

Perspectives

Adaptation to Climate Change in Forestry: A Perspective on Forest Ownership and Adaptation Responses

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Abstract: Adaptation to climate change has often been discussed from the perspectives of social vulnerability and community vulnerability, recognising that characteristics at local level will influence the particular adaptations undertaken. However, the extent to which national-level systemic factors influence and shape measures defined as adaptations has seldom been recognised. Focusing on adaptation to climate change in forestry, this study uses the example of two countries in the northern hemisphere with different forest ownership structures, forestry industry and traditions: Sweden, with strong private, non-industrial ownership, dominant forest industry and long forestry traditions; and Scotland, with forest ownership dominated by large estates and investment forestry based on plantations of exotic conifer species. The study shows how adaptation to climate change is structurally embedded and conditioned, which has resulted in specific challenges and constraints for different groups of forest owners within these two different contexts. This produces a specific set of political spaces and policy tools by rendering climate change in relation to forestry manageable, negotiable and practical/logical in specific ways. It is recommended that the focus of future work on climate-related issues and development of adaptation measures and policy should not be primarily on climate-related factors, but on institutional analysis of structural factors and logics in target sectors, in order to critically explore concepts of agency and power within these processes.

Keywords: adaptation capacity; institutions; context; agency; Scotland; Sweden

1. Introduction

In forestry, climate change can have extensive consequences due to its significant effects on both human society and ecosystems [1]. Reported changes in the physical condition of forest [2,3] emphasise the need for adaptive actions in forest management and planning [2,4]. Adaptation to climate change in forestry is a concern at different levels in national adaptation strategies and policy documents in several European countries. However, previous studies indicate great diversity in the scope and level of strategies, and also a relatively general level of development [5,6]. Although a number of present and future risks have been documented, as have multiple options for forest management adaptations [2,3,7–9], the pace of adaptation in forestry has been relatively slow [10], with only marginal adaptation by forest owners [11,12]. The Intergovernmental Panel on Climate Change (IPCC) states in recent reports [13,14] that, although knowledge is an important factor, it “is not sufficient to drive adaptive responses” [15]. This highlights the social and institutional barriers to implementation

of climate adaptation measures [16] and, in the case of forestry, the lack of alternative management practices for forest owners [12,17] and access to relevant expertise [17–19]. The differing experiences and perceptions of climate change among forest owners reflect geographical differences but, unlike in other areas, seem to have limited impacts on practice [20–22]. One consequence is that the lack of adaptation “cannot be reduced to the individual rationality of the (private) forest owners” [12].

Although recent studies indicate increasing concern and awareness among some groups of forest owners about the implications of climate change [17,22–24], other studies report relatively low awareness and adoption of climate change adaptation in the industry [21,25].

In relation to vulnerability in forestry, the lack of security for forest owners affected by weather-related hazards [26,27] generates perceptions of powerlessness and low self-efficacy, which in turn limits the grounds for individual action and realisation of adaptive capacities [28]. In some areas, the high financial dependence on forest further emphasises this position and the structural constraints [22,29]. The economic consequences of climate change-related hazards have received much attention in research [20,30,31], while other values in forest and forestry have received limited attention [32,33]. Structural constraints produce maladaptation, which in turn increases the vulnerability of systems, sectors or social groups [34].

In this paper, we explore adaptation strategies, policy and forest ownership and how diversity and variations in ownership structures may be related to whether or not forest owners are adapting. This derives from the fact that forest owners are not a homogeneous group and that the forest policy context itself influences perceptions of adaptation. In a national context, both the situated formal policy development and the various groups of forest owners produce the specific conditions of political challenges and implementation. Forest management traditions, the structure of forest ownership and the structure and role of the forestry sector and industry are some of the factors that shape the policy context and the understanding of various adaptation strategies (e.g., [6,25,35]). Within this, institutions and structural constraints favour some actors, ideas and policies and contending alternatives [36] and result in asymmetrical influence of agents based on the position they occupy within existing structures [37]. A multiple and relational understanding of power highlights how agency is both structurally embedded and contained [36]. This defines the potential range of alternative strategies and opens up spaces for critical exploration of how the issue of climate change is rendered “practical” through processes of governance, the logics which underpin them and the relations between various structural positions, institutions and climate change adaptation in forestry (cf. [16,38]).

