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Visualizing the Forest in a Boreal Forest Landscape—The Perspective of Swedish Municipal Comprehensive Planning

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Abstract: At the international policy level, there is a clear link between access to information about forests and the work towards sustainable land use. However, involving forests in planning for sustainable development (SuD) at the Swedish local level, by means of municipal comprehensive planning (MCP), is complicated by sector structure and legislation. Currently, there is a gap or hole in the MCP process when it comes to use and access to knowledge about forest conditions and forest land use. This hole limits the possibilities to formulate well-informed municipal visions and goals for sustainable forest land use as well as for overall SuD. Here we introduce an approach for compilation and presentation of geographic information to increase the preconditions for integrating forest information into Swedish MCP. We produce information about forest ownership patterns and forest conditions in terms of age and significant ecological and social values in forests for a case study municipality. We conclude that it is possible to effectively compile geographic and forest-related information to fill the hole in the municipal land use map. Through our approach, MCP could be strengthened as a tool for overall land use planning and hence as a base in SuD planning.

Keywords: sustainable development; municipal comprehensive planning; forest data assimilation; forest change analysis; non-industrial private forest owners; forest values

1. Introduction

The concept and meaning of local ecological, economic, and social sustainable development originates in the general global definition in *Our Common Future*, which states that sustainable development (SuD) is an activity that "meets the needs of the present without compromising the ability of future generations to meet their own needs" [1] (p. 8). Agenda 21, the program of action from the United Nations Earth Summit in Rio de Janeiro in 1992, recognizes the role of the local level for global SuD. Agenda 21 states that local authorities play a vital role in finding solutions for global sustainability-related problems because the problems commonly are rooted in local activities and human behaviors. Local authorities represent the level of governance closest to the people and who simultaneously interact with the public as well as with high-level authorities (regional, national, and international) [2–7]. In addition to the local SuD perspective, Agenda 21 identifies local-based spatial planning as important for SuD work [1,2]. Although the role of spatial planning has been questioned over the years cf. [8,9], it is now recognized as an important political tool for long-term sustainability [10,11]. Typically, in Europe, regional spatial planning is emphasized [12–15] as well as spatial planning led by the public sector [16]. However, to secure relevance in the planning,

local and practical examples are generally considered important cf. [17], and in countries with local self-governance such as Sweden, Norway, and Finland, local spatial planning led by the public sector is also possible to carry out. Thus, we argue that local spatial planning, such as the Swedish municipal comprehensive planning (MCP), can be an effective tool in SuD work if the MCP authorities have access to and can provide information about all types of land use cf. [7,11,18].

In Sweden, municipalities as local authorities have a monopoly on spatial planning, meaning, that they have the responsibility for managing territorial and landscape SuD [7,19,20]. The foundation of the spatial planning system in Sweden is an active and democratic MCP process that aims for overall SuD. The MCP process and document(s) have four main purposes cf. [19,21]:

(1) to give an up-to-date description of present and future use of land, water and the developed environment;
(2) to facilitate communication between the local and national levels about national interests;
(3) to be a strategic and democratic plan for future land use and development and for the implementation of central directives; and
(4) to guide all other planning in the municipality.

In many regions, forests have been identified as a key to fulfilling long-term objectives of sustainability in European societies through their vital role for socio-economic viability as well as for ecosystems [13,22,23]. Thus, knowledge about actual forest conditions and how they have developed is important. As the development of forest conditions is highly affected by the management performed by its owners within the legal frames and policies set up by the state, the owners and their management objectives need to be recognized. Furthermore, it is well known that different forest owners have different objectives and management strategies [24,25], so forest conditions reflect not only present but also past ownership structures [26]. Forest condition also reflects the role of the forest and its use in the overall development of society. For example, in Sweden, commercial use of forest land for timber production has been a main industry for over 100 years, and thus forestry constitutes a strong sectoral interest [27,28]. This has been the case for the 40% of forest land owned by private or state-controlled companies and the 50% of land in the hands of non-industrial forest (NIPF) owners [29,30].

From a European perspective, Sweden is sparsely populated, forest-dominated, and a forestry-dependent country [22] and the further north, the more sparsely populated and the more forest per inhabitant. Generally, the mechanization of forestry operations and concentration of forest industry has contributed to population declines in many municipalities in the north [31]. Clearly, these circumstances influence on the overall SuD of a municipality. When it comes to the most rural and boreal municipalities, NIPF enterprises constitute about half of all the local small businesses and thereby influence the socio-economic structures and cultural expressions of the local society [29,32–36]. Furthermore, several studies show that local tax revenue as well as the development of the local economy and culture is influenced by whether the forest owner lives in the municipality where the forest property is located (resident owners) or lives outside the municipality (non-resident owners) [24,29,37,38]. Regardless of residency, how forest owners use their forest resources indisputably affects large areas of a municipal territory. Given the prevailing rotation management practice, about 1% of the productive forest land is subjected to final felling every year, while another 3% is cleaned or thinned [39]. Overall, these activities significantly contribute to the landscape's characteristics.

On forest land, spatial planning is carried out on the estate level guided by the objectives of the owner, often expressed in a forest management plan (FMP), with a forestry sector focus and limited landscape consideration. In Sweden, the FMP is governed and regulated by the Forestry Act [40]. The regulations in the Act parallel regulations in the Environmental Code [41], and the Environmental Code regulates any forest land practices not regulated in the Forestry Act [19,40–42]. However, the provisions in the Environmental Code do not apply to on-going land use and final felling, issues that fall under the authority of the Forestry Act. The Forestry Act prioritizes the forestry practices

of the owners of forest properties, ignoring or at least de-emphasizing land uses such as reindeer husbandry and recreation. Nevertheless, the government and government agencies can appeal to the Environmental Code to designate forest land as a national interest from some aspect of land use other than forestry. According to adjustments to the Forestry Act in 1993, forest management should be carried out with equally valued targets regarding production and preservation of biodiversity. Yet, the increasing recreational and social demands on forest land have initiated a discussion whether social values should complement these stated targets [43]. Forests that hold (or may develop) high social values are characterized by their proximity to habitation, accessibility, and variation in tree composition that includes a predominance of large and old, so-called vital trees. These forests should maintain their natural and aesthetic qualities and be managed to keep (or further develop) these qualities [44–46]. To ensure these requirements are satisfied, authorities and the public need access to detailed knowledge about where to find these forests and who owns them as well as the tools that will encourage more integrated spatial planning.

