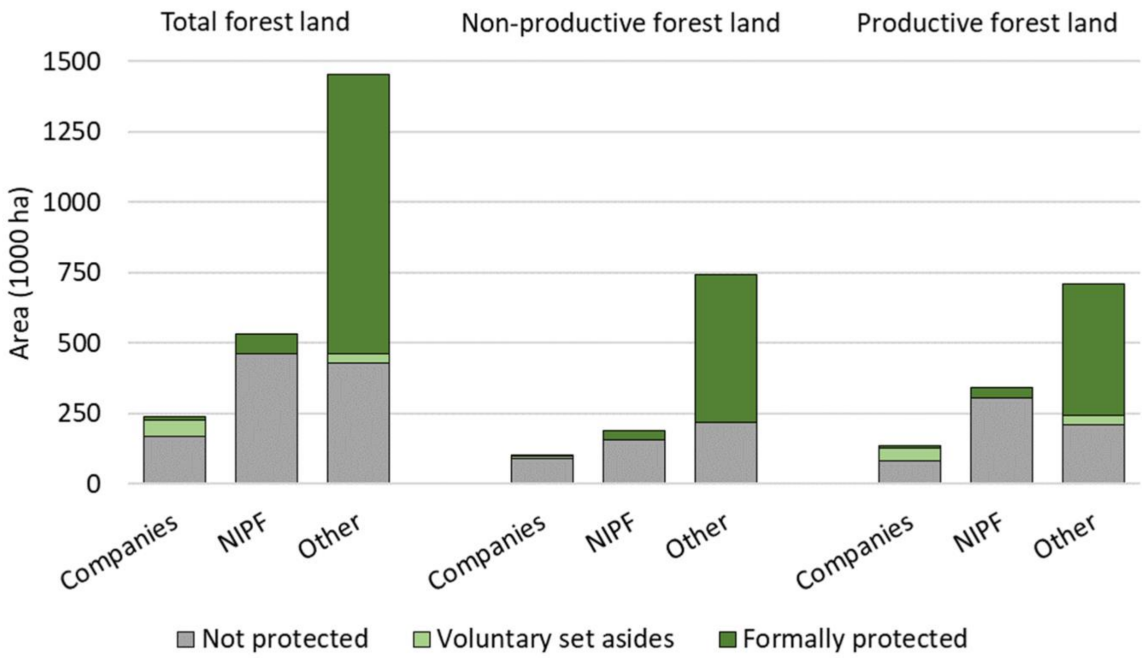

Figure 5. Distribution among land-owner categories of not protected, voluntary set aside and formally protected total forestland and productive forestland area for the region above the mountain forest border. Category "private companies" include stock-holding companies whereas category "NIPF" (non-industrial private forest landowners) does not. The category "other" combine public and collective ownership including the Sveaskog state forest company, the National Property Board, regional and municipal ownership, forest commons and other in-common forest estates, and church ownership. Data was extracted from the Swedish National Forest Inventory 2012–2016 (5 year average).

Data from the Swedish NFI [40] shows that 198,870 ha of mountain forests were harvested 1955–2016, of which the absolute majority before 1995 (177,846 ha or 89%), corresponding to an annual harvest rate of 0.37% (Figure 7). Forest harvesting decreased, and seemingly even stopped temporarily in the beginning of 1990s, and has since 1995 been at levels of 0.14% per year in productive forestland outside protected areas [40]. This can be compared to the average rate of 0.7% annually harvested area in north Sweden [57], but locally with rates >1.5% (Figure 6). The Swedish Forest Agency provides data on forest owners' application for harvest permits for final felling above the mountain forest border from 1995. The permit rate has been rather constant over time, with around 3000 ha harvested annually and with a higher share for private forest owners compared to other owner categories. The clear difference between the area applied for final felling (67,000 ha) and the area where this was realized (25,000 ha), indicates that the regulation of harvesting above the MFB has had an effect.