In many studies, adaptation strategies are not discussed in relation to these types of characteristics or broken down according to different forest owner categories, despite the fact that these have very different prerequisites for implementing adaptation, and even potentially different ranges of relevant adaptation options [5]. The current emphasis on *how* climate change is governed in research has significant consequences for the conceptualisation of structure and agency, the state and power [36]. The literature on adaptive strategies for climate change within forestry is limited and research exploring the relations between perceptions and uptake of different strategies among various groups of forest owners from a policy perspective is even more limited.

In order to explore the relationship between adaptation strategies, policy and forest ownership, this study draws upon a comparative analysis of two countries in the northern hemisphere with very different forest ownership structures, forestry industry and traditions: Sweden, with strong private, non-industrial ownership, dominant forest industry and long forestry traditions; and Scotland, where forest ownership is dominated by large estates and investment forestry based on plantations of exotic conifer species. The analysis sought to contribute to theory on factors that may influence adaptation to climate change in forestry [39]. Based on these two cases, the study assessed a number of considerations of the range of actors and motivation systems that forestry adaptation policy would need to consider in various contexts. Specific issues examined were:

- How is forest ownership structurally embedded in each country, and how is it related to the formal adaptation policies and actions with relevance for forestry introduced in each case?

- How do the structural constraints of forestry shape the development of adaptation to climate change, and what possibilities does this provide for forest owners to adapt?

Based on lessons from these two cases, the study contributes to the theoretical understanding and consideration of influential factors, structures and mechanisms within the processes of adapting forests to climate change. The cases chosen provide a basis for future theoretical developments through contextual elaborations and calibration as gaps in the literature and statistics are filled.

The remainder of this paper is structured as follows: First, the theoretical framework is presented, followed by a description of the methodological approach. The two contrasting cases of Sweden and Scotland are then described and situated in their histories, traditions and governing systems, with the emphasis on forest ownership. The policy field of climate change, focusing on adaptation, in the two contexts is elucidated. In the concluding discussion, the two cases and contexts are compared and the issue of forest ownership and adaptation capacity, incentives and vulnerability is further explored, with the aim of improving understanding and development of international and national adaptation-focused policies, primarily in relation to forest and natural resources. This is crucial in order to encourage adaptation in forest policy [8,40] and to develop policies to facilitate the creation and implementation of adaptive management responses to climate change [3,8,40].

2. Theoretical Framework and Method

Adaptation to climate change is frequently regarded as being related to the adaptive capacity, sometimes in relation to certain enablers, of different socio-ecological systems (e.g., [16]). This has led to a discussion on how underlying adaptive capacity or, broadly, resources are enabled in order to result in adaptation actions. In forestry, trees that are planted today in northern Europe are expected in some cases to stand for some 70–90 years before final felling. Given these time spans, forestry could be presumed to be an area for early adaptation to climate change, purely based on a requirement to take into account future conditions during the present. However, it has been shown that forestry has generally not been an area for early adaptation or for driving adaptation policy development in different countries, including countries in Western European where resources for adaptation could be presumed to exist (e.g., [41]). Adaptation to climate change in forestry has been developed in many countries, at least on policy level, but the policies and in some cases also practices of adaptation vary greatly depending on the forestry niche of the country [5]. Thus, adaptation may differ between favouring quick-growing exotic trees to maximise forestry production (e.g., Sweden) or favouring natural forest where introduction of exotic tree species is rejected and management overall is more limited (e.g., Italy) [6]. Scotland represents a ‘middle path’ in this regard, by supporting diversification of conifers, whether native or exotic [42]. Thus in effect, adaptation in forestry or forest management differs in different countries and addresses different management goals. While it is argued in the literature that adaptation has to be adjusted to local conditions (e.g., local vulnerability work and a broader social vulnerability perspective, (cf. [43,44])), studies of actual adaptation to climate change in forestry are likely to reflect a relationship to local, regional and national characteristics. This hampers discussions of adaptation in terms of adaptive capacity, but also any discussions of adaptation without a thorough understanding of the structures and institutions (materialised social norms) through which adaptation and adaptation goals are set. This has implications for forest ownership.