In contrast to sectorial planning, MCP should include all the important land use activities and needs that occur within a municipality's territory [19,41]. We argue that the municipalities need reliable and continuous data of all kinds about land use to develop effective MCP. Yet, as discussed by Stjernström et al. [43] and Bjärstig et al. [47], MCP provides limited integration of forest land such as agriculture, reindeer husbandry, mining, and wind power development. However, MCP is clearly influenced by the business sectorization of authorities and data (general information, statistics, geographic data, etc.) and by property rights and other legislation [48]. Sectorization makes it difficult to develop a more holistic view of natural resource use in society, the aim of MCP [35,49,50]. In present planning processes, property rights have a strong position relative to the public interest. However, the balancing act between property rights and the public interest is formally handled in the public planning process through the possibility of expropriation if the public interest is endangered or limited [43]. Laws and regulations associated with the environment and spatial planning separate forestry interest from the public planning to protect property rights and forest production [42,43]. Nevertheless, MCP aims for sustainable development, which implies planning for vital natural ecosystems, sustainable land use, social services, and infrastructure. This planning should be done for the benefit of all local inhabitants and businesses, including forest owners and forest enterprises, with consideration to regional and national policies and goals [21,29,35,51]. One argument for incorporating information about forest land use into the MCP is therefore the prospect of finding a more equal balance among the interests of private land owners, the public, and the state. A concrete example from the Swedish case is the Swedish practice of the Right of Public Access, which is commonly accepted by the public as well as by all forest owners. In many ways, this practice is a prerequisite for various land uses such as organized as well as privately-conducted recreational activities and tourism (which should be strategically planned for in MCP), but to some extent it limits property rights [19,52]. Furthermore, areas of national interest—e.g., natural and cultural environments, recreation, reindeer husbandry, wind and hydro power production, and mineral deposits—should be addressed in the MCP [19,41], often affecting property rights. The same situation applies for the legal rights of reindeer husbandry on all land within the official reindeer herding area, which covers half of Sweden's land area [53].

To conclude, there is a clear link between access to information about forests and the work towards overall sustainable development at the European and Swedish national policy levels. However, when it comes to MCP, as SuD planning at the local level, the relationship between the municipalities and the forest sector (among other land use sectors) is complicated by sectorization, property rights, and other legislation. This causes a hole in the MCP when it comes to basic information about forest conditions and integration of forest land use. The limitation that this has on MCP makes it difficult for the local government to formulate well-informed municipal visions and goals for sustainable forest land use, particularly for forest lands with multiple land use claims, and for overall SuD.

Given the extent and importance of the use of forest lands in Sweden, we intend to illustrate how a local government responsible for territorial SuD by means of spatial planning (including MCP)

can access relevant knowledge about local forest conditions, forest uses, and its forest owners. Such knowledge is important for improved communication and for informed standpoints throughout the MCP process. Thus, we use data overlay and spatial analysis to produce information and to identify issues related to the use of forest lands of high relevance in the MCP process and to examine how these issues can be addressed. By applying such an approach, we intend to compile, analyze, and communicate the following information:

- Current land ownership patterns: Within a municipality, who owns the forest lands and how much do they own?
- Present forest conditions: How old is the forest and which owner category does the owner belong to? (This information determines how the forest can be used today and by whom.)
- Ecological and social values: Where are the forests located that offer the most significant ecological and social values, and who owns these forests?

Finally, we discuss how information from overlay and spatial analysis of geographical data on forest ownership and forest conditions; the Forest Data Assimilation Approach (FoDAA), can be used and evaluated. We also discuss ways local governments (municipalities) can increase their knowledge about local forest ownership and forest land use. Furthermore, we discuss how methods and knowledge, such as the ones presented in this study, can aid the MCP process.

2. Materials and Methods

2.1. Case Study Area

Vilhelmina municipality in Västerbotten County in northern Sweden represents forest-dependent northern Swedish municipalities both from a spatial planning perspective and from a land use perspective. Primary laws regulating municipal spatial planning and forestry are the same all over Sweden. From a European perspective, most Swedish municipalities are defined as rural, and in terms of population density Vilhelmina is among the least populated, with less than 1 person/km^2 [54–56]. However, during high season the population in some villages in the mountain region can significantly increase due to tourism and people staying in their second home residences [57,58].

The municipality extends from the Norwegian border in the northwest through high and low mountainous regions, descending to mires and forests in the southeast where about half of the 6700 municipal inhabitants live (almost exclusively in the community center). The municipality covers more than 8700 km^2. Almost 670 km^2 is water. Mostly located in the western part, 16% of the municipality area is protected as nature reserves and other types of legal protections. Over 4000 km^2 are boreal forest land and of this area 3150 km^2 are classified as productive forests cf. [25]. Compilations and analyses for this study are made for the entire municipality as well as for our focus study area, which is in the eastern half of the municipality (4170 km^2 of which 2670 km^2 is forest land) (Figure 1).

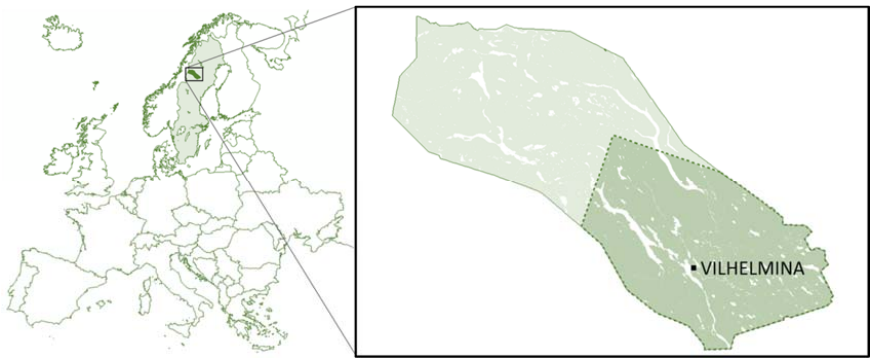

Figure 1. The location of Vilhelmina municipality (Sweden) and our focus study area within the municipality.