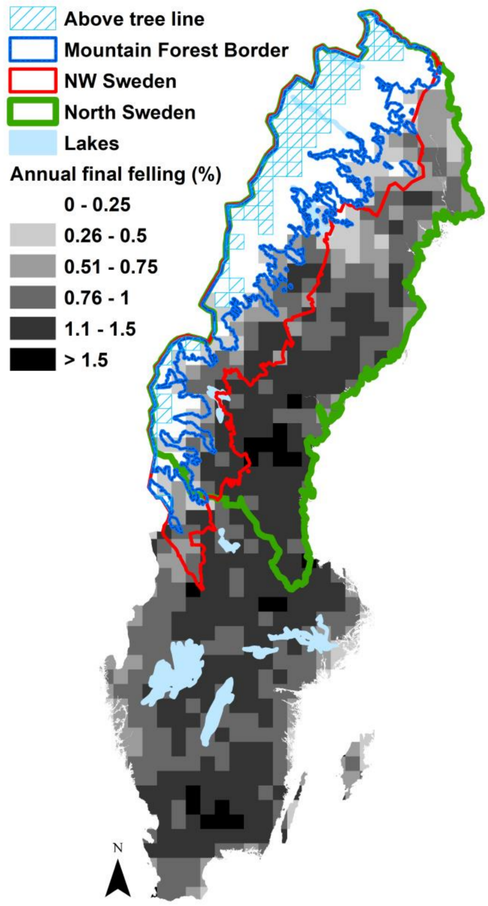

Figure 6. Mean annual forest loss [defined in reference [54] as proxy of the annual final felling rate in percent. Overall, 93% of forest loss is clear-felling and the rest to is linked to forest fire and windfall. A mean harvest rate of one percent corresponds to a 100 year rotation time in even-aged industrial forestry. The grid cell size is 25 × 25 km.

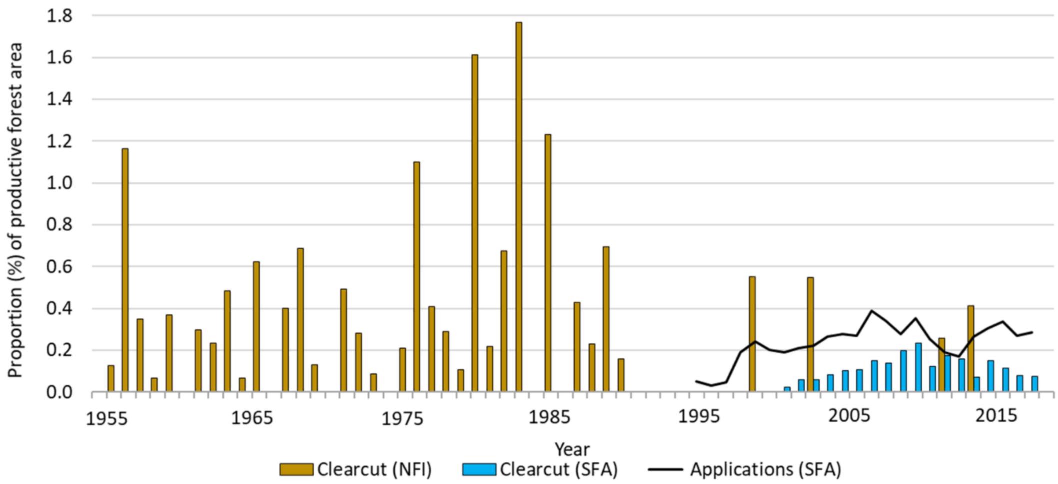

Figure 7. Annual clear-cut area 1955–2018 above the mountain forest border based on plot-based field data from the Swedish National Forest Inventory, annual clear-cut area 1995–2018 based on the Swedish Forest Agency statistical database [51], and annual clear-cut applications 1995–2018 based on the Swedish Forest Agency statistical database [51]. Note that clear-cut applications do not necessarily become clear-cut the same year as the application was registered, and that a proportion of the applications do not result in clear-felling.

Analyses based on remote sensing covering the period from 1955 to present suggest that about 17% of the productive forest above the MFB has been harvested [52]. Given that currently (December 2018), 52.5% is formally protected or in the process of being protected, and that 7% is voluntarily set aside, only around 23% of the productive forest above the MFB is currently available for forest harvesting – an area corresponding to roughly 300,000 ha (Figure 8). Available statistics does not allow a detailed analysis of landowner structure of this remaining area for harvesting. It can be assumed, however, that the ownership pattern mirrors that of productive forests outside formal protection (see above), i.e., with the State still being a significant owner.