Situating itself broadly within an institutionalist tradition, this study explores the relations between adaptation strategies, policy and forest ownership. The work is based on the assumption that adaptation of forestry to climate change, at the national level, can be understood through appreciation of important institutional factors, including structural settings, i.e., the structure of forest industry in the country, the structure of forest ownership in the country and the economic role of forestry in a national perspective. While these factors must be considered in relation to broader societal institutions such as forestry, forest use traditions and inheritance of forest, they can serve as a proxy for understanding the way in which adaptation to climate change in forestry may be manifested.

Our underlying assumption in this analysis is that many of the actions suggested or taken within forest management are based on the structure of forest industry in a country, including the economic role of forestry in a national perspective (e.g., timber production or multi-use). Our assumption is that a forest management system concentrating largely on timber production on an international market and playing an important role for gross domestic product (GDP)/export value, such as the Swedish system, will largely employ adaptations that are built into the system and do not affect the high forest production output. This type of system is dependent on integration of various groups of forest owners, e.g., with the support of technology, within the forest regime—which might also have implications for the development of reactive or proactive adaptation strategies (cf. [13,45]). Adaptations could of course be based on whether the system applies long-term or only short-term planning, e.g., limiting adaptations to those that do not compromise short-term production, or it could re-organise to a much higher extent to ensure that production is still possible under very challenging conditions. The choice between these two types of approaches is presumably related to the extent to which climate change is seen as a serious threat or more as an opportunity, and also the extent to which climate change risks (and their types) are seen as more or less certain and thus possible to integrate in planning. In both these cases, an assumption was made that a strong planning system exists.

In cases where less emphasis is placed on production and specific economic output, it could be assumed instead that a broader number of adaptations will be discussed in policy and potentially also implemented in practice. However, if dominant planning and governing systems are present, including e.g., forest management plans and advisory systems, it would be much more difficult to develop strong steering on adaptation or to develop adaptation amongst forest owners. Undertaking formal management measures may also be restricted to public agencies, as costly forest management may be of less interest to actors receiving limited economic benefits from forest. Whilst this type of system may be most applicable in countries such as Italy, it also approximates the case in Scotland, which was chosen here to investigate the role of this type of forest system.

In both these cases, an open question concerns the information and space these different types of systems provide to the individual forest owner or forest interests, i.e., whether an individual forest owner in each case can actually determine actions to be undertaken in their own forest and whether these actions are steered by assumptions and rationales in the system (which may underplay the role of adaptation). On a policy level, adaptation conceptions and responses of different cases are in various ways shaped, facilitated and limited by dominant institutions, such as the forest industry in the case of Sweden (production-orientated or limited adaptation) and larger estate ownership traditions in Scotland (limited policy responses on adaptation).

In order to examine the role of forest ownership in climate change adaptation, we examined cases with different forest ownership patterns and policy decentralisation, including differences in the legal systems (Table 1). A “focused comparison” approach is well suited for studies exploring the contextual features of countries that have some inherent geographical and political similarities [46]. On the basis of the two research questions and the theoretical framework applied in this study, the comparison was structured into three sections that combine scale and the intuitional contexts, policy and agency of forest owners in climate change. These were: Role and structure of forestry and forest ownership; Development of adaptation policy within forestry and related actions and Structural positions and adaptive spaces of forest owners. The theoretical framework combined with the comparative design provided the basis for a broader general discussion on forest ownership and climate change.