The area has a long history of diverse uses of the forest landscape. The first inhabitants were fishers and hunters tracing back to about 10,000 years ago [59,60]. These people eventually turned to seminomadic reindeer husbandry to make a living [53,61–63]. Today, reindeer husbandry is practiced across Vilhelmina municipality as well as the entire northern half of Sweden. Legally protected, and alongside many other land use forms, reindeer husbandry receives access for grazing on public as well as private land. Incorporating reindeer husbandry into comprehensive land use planning therefore requires a full understanding and evaluation of all forest lands. In addition to reindeer husbandry, Vilhelmina has a tradition of farming. The first farmers settled in the Vilhelmina area in the middle of the 18th century [64]. Eventually, forestry came to dominate the area. Between the 1850s and the 1950s, selective forestry was the common practice since the settlers mainly used the forest for building materials, fuel wood, and grazing [65]. In 1958, the first application for clear cutting was submitted to the Swedish Forest Agency (SFA). Since then, stand replacement forestry followed by intensive reforestation efforts using soil scarification, planting, and sowing have been the common practice and a major industry [65,66]. Large parts of the river system of Ångermanälven within Vilhelmina municipality were affected by timber rafting (until the 1950s) and the construction of hydro power plants and reservoirs (between the early 1940s and the 1980s) [67]. There are a few wind mills (five) in the area, but wind farms with a total of about 200 wind mills are waiting for approval [68,69]. During the 1970s and 1980s, there were some mining activities in the mountain area. Today, there are no active mines, but there are several ongoing explorations [70,71]. Based on property rights and the Right of Public Access, recreational activities such as fishing, hunting, berry picking, snow mobile driving, skiing, and hiking are conducted throughout the area in private as well as commercial contexts [72–76].

2.2. Geographic Data on Forest Land Use

Satellite images are useful sources for forest resource assessment in general [77] and archives of satellite imagery can document land use activities. Accordingly, we use changes in satellite imagery to map forest areas that have been subjected to final felling. That is, we use results from a change detection analysis of a time series of satellite images to date forest patches subjected to final felling for the image pairs 1973–1986, 1986–1990, 1990–2000, and 2000–2014 [78]. For the period 1958–1973, this Forest Change Analysis (FCA) was supplemented with other satellite imagery information [79] and data from the National Forest Inventory [80]. Specifics of the process are summarized by Svensson et al. [78]. Based on detected and dated final felling, we know when new forest stands were established and consequently we know the forest age. We compiled such information for all forest land in our focus study area and for different forest owner categories.

Data on forest cover for Vilhelmina municipality was retrieved from the Swedish roadmap (1:100,000) [81]. A property map with property id-numbers was provided by Vilhelmina municipality [82]. Information about forest owners within Vilhelmina municipality was provided by the SFA [83]. The information links forest owners to their properties through property id-numbers and provides general forest owner classification as well as postal codes. We used this information to categorize the forest owners: state, company (i.e., large-scale forest enterprises), community (a large forest common, the municipality, and a few village commons), non-industrial private forest owners (NIPF), and others. The NIPF category was subdivided into resident owners, non-resident owners, and mixed (based on residency within or outside the municipality or if the owners were a mix of both residents and non-residents). The ownership situation reflects the status for January 2016 [81–83].

In our analysis, we included geographic data on formally protected areas to indicate areas of primarily high ecological values. From the County Administrative Board (CAB) [84], we obtained data on nature reserves; from the SFA, we obtained geographic data on forestry-related types of formally protected areas—i.e., biotope protection (*biotopskydd*) and nature management agreements (*naturvårdsavtal*) [85,86]. Historical or cultural sites in the forest landscape were downloaded from the SFA [87]. Additional data describing ancient monuments and other cultural relics were obtained from the Swedish National History Board (*Riksantikvarieämbetet*) database *Fornsök* [88]. In terms of social

values, Hörnsten and Fredman argue that forest areas within 300 m and up to 1 km from residences are the most significant to people [89] as such areas are very likely to be used for recreational purposes like berry and mushroom picking, hiking, and skiing. In this study, we map these areas based on housing data produced by Lantmäteriet and provided by Vilhelmina municipality [90]. Hunting and snowmobiling are recreational activities conducted widely within Vilhelmina Municipality, not just within a kilometer from residences. We obtained non-official digital data of snowmobile tracks on forest land from Vilhelmina municipality. Regarding hunting (large and small game), there were no relevant data available for analyses. Hunting is performed on virtually all land but the hunting season differs depending on the game and is regulated by law [91].

2.3. Data Overlay

To meet the municipal need for basic information about forest conditions and ownership status for integration into MCP, we performed several data layer overlays in a geographical information system (ESRI ArcGIS) by means of what we call the Forest Data Assimilation Approach (FoDAA). We combined results from FCA with official property data, information on forest extent, protected areas, historic/cultural sites, and relics and geographic data on permanent and second-home residences and snowmobile tracks (Figure 2). Using this approach, we obtained specific information about the forest and individual forest owners (e.g., forest owner category).