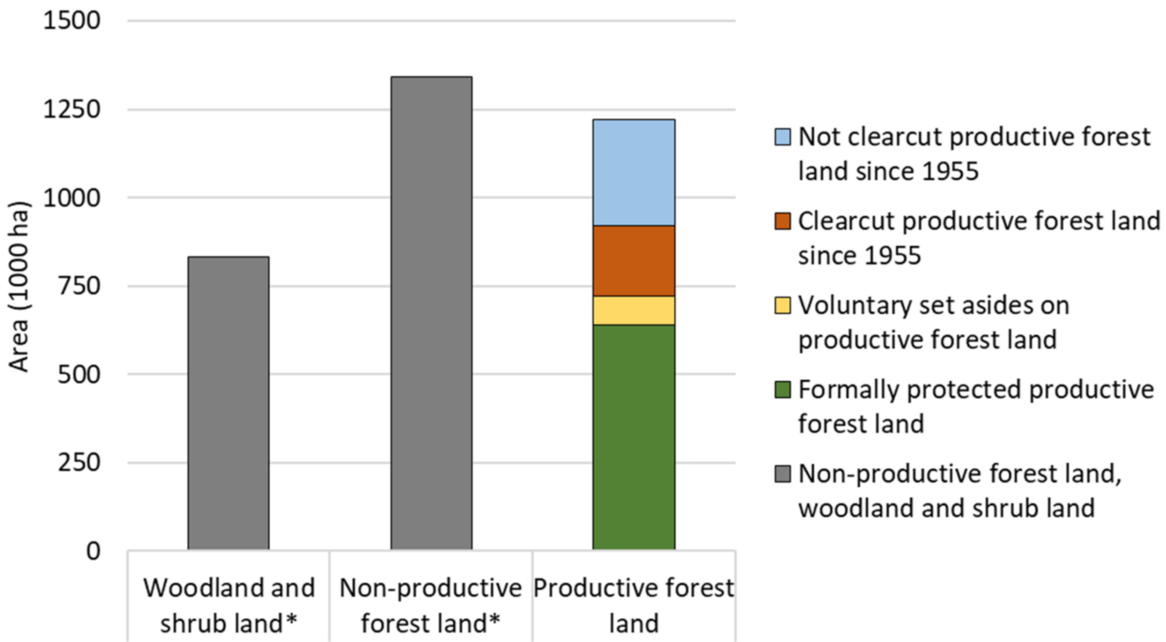

Figure 8. Area distribution in the region above the mountain forest border of woodland and shrub land (*), non-productive forestland [53], protected productive forestland [50], clear-cut productive forestland since 1955 [57], and not clear-cut productive forestland since 1955. Data on productive forestland (1221 × 10^3 ha) is according to NMD [53]. * Data on woodland and shrub land is our interpretation of the difference between two forests layers (one from NMD [54] and one from the National Land Survey) and should be regarded as provisional. Open land can occur to some extent in both categories, and the division between the two categories is not firmly assessed.

3.2. Policy Development to Regulate Land Use

There is a long history of regulation by separating areas for different types and intensities of land use in NW Sweden. One example is the regulation between Sami reindeer herding in the mountain areas and large parts of the inland of north Sweden, and an expanding farming with animal husbandry and later agriculture at lower altitudes in river valleys and coastal areas. Already in 1673, 1695 and 1749, ordnances regulated the border between Sami land use, and land where colonization by non-Sami people from Sweden and today's Finland should be encouraged [33,58,59]. Later (1751–1753), the first restriction emerged regarding how far into Sami land agricultural development should be encouraged. To protect land for reindeer grazing, a border limiting agricultural development was defined in 1867 and 1890 [60].

Another example of a regulative border emerged in the 1903 Forest Act, when the frontier of selective felling of large trees had reached the mountain forests, and clear-felling methods and active silviculture were gradually introduced to north Sweden. The regulation concerned so called "protective forests", was valid from 1903 to 1923, and required a permit to be granted by the state. The purpose of this regulation was to avoid a lowered tree line due to clear-cutting and subsequent artificial-regeneration failure in the mountain forests, and in south Sweden to reduce the risk of spreading sand dunes and other degeneration and loss of forest land [61]. Additionally, the concept of "forest difficult to regenerate" was subsequently introduced as a biologically founded regulation in the 1923 Forest Law, with the aim of securing regeneration in the mountain forests, and avoiding downward expansion of treeless mountain vegetation. These two types of regulations were confirmed in the 1948 Forestry Act. The locations of "forest difficult to regenerate" were defined in 1951–1954. The Swedish Forest Agency was commissioned to review the need for keeping this regulation in 2007, in line with the process of general forest deregulation in Sweden since 1993. The reason for this was that delineation of high elevation and climate-constrained forest areas that were difficult to regenerate artificially was viewed as a policy restricting the introduction of clear-felling and subsequent regeneration [62]. A forest border commission [63] proposed to remove this regulation, primarily by removing the need for a permit to harvest. Instead, an application for harvesting, with passive acknowledgement by the Swedish Forest Agency unless harvesting was not permitted, should be introduced. This passive acknowledgement has generally been standard in Sweden since 1974. Following the abandonment of the "forestland difficult to regenerate" policy in the 1970s [40,63], forest harvesting expanded during the 1970s and the first half of 1980s to higher altitudes and westward into previously inaccessible areas with unexploited mountain forest landscapes [16,18,40].