Table 1. Climate change adaptation in Swedish and Scottish forestry.

	Sweden	Scotland
National vulnerability assessments	Swedish Commission on Climate and Vulnerability (2007)	ASC ¹ (2016) UK Climate Change Risk Assessment 2017 Evidence Report—Summary for Scotland
National adaptation strategy or policy	Swedish Commission on Climate and Vulnerability (2007), Climate Bill 2009, policy development	Climate Ready Scotland: Scottish Climate Change Adaptation Programme (2014)
Sectorial adaptation strategy or policy	Instructions to the Forest Agency to revise the Forestry Act and develop information campaign and guidance	The Land Use Strategy (2011, 2016), forthcoming revisions to the Forestry Strategy
Forest cover	66%	18%
Forest owner structure	Dominated by non-industrial private forest owners and forest companies	Dominated by larger estates and investment forestry (limited data)
Role of forest industry	Influential position based on GDP ² , market position, forest ownership and guidance provider	Investment forestry representatives vociferous in advocating further afforestation and growth of industry; conflict with so-called 'traditional' deer stalking
Forest governance system	Largely deregulated and dependent on social norms, shared interests and advisory and planning systems, including certification schemes	Weighted toward voluntary regulation i.e., certification; incentives for new forest planting; regulatory framework affects felling
Forest management systems	Dominated by monoculture, clear-felling and active replantation	Commercial forests are planted, dominated by exotic conifers. Mainly monoculture, clear-felling and active replantation
Forest advisory systems	Public and private, but dominated by timber purchasing organisations (incl. forest owners' associations)	In commercial sector, private forest agents
Main adaptations strategies	Reactive/coping or limited (measures that can be included within present institutional logics)	Limited; main adaptations have been reactive to tree health crises
Potential policy barriers for adaptation	Limited tools of implementation (incl. certification) and unclear conceptualisation of adaptation for different groups of forest owners	Limited data on forest ownership and lack of policy tools (incl. certification); tax incentives for investment forestry deter diversification of species choice; strength of deer-stalking sector
Potential structural barriers for adaptation	Dominant production-orientated logics and connected planning and advisory systems	Nursery supply, sawmill demands, invisible dominance of investment forestry and unequal distribution of land

¹ Adaptation Sub-committee; ² Gross domestic product

3. Case Analysis

3.1. Sweden

3.1.1. Role and Structure of Forestry and Forest Ownership

Forestry is more important in Sweden than in any other EU country apart from Finland, and accounts for about 12% of total Swedish exports, as well as high industry employment, turnover and value added activity. Sweden is the fourth largest pulp exporter, third largest paper exporter and second largest sawn timber exporter globally. Forest covers some 66% of Swedish land area, and the industry indirectly and directly employs 6% of the workforce, much of which in sparsely populated areas. Spruce and pine constitute more than 80% of the timber stock, most logged forests are actively re-planted and forest management is relatively active (improved forest management is expected to further increase growth) [47,48].

Although more than half of the Swedish forest is owned by some 330,000 non-industrial private forest owners within small-scale or family forestry operations, large-scale forestry, i.e., private and