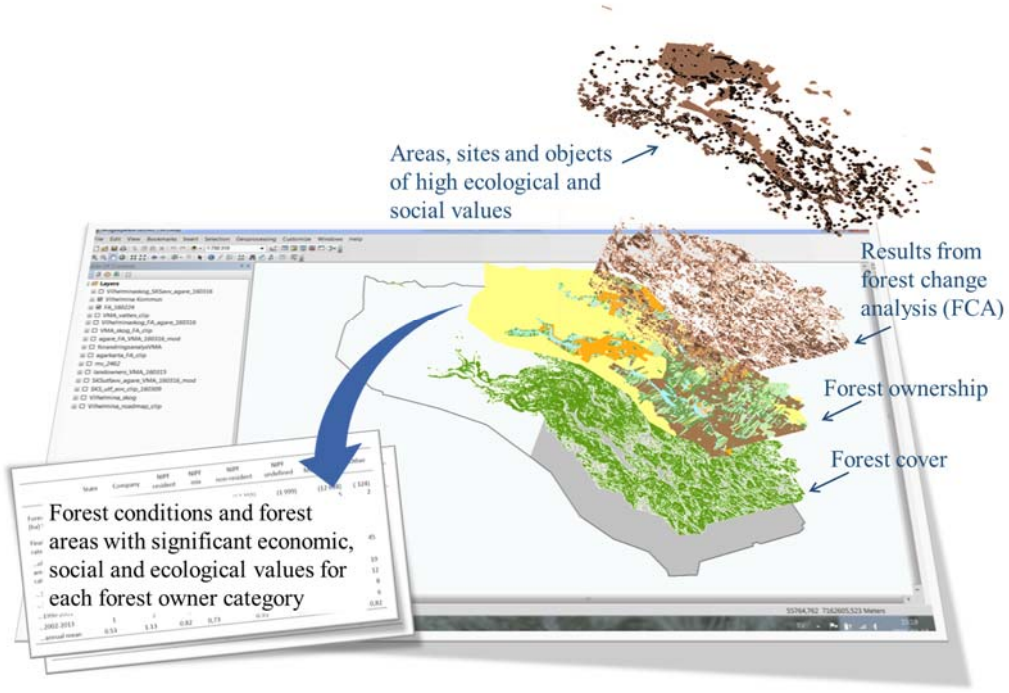

Figure 2. Data overlay procedure. Results from forest change analysis (FCA) in our focus study area in the eastern part of Vilhelmina municipality (Sweden) are combined with information on forest ownership, forest cover, and areas of high ecological and social values in the entire Vilhelmina municipality. This information was used as a base for calculating percentages of forest areas of different ages and values for each forest owner category.

Data overlay was performed for the entire municipality, but the relationship between forests of different ages, protected land, historical sites, and lands of potentially great importance for recreational activities are merely presented for the focus study area, which is in the eastern part of the municipality (Figure 2). Cloud-free satellite images were not available for all time steps in the satellite image time series for the western portion of Vilhelmina municipality, so they were not covered by the FCA [78].

3. Results

3.1. Land Ownership Patterns

By merging information on individual forest owners in different owner categories with their respective forest holdings, we recorded the distribution of land types in Vilhelmina municipality for each owner category (Table 1).

Table 1. Distribution of land cover types (water excluded) for the entire Vilhelmina municipality (entire VMA) of Sweden and our focus study area (focus area) within different forest owner categories. Note that distribution of land between owner categories refers to the situation in January 2016.

Land Cover	Entire VMA (km^2, %)	Focus Area (km^2, %)	Owner Category * Possession of Land Type (% in Entire VMA and in Focus Study Area)				
			State	Company	NIPF	Community	Other
Sum	8129.7	3864.6	45.9	15.6	25.4	7.8	5.3
	100	*100*	*16.1*	*30.5*	*42.4*	*4.2*	*6.8*
Forest land	4064.4	2671.6	23.2	24.1	37.5	13.0	2.1
	50.0	*69.1*	*14.9*	*33.2*	*45.0*	*4.7*	*2.1*
Wetlands	1625.9	1100.2	36.8	21.1	33.6	6.7	1.7
	20.0	*28.5*	*20.7*	*30.3*	*43.7*	*3.6*	*1.7*
Mountains	1298.1	0.1	99.7	0.0	0.1	0.2	0.0
	16.0	*0.0*	*15.0*	*0.0*	*75.0*	*0.0*	*0.0*
Mountain Birch forests	1042.7	19	93.8	0.0	4.8	1.0	0.4
	12.8	*0.5*	*88.1*	*0.0*	*11.9*	*0.0*	*0.0*
Open lands (arable/developed)	87.8	68.9	3.9	6.4	74.6	2.4	12.8
	1.1	*1.8*	*2.0*	*7.8*	*77.2*	*1.5*	*11.4*

* Land ownership is categorized as State, Company (large-scale forest companies), Non-industrial private forest owners identified as living in or outside the municipality (NIPF), Community (a large forest common, the municipality, and some smaller village commons), and Other (the church, foundations, and unidentified owners).

Land cover types and land ownership patterns differ significantly between the Vilhelmina municipality area and our focus study area. The proportion of non-forest land (mostly mountains) and the proportion of state-owned lands are higher for the entire municipality. Conversely, the proportion of forest land, the proportion of NIPF, and the proportion of company-owned lands is much higher in our focus study area (Figure 3).

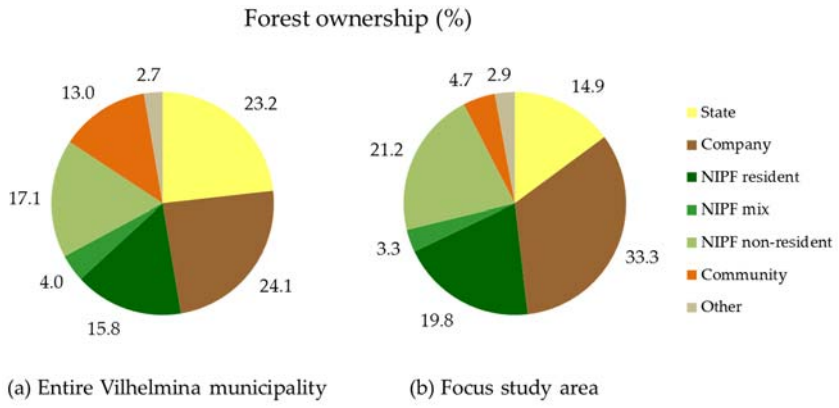

Figure 3. The distribution of forest lands by owner categories for (**a**) the entire Vilhelmina municipality (Sweden) and (**b**) for our focus study area as of January 2016. Land ownership is categorized into State, Company (large-scale forest companies), NIPF resident and NIPF non-resident (non-industrial private forest owners identified as living in or outside the municipality), NIPF mix (a mix of NIPF resident and NIPF non-resident owners), Community (a large forest common, the municipality and some smaller village commons), and Other (the church, foundations, and unidentified owners).

Figure 4 depicts maps of land cover types and ownership patterns in Vilhelmina municipality. The state is the largest single landowner in Vilhelmina municipality and most lands owned by the state and by communities are found in the northwest (Figure 4b).