Finally, regulation has been used to support biodiversity conservation by establishing the mountain forest border. The abandonment of implementation of the "forestland difficult to regenerate" policy in the 1970s caused a rapid loss of intact forest, which, in combination with an active environmental movement, resulted in a heated media and parliamentary debate [64]. A parliamentary decision was made in 1985 [40] to promote a more nature conservation-oriented policy. In 1988 von Sydow [41] argued that only half of the productive forestland remained in a contiguous and intact green belt, which needed to be conserved by re-defining a border restricting forestry. In 1989 the Member of Parliament Ragnhild Pohanka argued that "*in reality the decision* (taken in 1985; see [40]) *is a failure. Presently, more than 14,000 ha mountain foothills forests have been harvested, which equals 13 ha every day the year around*". Eventually, the mountain forest border (MFB) as it is today was established [62,63] based on a recommendation by von Sydow [41]. It became recognized in the 1991 Forestry Act as a new legally-defined border delineating an area with a more strict forestry regulation (see Figure 1). The MFB was confirmed by a Border Commission (Sw: Gränsskogsutredningen) in 2009 [63]. In the current Forestry Act (2018), Section 15 states that the Swedish Forest Agency (SFA) has to explicitly approve harvesting above this border instead of passively acknowledging applications as is the standard below this border, and Section 18 states that the Agency can prohibit harvesting if values associated with nature conservation, cultural heritage and reindeer husbandry may be negatively affected. An outcome of the 2009 Border Commission [63] was the notion that the Swedish Forest Agency had never, to that point in time, prohibited clearcutting above the mountain forest border [41]. Data on clear-felling applications, available since 1995 with the first years being incomplete, indicate that in total 38,000 ha of final felling were applied for to and including 2018, of which 11,000 ha have been realized [51]. From 2010 up to 2017, SFA rejected 96 out of 2170 applications, equal to about 3000 ha of a total of 25,500 ha. To conclude, the mountain forest border has thus had the function of a conservation tool. As a consequence, the landscapes above the mountain forest border clearly shows high or very high nature conservation values compared with the landscapes below the border (Figure 6).

3.3. Implications of the Änok Case

To illustrate the complexity of policy implementation and decision making on forest management west of the mountain forest border, this section reviews a specific event of certain importance for policy implementation – the "Änok case". The Änok river delta is a privately owned enclave surrounded by nature reserves (e.g., Kvikkjokk-Kabla reserve) located in the north-westernmost mountainous part above the mountain forest border in the Lule River catchment in Norrbotten County. Änok is recognized as an area with high nature conservation values at levels that are not different from the values in the nature reserves. The Swedish Forest Agency (SFA) has registered woodland key habitats on more or less the whole Änok enclave [65]. The Änok case has influenced and formed the whole process of forest policy enforcement, governance principles, and decision making on forest harvesting above the mountain forest border. In its extension, it has also influenced the current debate on the continuation of the inventory of high conservation value forests in northwest Sweden; the woodland key habitat inventory, e.g., [66], and the cancelling of the inventory in 2019 [67].