state-owned companies, has historically had a major impact on the management of Swedish forests and forestry operations. These forest companies own 37% of the forest, while the remainder is held by other private owners, state authorities or other public owners [48]. During the past century, this mix of ownership and actors has shaped the development of the 'Swedish forestry model' of shared interests and practices, providing the foundation for historical expansion of the Swedish forest industry [49,50]. The governing practices and relations between the state and the forest industry also constitute a key factor within the Swedish forestry model, to maintain high activity in family forestry and supply industry with timber. This has been achieved through creation of a shared rationale and mentality by the forest industry and the Swedish Forest Agency, with the main focus on timber production and with 'freedom with responsibility' as the governing system [51]. Shared interests and practices, supported by forest media, forest days, forest fairs, study campaigns and other public training activities, constitute the basis of forest owner norm-building regarding good forest management [49,50,52,53]. Swedish forest policy was largely deregulated with the introduction of the new Forest Act in 1993. This instituted the dual goals of biodiversity conservation and timber production, but left decisions on how these are achieved largely to the forest sector, with general environmental considerations in forestry complemented with voluntary set-aside of protected areas [54,55]. As a result, Swedish forest policy includes several levels: a minimum legal level; a higher 'guidance' level that characterises guidance by the Swedish Forest Agency and which is seen as necessary to achieve Sweden's environmental protection goals; and forest certification (via Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC)), which despite being a non-government, market-based system is seen as supporting Swedish forest policy [56]. More than 60% of Swedish forest land is certified by either or both of these schemes [47]. However, adaptation has not been integrated into certification schemes, although these at present constitute the most demanding requirements for environmental consideration and are widely practised in Sweden.

The state forest, owned and managed by the company Sveaskog, aims to serve as a good example concerning sustainability, but on a commercial basis [57]. Through the corporatist development of Swedish forestry [58–60], the Swedish forestry model has managed to maintain the economic motivation of multiple actors, i.e., forest owners, forest contractors, timber purchasing organisations and the forest industry, connected to timber production in general and silviculture and harvesting activities in particular across the whole of Sweden. However, during the 20th century, this has led to forest dominated by monocultures [61]. Nevertheless, the character and practices of the Swedish forestry model and the forest governing system have changed during recent decades, owing to increasing internationalisation and integration of new policy areas [62] and market-based certification systems [63,64]. Shifting values, attitudes and practices among various groups of forest owners [33,65,66] and users [67,68] have added to these changes by increasing the heterogeneity of interests and knowledge within the forest landscape.

3.1.2. Development of Adaptation Policy within Forestry and Related Actions

The main developments in adaptation in Sweden have taken place through a commission and subsequent bill. The Commission on Climate and Vulnerability, appointed in June 2005, published its findings in a report in October 2007 [69,70], with recommendations broadly taken forward in a 2009 Bill [71]. With regard to forestry, the Commission recommended that the government's instructions to the Swedish Forest Agency should be revised to include responsibility for adaptation in the sector; that it should review the Forestry Act with regard to climate change, monitor and evaluate forest damage and establish test sites for tree species selection and management; and that it should develop an information campaign targeting small-scale forest owners, who own about half of all Swedish forest land [69]; see also [72].

Following this development, adaptation to climate change has been included at the guidance level of the deregulated Swedish forest policy, with the Swedish Forest Agency currently providing guidance on adaptation to climate change, largely orientated towards 'forest owners' as a general

category. This guidance notes that temperatures in southern Sweden in 50–80 years will be similar to current temperatures south of the Baltic Sea, while temperatures in northern Sweden will be similar to those 500–1000 km to the south, as climate zones move northwards by some 5–10 km/year [73]. As a result, a number of measures are listed. Examples include:

- Adapting planting: to ground conditions and current climate, with up-to-date information as the climate is already changing, and with consideration of risks of increased windthrow (storm felling) and tree species-specific forest pest outbreaks (potentially increasing the number of tree species planted in these areas, and thereby the amount of mixed forest).
- Increasing the amount of mixed forest and continuity forestry (the former decreasing risks of windthrow and the spread and severity of pest outbreaks, the latter e.g., increasing resistance to drought).
- Avoiding over-planting of spruce, which is more sensitive to drought, windthrow and spruce bark beetle damage [74].
- Thinning forests to decrease the risk of breakages under heavy snow and potentially decrease the risk of windthrow.
- Limiting damage from forestry machinery during logging, as this becomes more severe during warmer and wetter winters (a factor that also sets higher requirements on forest road maintenance and development) [74].