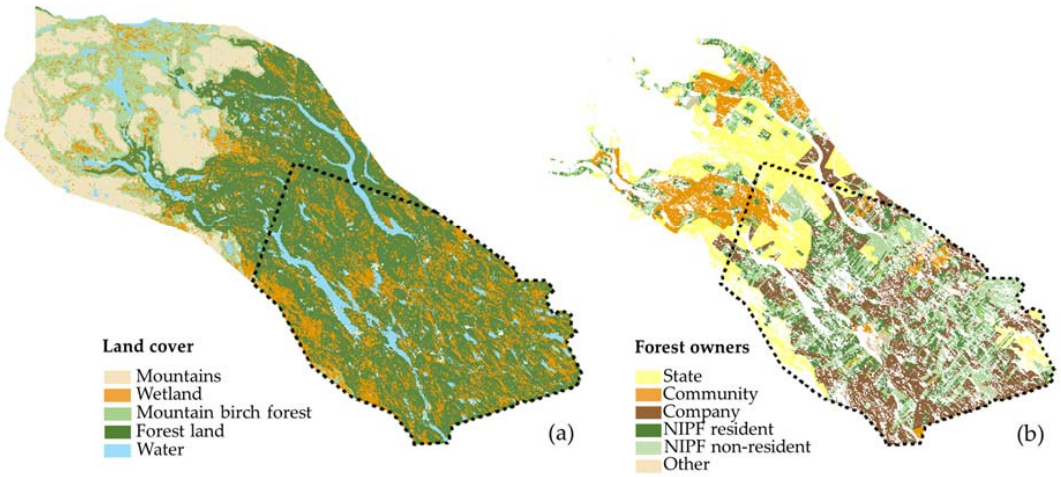

Figure 4. Maps of Vilhelmina municipality (Sweden) illustrating (**a**) major land cover types and (**b**) forest ownership patterns (as of January 2016), with a separation of resident and non-resident NIPF owners. The dotted line marks our focus study area. Land ownership is categorized into State, Company (large-scale forest companies), NIPF resident and NIPF non-resident (non-industrial private forest owners identified as living in or outside the municipality), NIPF mix (a mix of NIPF resident and NIPF non-resident owners), Community (a large forest common, the municipality, and some smaller village commons), and Other (the church, foundations, and unidentified owners).

3.2. Forest Conditions

Based on dated final felling events detected from the FCA, we present a dataset describing forest age for all forest land independent of forest owner for our focus study area. Such full cover and accurate information about forest age requires satellite time-series analysis and could not be produced by single image optical satellite images nor by laser scanning. We combined the information depicting forest age with land owner information and revealed large variations in distribution of forest age classes between the different owner categories (Figure 5). A large part of the forest that was final felled between 44 and 58 years ago is owned by companies and non-resident NIPF owners and there is also a large proportion of NIPF forests, as well as company forests, that are 27–43 years old. NIPF owners hold about twice as much (21%) of the non-final felled forests (>58 years old forests) as companies and the state, who hold 11% and 13%, respectively. Before applying the FCA, such information only existed for some industrial timber lands and was not available for organizations such as municipalities.

Of the company-owned forests, 62% are younger than 58 years as of today. The corresponding number for state-owned forests is 29%. NIPF forest lands show a more even age distribution, but there is a surprisingly large variation in forest age among the different NIPF owner categories. Non-residents own a larger area of forests 58 years old or younger (51%) than resident owners (45%). Consequently, the proportion of forest land for the different forest owner categories that has not been subjected to final felling between 1958 and 2013 (i.e., >58 years) are lowest on company land (38%), followed by non-resident NIPF, and community-owned land (49%). The resident NIPF owners have 55% of forests >58 years of age and on state-owned land it is 71% (Figure 6).

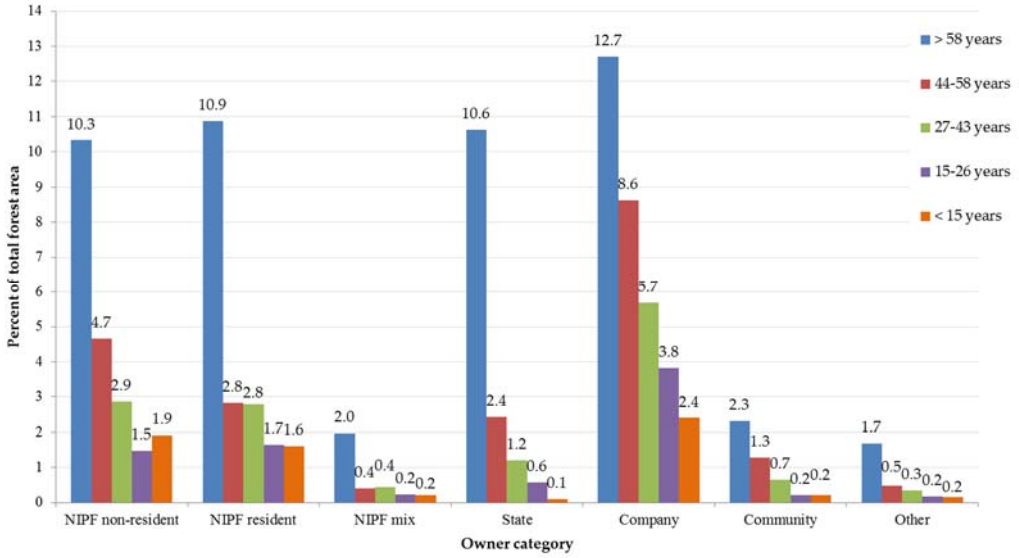

Figure 5. Distribution of the total forest area (2674 km^2) among owner categories in our focus study area within Vilhelmina municipality, Sweden. The distribution is presented in intervals of forest age: from >58 years old (not subjected to final felling) to <15 years. Note that data on owner category refers to the situation in January 2016. Land ownership is categorized into State, Company (large-scale forest companies), NIPF resident and NIPF non-resident (non-industrial private forest owners identified as living in or outside the municipality), NIPF mix (a mix of NIPF resident and NIPF non-resident owners), Community (a large forest common, the municipality, and some smaller village commons) and Other (the church, foundations, and unidentified owners).