In 2001, applications for clear-felling in the Änok area were submitted to the Swedish Forest Agency. Following Claesson [40], in 2010, i.e., after 10 years of handling, SFA approved the application. The Swedish Society for Nature Conservation (SNF) appealed to the Administrative Court (Sw: "Förvaltningsrätten"), which determined that the SFA approval was not correct. Following this, both the SFA and the land owner appealed to the Administrative Appeal Court (Sw: "Kammarrätten"), which abated the Administrative Court decision based on a declaration that SNF was not to be considered as a formal stakeholder with the right to appeal the SFA decision. In the next step, SNF appealed to the highest court level, the Supreme Administrative Court (Sw: "Högsta förvaltningsdomstolen"), which abated the Appeal Court decision based on their declaration that SNF is to be considered as a formal stakeholder, and returned the case. In its second examination, the Administrative Appeal Court changed their earlier decision and confirmed that the SFA harvesting approval was not correct. In the final step, the SFA appealed again to the Supreme Administrative Court, which in the beginning of 2015 declared that the case was not approved for further judicial processing. Thus, after one and a half decade of processing, the forest harvesting in Änok was formally and judicially not approved. Änok became a guidance-case for a strict enforcement of the forest law regulations, sections 15 and 18, on harvesting above the mountain forest border.

Here, the story could have ended. However (following Claesson [40]), the question on the land owners right to economic compensation for rejected forest harvesting (Section 19 of the forest law) was recently raised and became subject to a new judicial process. The SFA decided to deny compensation for rejected harvesting above the MFB in November 2016, with the argument that the land owner authority and stakeholder rights for economic compensation as a consequence of rejected harvesting, needed to be investigated. Following this, 25 land owners pressed charges against the State, as represented by the SFA through the legal, financial and administrative services agency (Sw: "Kammarkollegiet"). The District Land and Environmental Court (Sw: "Mark- och miljödomstolen") declared in January 2019 that rejected harvesting should be followed by economic compensation. In the next and still not completed step, the SFA has appealed this decision to the Land and Environmental Court (Sw: "Mark- och miljööverdomstolen"), which in 31 May 2019, approved continued judicial processing.

The Änok case initiated a now close to two decades' long process on how the current strict policy on forest harvesting above the mountain forest border should be applied, judicially and in practice. In order to finally reveal the combatting arguments, knowledge on conservation values relative to rural sustainable development based on different value chains needs to be fed into the process and further explored.

4. Discussion

4.1. The Swedish Mountain Forest Landscapes and Their Conservation

With a European Union perspective, the Scandinavian mountain forest green belt provides unique opportunities for conservation of biodiversity, maintenance of ecological integrity and resilience capacity to climate change. Extending ca. 1000 km from north to south and with considerable altitudinal variation, this green belt is more likely to cope with climate change than other mountain areas in the EU. The reasons for this are that the latter have a west-east orientation and are fragmented by anthropogenic infrastructures. Hence, species adapted to cool forests have more limited dispersal opportunities.

From this conservation perspective, the effect of the mountain forest (Sw: fjällnära skog) border policy in Sweden is a noteworthy example of effective state regulation. Clearly, this regulation has helped to secure the Swedish natural and near-natural mountain forests. Currently, 56% of total forestland and 52% of the productive forestland is formally protected, and an additional 4% and 7% are voluntarily set aside areas. Furthermore, the spatial configuration of formally protected and voluntarily set aside areas is favorable in the mountain forest region with 95% of the area being functionally connected for focal species, as opposed to from only 36% to 66% in the other Swedish forest regions [18].

As exemplified by the Änok case, the implementation in practice of the regulation of forest harvesting above the MFB has not been and is still not without complications. Although this regulation was included in the forest law already in 1991, the Swedish Forest Agency did not prohibit any harvesting before 2010 [40]. The Änok case, which commenced in 2001, also points to the fact that the authority with decision-making mandate – the Swedish Forest Agency – is not equipped with established routines to exercise existing policy. It took a decade from the submission of the harvesting application in Änok to the first decision to approve harvesting, and following this the process continued into the current decade with an endless judicial process involving all court levels in Sweden. At present (31 May 2019), the decision to continue the process even further has been made. The policy routines following the 1991 parliamentary decisions are thus still, almost 20 years later after this case commenced, being shaped by judicial processing. Clearly, implementation in practice of the policy regulating forest harvesting above the MFB is difficult, which opens up conflicting views and heated debates.

The Swedish mountain forests currently figure in the debate about intensified forestry to support an expanding bio-economy policy trajectory, and in narratives supporting the freedom of land owners to decide about how their land should be managed and used [68]. The debate also relates to the role of forests for climate change mitigation through carbon sequestration in forests and subsequent wood-based processed products. The Swedish mountain forests provide a large existing carbon sequestration function associated with high organic stock in old-growth forests and soils, see also [6]. Given low productivity of mountain forests, the recovery after harvesting may take centuries, e.g., [7]. This supports climate mitigation arguments against harvesting remaining intact mountain forests.