In order to protect biodiversity, which will be threatened by climate change, increased environmental consideration is also emphasised, e.g., avoiding traffic damage and increasing environmental protection close to water [74]. More large-scale potential measures include adapting game management to limit damage to newly planted forest and increasing preparedness for forest fires by removing stumps and branches from logged areas [74]. In order to further support this guidance, the Swedish Forest Agency also provides cost-free advice for forest owners in their own forest and through courses, for instance related to the EU Rural Development programme (funded in equal parts by Sweden and the EU) [75,76]. Parallel activities are available to farmers through the Swedish Board of Agriculture [76]. With regard to invasive pest species that result in forest damage, early warning and action plan development is also underway in cooperation between the two sectors [76].

However, studies of adaptation uptake indicate that many of the actions suggested above are mainly potential rather than actual. When reviewing actual adaptations to climate change in forestry, it has been shown that adaptation is relatively low on the agenda of most actors within forestry, including forest owners' associations, which often communicate directly with small-scale forest owners [77]. Moreover, the types of adaptation that have been undertaken are often those in line with Swedish forestry principles and would have been undertaken anyway (coping) or capitalise on climate change to promote uptake [12,77]. Thus, more costly actions, such as increasing the extent of mixed forest, have been limited (e.g., [78]), while actions that are underpinned by the current production-orientated approach, such as shorter rotations and planting fast-growing non-native species, are more common and practised on a more short-term, event-related basis [77].

3.1.3. Structural Positions and Adaptive Spaces of Forest Owners

Adaptation actions are thus not differentiated according to different types of forest owners and there are no published data on the extent of uptake of adaptation measures by different owner groups. Adaptation to climate change in Swedish forests may be particularly complex given that many of the adaptation decisions will be made by private small-scale forest owners, often guided, through advisory systems, by forest companies, timber purchasing organisations (e.g., sawmills) and forest owners' associations [12,17,77] or, to some extent, by the Swedish Forest Agency [19]. Awareness and knowledge about adaptation to climate change in general and in forest management in particular is low among all groups of forest owners and forest professionals [19,21,77]. However, in some areas there is growing concern among forest owners, especially in relation to windthrow [17,22,23,79]. The extensive

forest damage due to storms in the past decade has highlighted the risks associated with climate change and the specific risks to spruce-dominated forests in Sweden [12,80]. However, even in damaged areas, only marginal adaptations have been introduced by forest owners in the replantation process [11,12].

Moreover, many small-scale family forest owners are non-traditional, i.e., not dependent on forest income: around a third live in different municipalities from their forest, 22% are pensioners whose forest may with some likelihood be inherited by urban dwellers (given that Sweden is one of the most rapidly urbanising countries in Europe) and 38% are women. Many of these forest owners also have multiple objectives, i.e., not only timber production. Further guidance and outreach to these owners could be possible, since around 100,000 of them (owning half the small-scale family forest-owned land in Sweden) are members of one of the four regional forest owners' associations (Norra Skog, Norrskog, Mellanskog and Södra), which in turn are part of the forest owners' national policy organisation (LRF Skogsägarna) [47]. Family forest owners often look to these organisations for purchasing forest management and logging services.

While adaptation in Swedish forests could be seen as crucial given the role that forestry plays in the national economy, the economic importance of forestry may also result in an emphasis on 'business and production as usual' (with potentially major challenges in shifting to more mixed forests rather than high-value but potentially sensitive spruce) [12,77,79,81], resulting in limited active management of risks [82]. The present rationales of Swedish forestry are mainly shaped by sector structure, demand from industry, economics and traditions, the process and meaning of climate change adaptation in forest management [77,79]. Most of the adaptive measures, i.e., revised guidelines for cleaning, thinning and harvesting operations, are attention-driven by major events/weather-related hazards, mainly storms. This reflects the present coping approach to climate change and the lack of strategic and planned adaptation within Swedish forestry [72,77,79]. Within a governing system based on the epistemic authority of forest professionals to guide, support and transfer knowledge and norms on what is regarded as good forest management to small-scale private forest owners [49], responsibility for the combination of low awareness of climate change adaptation among forest owners [21] and inequality of knowledge between individual small-scale forest owners and the forestry organisation [83] must lie with the forestry organisations and the Swedish Forest Agency. However, the agency has suffered organisational downsizing and budget reductions since the 1990s [18,49], consequently requiring forestry organisations to carry the main responsibility for climate change adaptation and the forest knowledge regime.