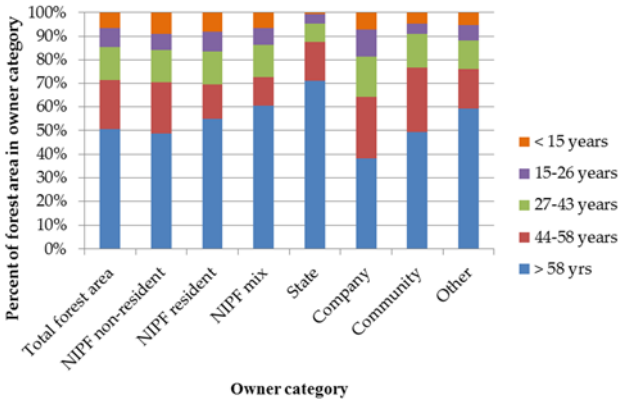

Figure 6. The distribution of forest age within forest owner categories in our focus study area within Vilhelmina municipality, Sweden. Note that data on owner category refers to the situation in January 2016. Land ownership is categorized into State, Company (large-scale forest companies), NIPF resident and NIPF non-resident (non-industrial private forest owners identified as living in or outside the municipality), NIPF mix (a mix of NIPF resident and NIPF non-resident owners), Community (a large forest common, the municipality, and some smaller village commons) and Other (the church, foundations, and unidentified owners).

3.3. Significant Values in the Forest

For the entire Vilhelmina municipality, forests that are formally protected because of their high ecological values encompass 476.3 km^2 or 12% of all forest land. In our focus study area, 179.9 km^2, or 7%, of the forests are protected. Among the protected forest lands, 85% have not been subjected to final felling, 13% are in the 44–58 year age category, and 2% are in the 27–43 year age category. Most

protected areas (94%) are owned by the state. The forestry-related protected areas (biotope protection and nature management agreements) represent less than 2 km^2 in total. However, resident owners own twice as much of these protected areas than the non-resident owners. To explain this notable situation, further investigation is needed.

There are 1502 historical and culturally valuable objects and sites recorded by the Swedish National Heritage Board and the SFA on forest land in Vilhelmina municipality. Most of these forests have not been subjected to final felling during the last 58 years (Table 2).

Table 2. Historically and culturally valuable objects and sites in forests of different ages in the entire Vilhelmina municipality (Sweden) and in our focus study area. The objects and sites are recorded as points, lines, and areas.

		Historical/Cultural Sites in Forest		
		Points (Number)	**Lines (km)**	**Areas (km^2)**
Study Area:	**Entire Municipality:**	985	10.76	16.7
	Focus Area:	747	8.71	16.2
Forest Age in Focus Area:	**>58 years:**	504	5.53	10.6
	44–58 years:	105	0.78	2.4
	27–43 years:	64	1.10	2.9
	15–26 years:	43	0.39	0.1
	<15 years:	31	0.91	0.2

There are 1438 km of snowmobile tracks in the entire municipality of which 637 km are located within our focus study area. On public and private forest land, respectively, 420 km (29%) and 233 km (37%) are found. Most tracks are found in forests >58 years (57%), 19% are found in 44–58-year-old forests and 14% in 27–43-year-old forests. Less than 11% of the tracks are found in forests younger than 26 years.

In the entire municipality of Vilhelmina, 1347 km^2 of the forest land are of high social value in terms of high potential use for recreational purposes due to the proximity to residences (<1 km). In our focus study area, this area constitutes 895.9 km^2, where 51% is found in forests not subjected to final felling, 19% in 44–58-year-old forests, 14% in 27–43-year-old forests, 9% in 15–26-year-old forests and 8% in forests younger than 15 years. A majority (65%) of the forest land within 1 km from residences are NIPF (31% is owned by NIPF resident owners and 27% by NIPF non-resident owners). Companies own 26% of the forest land within 1 km of residences (Table 3).

Table 3. Areas within 1 km from residences per forest owner category in Vilhelmina municipality (Sweden) and in our focus study area. Land ownership is categorized in State, Company (large-scale forest companies), NIPF resident and NIPF non-resident (non-industrial private forest owners identified as living in or outside the municipality) and NIPF mix (a mix of NIPF resident and NIPF non-resident owners), Community (a large forest common, the municipality, and some smaller village commons), and Other (the church, foundations, and unidentified owners).

		Forest Areas within 1 km from Residences					
		(*km^2 in Study Area*, % of Focus Area per Forest Age Interval)	(% of Study Area per Owner Category)				
			State	**Company**	**NIPF**	**Community**	**Other**
Study Area:	**Entire Municipality:**	*1347.1*	8.0	19.3	58.4	10.9	3.3
	Focus Area:	*895.9*	2.5	26.1	64.5	3.9	3.0
Forest Age in Focus Area:	**>58 years:**	50.7	1.6	9.3	36.0	2.0	1.9
	44–58 years:	19.2	0.4	7.1	10.3	0.9	0.5
	27–43 years:	13.7	0.3	4.4	8.1	0.5	0.4
	15–26 years:	8.5	0.2	3.3	4.6	0.3	0.2
	<15 years:	7.9	0.1	2.1	5.4	0.2	0.1

4. Discussion

4.1. Land Ownership Patterns

According to Swedish acquisition law and established practice, juridical persons (e.g., forest companies and the state) have very limited possibilities to buy new forest land from private individuals unless they sell off an equivalent piece of land to private individuals [92]. Thus, we assumed that the land recorded as owned by the state and by companies in 2016 also was the amount of state- and company-owned land in 1958. An exception is the lands of the state-owned company Sveaskog. The company can be assumed to act as any other large-scale forest company, but in 2002 the owner (the state) decided that Sveaskog should sell 10% of its lands to promote private agriculture and farming [93–95]. The preconditions for the selling have changed somewhat since 2002, but as of November 2016 Sveaskog has sold approximately 8% of its total land in Sweden, approximately 9% in the county of Västerbotten, and slightly more than 20% in Vilhelmina municipality [96]. An overall stable ownership pattern applies to the NIPF owner category. However, within the NIPF owner category, largely due to the out-migration of people from Vilhelmina from 1958 [55,56], it can be assumed that a substantial proportion of the forest land owned by resident owners in 1958 is now owned by non-residents, while the forest land owned by resident owners in 1958 is still owned by resident owners. Considering results from studies on ownership and migration [97], it is surprising that only 3% of the forest land is owned by a mix of non-residents and residents.