Also, traditional wood-based economic motives cast doubts on the long-term benefits of harvesting mountain forests. Recent shutdowns of forest industries in NW Sweden hamper the availability of traditional forest-sector job opportunities. Additionally, remnant, often low productive, stands are located far from forest industries at the coast and with associated high transportation costs. Some of these areas are also located in difficult terrain and locations, such as in steep areas or as forest islands in mire complexes, that cannot be reached without extraordinary investments. Nevertheless, and in spite of reduced availability of forest mature for final felling, harvesting of mountain forest is advocated by industrial actors operating on distance. With low economic return and long transporting distances to industries in the coastal parts of north Sweden, harvesting the last mountain forests this represent a wave of "wood mining" as in other regions with large intact forest landscapes [69].

4.2. Alternative Forest Value Chains

The use and benefit profile of forest resources (goods, services, and values) is dynamic in time and space. This has resulted in heterogeneity of products over time across the European Union and elsewhere globally, e.g., [70,71]. The trade of timber, forest biomass, intermediate and final forest products has increased due to globalization, trade liberalization and political integration in Europe, especially of the new EU member states [72]. This phenomenon follows the Ricardian theory of comparative (cost) advantages, which are realized through specialization on different steps of the value chain, and has lowered EU and national dependency on regional provisioning ecosystem services, which in turn is leading to changes in land use. This phenomenon also has economic (e.g., number and types of forest-related jobs and qualification levels, degree of regional value creation), socio-cultural (e.g., resource sovereignty, social capital, education levels, changes of social landscape values and preferences), and ecological impacts (e.g., gain and loss of biodiversity) [73–75]. Traditional wood-based economic value chains are often in conflict with value chains based on socio-cultural and ecological benefits [76]. Thus, there is an urgent need to identify methods for comparing wood/biomass-based value chains and new value chains that take into account both direct benefits (such as wood or mushrooms) and indirect benefits linked to immaterial forest values (such as recreation and tourism), as well as non-use and bequest values.

In addition, management of forests above the mountain forest border should be in agreement with one of the Swedish national environmental quality objectives, namely "A Magnificent Mountain Landscape", stating; "*The pristine character of the mountain environment must be largely preserved, in terms of biological diversity, recreational value, and natural and cultural assets. Activities in mountain areas must respect these values and assets, with a view to promoting sustainable development. Particularly valuable areas must be protected from encroachment and other disturbance*" [77]. Intensive forest management will affect the ability of the area to deliver several unique ecosystem services including amenity values. Hedblom et al. [78] showed that "A magnificent mountain landscape" is perceived as an opportunity providing for well-being based on silence, tranquility, wildlife observations and not being disturbed by invasive land uses.

4.3. Ways out of the Deadlock

Effective wood production using clear-felling followed by an efficient silvicultural cycle to satisfy the needs of the forest industry is the overarching objective of the Swedish forestry model. This is currently being questioned [79]. The debate over protection and setting aside forests in Sweden is currently intense, with strong landowner organizations arguing that formal protection and strong legal regulations threatens ownership rights and influence their freedom to manage their forests. This has been particularly evident in relation to the Swedish forests west of the mountain forest border. The narrative is that there is already a significant share of the region that is protected, and that the marginal value of additional set-asides is limited, while the local traditional wood-based economy is dependent on continued large-scale forest harvesting, mainly under control of forest sector actors outside the mountain forest region. This ongoing conflict has spread into the general discussion on how to balance production goals aimed at increased wood production and bio-economy on the one hand, and environmental concern for biodiversity, human well-being, and local perspectives on the Swedish forests at large. Both narratives argue for rural regional development, but from different perspectives.