4.2. Forest Conditions

Before 1958, the general forestry practice in Vilhelmina was selective harvest [65,66]. Therefore, large parts of company-, state-, and community-owned forest land had low stocks. The FCA shows a large portion of forests of 44–58 years of age, which reflect the extensive restoration of understocked stands that took place between the 1950s and the 1980s. Large areas were first clear cut and then regenerated (or at least this was attempted) by planting or sowing. Driven by their interest of securing long-term supplies of timber, forest companies were the first to phase out their low stocked stands, while many NIPF owners needed to be incentivized by state subsidies offered during the 1980s [98]. The apparent difference in forest age distribution between the different NIPF categories, indicating different management behaviors, is harder to explain. More information is needed to explain the relation between residency and management practice. This kind of knowledge—i.e., who owns what forest land and how the forest lands are likely to be managed—would help municipalities to strategically plan housing developments, industrial exploitation (mines, power production, etc.), and safeguards for ecological and social values in the forest landscape.

4.3. Significant Values in the Forest

In Sweden, most protected forest area is state-owned nature reserves. The reserves aim to protect larger areas with high values related to biodiversity, geography, scenery, recreation, etc. The monopoly regarding spatial planning, with MCP as a base, puts a vast responsibility on municipalities to safeguard national interests and to fulfill national environmental quality goals. Among other things, MCP must address the protection of forest land and its different values [99]. Our study shows that most forest areas with significant cultural/historical or recreational values have not been subjected to final felling (i.e., >58 years old). However, our results do not explain why this is so. Olsson illustrates the importance of proximity to urban areas to explain frequently used forests and the importance of urban fringe forests [100,101]. These findings mean that municipalities need to keep informed not only about existing forest protection but also about various recorded and experienced values in the forest landscape related to where people would like to live and conduct various recreational activities. Without this knowledge, it is not possible to have a grounded opinion about further protection or to make statements or priorities concerning development strategies and changes in land use on forest land.

4.4. Data Overlay and Spatial Analysis

Vilhelmina represents a suitable case study in terms of evaluating MCP as a planning tool for SuD. The laws and regulations regarding MCP are the same for all Swedish municipalities. Furthermore, land use and forests in Vilhelmina have been studied and described from various perspectives over the years cf. [25,66,67,102–111]. This history gives a unique opportunity to combine and compare information from our study with other research to further analyze and learn about local forests from a municipal perspective.

Apart from the FCA, the municipality already has access to all demographic and geographic information we used for our analysis in this study. However, because the data are not structured in a way that easily allows for the FoDAA, municipalities have not been able to take advantage and analyze available data. Today, the access to FCA is still limited for other municipalities, but geographic data on forest change in terms of final felling since 2002 are available from the SFA website. This access makes it possible for any municipality to start building their forest land use history, and hopefully more historical data can be provided in the near future as well. A more tangible problem is the generally-known shortage in municipal resources for spatial planning such as MCP cf. [47,112–114]. Although analyzing how to coordinate land use interests and land use planning is not within the scope of this paper, it is important to consider whether municipalities should conduct the FoDAA themselves or if it should be done on a national/regional level and then be provided to the municipalities. This is an approach that resembles how geographic data and other vital information for planning are provided by CABs regarding other types of land use.

4.5. The Aids of Integrating Geographic Forest Data in MCP

In Sweden, municipalities, with some exceptions (e.g., forestry and mining), have had the major responsibility for territorial land use planning and decisions. The degree of local self-governance is rather unique in an international perspective. In most other industrialized countries, the regional level is more apparent. However, forests and forestry have not been an obvious part of the Swedish MCP. Today, the municipal spatial planners most likely are unaware if, how, or why they should integrate forest and forest land use in MCP cf. [47].

General lack of resources for MCP [47] and the rather unclear mix of sectorial and territorial planning in MCP are major barriers to implementing MCP and incorporating forest land use in the planning process. Property rights are sometimes understood as a barrier [43], but this is a misinterpretation. To include a land use interest in the public planning process does not imply that the land automatically will be controlled or that the property rights will be challenged by the planning authority. In fact, including forest land into the formal MCP process could expand property rights. We argue that the FoDAA provides a piece in the spatial planning puzzle that is missing. The picture of the local forest and its owners is important new knowledge for MCP. Furthermore, one might say that forest land is already included in MCP. The forest owners engage in enterprises considered to be very important for the national forest industry. Depending on where they live and how they manage their forest, the forest owners also contribute to and affect the local society through their management of the landscape, local trade, and taxes. Closer cooperation and concerted planning would offer a better overview of the forest as a locally as well as a nationally important resource. Forest land is also affected by some of the national and public interests that should be considered in MCP (e.g., national interest of nature management, recreation, and tourism and, in the north, the national interest of reindeer husbandry as well as the legally required planning for rural development in watershed areas). The ongoing forestry activities are not affected by the national interests, but if forest owners wish to switch to another land use form and/or to build something in a watershed area that is not considered to be of general importance to rural development, their property rights are not very strong. The forest owners also have a rather relaxed relation to the public using their land in accordance to the Right of Public Access [115]. This custom is beneficial for forest owners as well because it grants access to other owners' lands. However, the MCP is meant to be a strategic tool for sustainable land use and

development on the territorial level, which means that the local government should express where and how different types of land use should be carried out within the municipality borders. Some of these land uses, such as tourism, lean on the Right of Public Access. Extensive forestry activities, such as final felling, are often perceived as having a negative effect on social (and ecological) values of the forest land. On the other hand, thinning (carried out two or three times during a rotation cycle of about 100 years) can be considered to improve the accessibility and the social values of the forest. Furthermore, the network of forest roads increases the access in the landscape for the general public as well as for commercial activities. In sum, the municipal planning for other uses of the forest land could affect the lands of various forest owners and their possibility to use or not use the land in the way that they wish.