We see four possible complementary policy and management avenues to support the conservation of the Swedish mountain forests as a base for rural development built on sustainable forest landscape management. First, the State provides economic compensation to affected landowners, and thus gradually sets aside remaining areas of intact mountain forest that form a green infrastructure. Combined with spatial planning to maintain large areas with functional connectivity, this avenue would further strengthen the value of the Swedish mountain forests as a green belt and green infrastructure for sustainable rural development. Second, to introduce alternatives to the dominating even-aged forest management system that is practiced today. This avenue is likely possible in the mountain forests given that they are inherently heterogeneous in layering, spatial heterogeneity and tree species, and are hence suitable for continuous cover forestry and other conservation-adapted forestry systems. Out of the remaining 300,000 ha of mountain forest, large areas are owned by the State; the major owner (National Property Board) has already decided to implement continuous cover forestry, which is practiced traditionally in the mountain forest region [80]. However, there is considerable terminological confusion whereby continuous cover forestry is mixed up with uneven-aged selection felling systems, selective cuttings and high-grading of valuable trees that was common in the area before the 1950s. Also, this second avenue is likely to need support by economic compensation to land-owners, such as in the form of nature conservation agreements. Third, comparisons of wood-based value chains and those based on rural development built on wilderness, nature and culture tourism are needed, which require not only economic valuation [81]. The reason is that economic benefits, and to whom and at what spatial scale, of the remaining natural forests depend on the type of value chain. The fourth avenue is an ongoing expansion of the industrial sustained yield even-aged forest management system into the mountain forest region.

Given the high international-level conservation values [16] and the rich socio-cultural resources of the Scandinavian mountain range green belt, forest-related policy and policy enforcement could provide successful sustainable and multi-objective governance and management opportunities. State authorities and other actors need to be equipped with functional policy directives and tools, which need to be transparent, reasonable and understandable to land owners, the Sami people, local residents, environmental organizations and other stakeholders. This calls for spatial comprehensive planning with higher ambition levels of biodiversity conservation and landscape-level spatial planning that simultaneously considers all aspects of using forestland, including economic and immaterial values such as aesthetics and sense of wilderness [78]. The 15 mountain municipalities of NW Sweden have key but difficult role in exercising their landscape planning mandate [26–29].

To effectively translate EU-wide sustainable forest management and related policies into action in local landscapes, it is crucial to acknowledge that there are different land ownership structures, landscape histories and alternative value chains based on multiple ecosystem goods and services. Therefore, regionally adapted landscape approaches engaging multiple stakeholders and actors through evidence-based landscape governance and stewardship towards sustainable forest landscape management are needed [23]. The mountain forest border represents an example of a regulatory policy instrument that in practice was successfully able to conserve mountain forests in Sweden, which according to Sayer [82], Chazdon et al. [83] and Mansourian [84] is a rarely recognized outcome in practice for policy instruments with such intentions.

5. Conclusions

We highlight the distinctive natural and near-natural qualities of one of very few identified and recognized intact areas in the European Union – the mountain forest green belt along the Swedish eastern slopes of the Scandinavian Mountain range. The rich and multi-facetted values of this area are at stake: current policies about conservation and sustainability are questioned, arguments are raised for intensified industrial forestry, and continued collection and compilation of data on high nature conservation values is put on hold. Thus, accurate and relevant knowledge on the qualities at stake are highly needed for evidence-based decision-making in line with national, EU, Pan-European and global environmental policy.

The remaining about 300,000 ha of so far not harvested mountain forest represents only 0.7% of the Swedish productive forest area, and generally is of low economic value in terms of wood yield (remote location, low rate of wood production). In comparison with continued uncritical use of traditional even-aged forestry aimed at sustained yield wood production, we argue in favor of evidence-based analyses of the economic, ecological, social and cultural consequences of value chains based on wood vs. on landscape values built on amenity values related to biodiversity and wilderness. This requires a dialogue among actors and stakeholders, development and application of expanded continuous forest cover and multiple-use management strategies, combined with further forest protection aimed at securing large intact areas with functional connectivity. These measures yield values on which novel value chains can be built to the benefit of rural development in "cool" forests as social-ecological systems.

Author Contributions: B.G.J., J.S. and P.A. conceived and designed the study. Data collection and analyses was undertaken by B.G.J., J.S., M.M. and P.A. Writing, revision and editing the paper was performed by B.G.J., J.S., G.M., M.M. and P.A.

Funding: B.G.J., J.S., and G.M. acknowledge funding from the Swedish EPA (project NV-03501-15), all from the current Swedish EPA project (NV-03728.17), P.A. acknowledges funding from FORMAS (project number 2017:1342, and M.M. and P.A. from the Lithuanian Science Council [grant number P-MIP-17-210] for the FunGILT project.

Acknowledgments: We thank Svante Claesson (Swedish Forest Agency) and Eva Ahlkrona (Metria) for valuable discussions and support.

Conflicts of Interest: The authors declare no conflict of interest.

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