Supplementing MCP with data on forest and forest owners also improves preconditions for communication in the planning process. With forests and forest land use added to the overall map of land use, the local government (in our case the municipality) has a better point of departure for dialogue with forest owners (as well as other land use actors and authorities). The FoDAA provides a common base and a communicative tool. Using the FCA to identify if forests have been subjected to final felling also provides a time perspective to the tool. The FoDAA can be used in discussions and possibly for co-production of new and more in-depth knowledge about forest values and about the needs and desires of the users, including the forest owners, of forest land considered in MCP. Moreover, the FoDAA can be used on the property level or over larger areas, such as a region or a country, a flexibility that enables the scale up or down in level of detail as well as geography. This advantage offers governmental agencies and other types of actors in different sectors on different societal levels the same knowledge and ensures that they all refer to the same facts even though it can be presented with various resolutions. Extensive and shared knowledge on forest land use is undoubtedly important for successful communication and cooperation between actors in different sectors [76]. Hence, assimilation of geographic data of good quality on forest land use in MCP could improve the prospect of anticipating and avoiding local land use conflicts.

5. Conclusions

Various types of land use, as well as formal decisions, can affect large geographic areas more or less independent of land cover types, forest conditions, and ownership boundaries. In Sweden, land use without boundaries includes all land uses related to grazing rights in reindeer husbandry, the Right of Public Access, the appointment and application of national interests (*Riksintressen*), and various environmental issues. The necessity of data without boundaries in MCP, as local spatial planning in a sustainable development context, becomes apparent. In this paper, we have argued for a better integration of forest land use as well as information about forests in MCP. We introduced the notion of a hole in the MCP land use map regarding basic information about forest conditions, forest owners, and forest land use. In our focus area, the size of this hole represents 64% of the territory (and 46% in the entire municipality). By applying the Forest Data Assimilation Approach, we have shown that ownership probably affects forest conditions, in this case, specifically in terms of when and where final felling has been carried out and hence the age of the forest and where the remaining non-final felled forests are found. Although knowledge about the proportion and location of forests of different ages is certainly valuable information, even more important knowledge is the specific location of forests with certain qualities, indicated by their age, by their ownership, and by their significant social, historical, and ecological values (Figure 7). Furthermore, land uses and rights such as reindeer husbandry and the Right of Public Access span most types of land including the forest land hole. With such land uses in practice, the need for an accurate description of the hole increases.

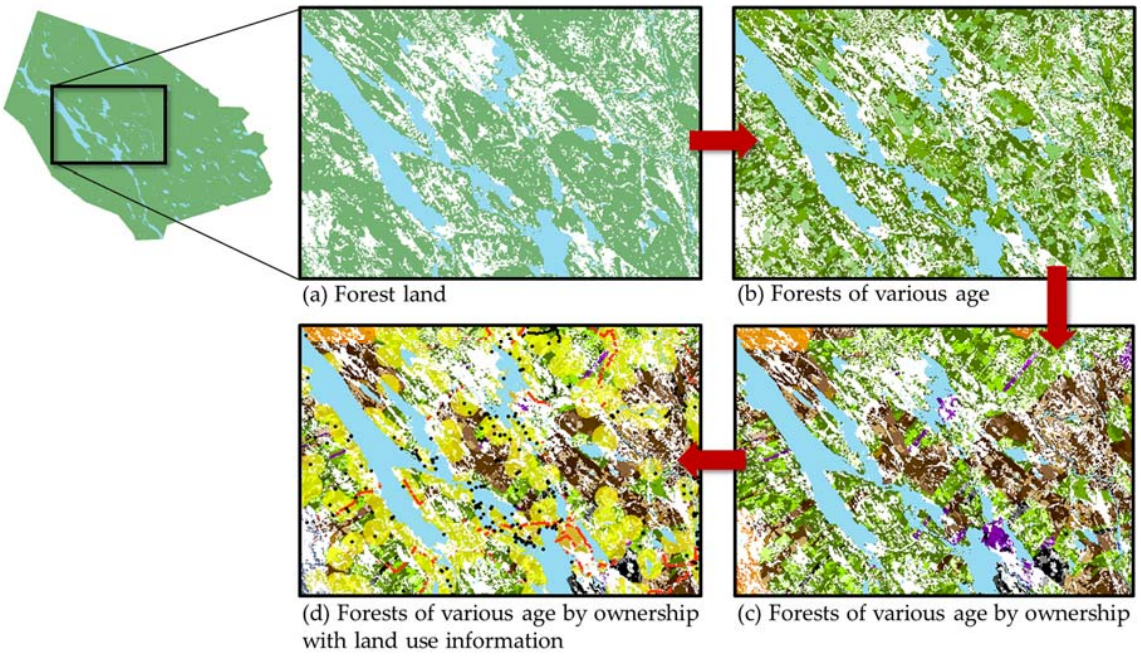

Figure 7. Maps illustrating the results from the Forest Data Assimilation Approach for our focus study area in Vilhelmina municipality, Sweden: (**a**) proportion and location of forest land; (**b**) area and location of forest land of various ages and thereby character; (**c**) area and location of forest land of various ages by ownership; and (**d**) area and location of forest land of various ages by ownership with information about the use of forest land for various purposes.

Our study demonstrates that spatial analysis and overlay of geographic forest data and forest owner information according to the FoDAA can provide opportunities to view forest property and the individual forest owner in a landscape perspective. This approach provides a picture of forest ownership and the relationship between forest owners and their forests, making it possible to analyze the forest assets and the joint activity of different owner categories in relation to each other and to conditions for forest land use associated with ecological, social, and economic values of the forest. Our approach creates a visible link from the individual forest owner and his/her forest to planning and decision-making organs of society at different levels. The approach allows us to learn from the past to better plan for the future. It can place the forest owner and forest land use on the map in time and space. This perspective is vital to a planning process that aims to make way for and balance different land use interests in a given landscape in a sustainable manner cf. [111]. There are of course challenges to overcome in this balancing act, among them the capacity of local (municipal) planning, lack of resources for planning, and the coordination of multi-level governance (local level versus central level). However, we have shown that it should be possible to improve the holistic perspective in municipal comprehensive planning with available data. Hence, the outcome of the planning process is more likely to consider and balance the needs of all municipal (local) inhabitants and businesses, including forest owners and forest enterprises, and at the same time consider regional and national policies and goals. What the achieved information says about previous and current land use, including potential future claims or expectations, will increase the municipalities' space of action, competence, and capacity to take planning actions towards sustainable development.

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