3.2. Scotland

3.2.1. Role and Structure of Forestry and Forest Ownership

The four countries of the UK (England, Scotland, Wales and Northern Ireland) are governed by the overarching Forestry Act of 1967 (which regulates felling), but since 2002–2003 each country has its own forest strategy and increasingly the state forestry bodies are also diverging. The Scottish Forestry Strategy (SFS) was published in 2006 and an update is currently envisaged (2017). Forest policy is now influenced by wider thinking about land use. The Land Use Strategy (both 2011 and 2016) was prepared as a result of a policy commitment in the Climate Change (Scotland) Act 2009 (Section 57), and in turn makes a commitment to revise the Scottish Forestry Strategy [84]. At the same time, a focus on institutional change, new structures and policies over the last 20 years, combined with reduced budgets and staff since 2010, and several high-impact tree health disasters, have all taken their toll on the forestry sector's capacity to innovate and adapt [42,85]. In 2017, the Scottish Government consulted on a new Forestry and Land Management Bill for Scotland, which is likely to bring forestry under the umbrella of the main Scottish civil service and to reduce the primacy of forest over other land uses (such as renewable energy).

Of the four countries in the UK, Scotland has the highest percentage forest cover, and also the most productive forestry sector [86,87]. As a devolved nation within the UK, separate GDP figures

are not available for Scotland, but a 2015 report on the economic contribution of the forestry sector in Scotland provides updated figures on employment and gross value added (GVA) [88]. The total employment associated with the sector is 25,867 full-time equivalent (FTE) jobs, of which about 50% are direct employment in the forestry sector and 80% represent forestry and timber processing combined. The total contribution of the forestry sector to GVA is £954 million (0.8% of Scottish GVA) [88].

Forest area in Scotland has increased greatly over the past century, from a low point of 5% in 1919 to 18% in 2016 [89]. As a result, about 75% of Scotland's forests are relatively recently established plantations. Non-native conifers constitute more than 80% of the forest cover and, of those, 60% are Sitka spruce (*Picea sitchensis*), an exotic conifer which grows fast in Scottish conditions, with typical rotation lengths of 35–50 years [90]. Around 33% of Scotland's forest cover (and 41% of the coniferous forest cover) is owned by the Scottish Government and managed by Forest Enterprise Scotland [91].

According to data submitted to a Joint Forest Europe/ United Nations Economic Commission for Europe(UNECE)/ Food and Agricultural Organization of the United Nations(FAO) questionnaire on pan-European indicators for sustainable forest management (SFM), about half the net annual increment is felled in the UK (in forest available for wood supply) (11.7 million m³ of 23.1 million m³). This supports the British government's concern that much potential remains under-utilised in the UK (separate figures are not available for Scotland).

National standards for SFM in public forests are set by the UK Forestry Standard (UKFS), recently updated by the Forestry Commission through a stakeholder consultation process [92]. The UKFS is also relevant to the private sector, as felling licences are awarded only when felling plans are compliant with the UKFS, which requires that felled forest is replaced, usually through restocking. The UKFS also forms the reference standard for the UK Woodland Assurance Scheme, the standard approved by the Forest Stewardship Council and PEFC, and therefore in certifying privately-owned woodlands on a voluntary basis.

3.2.2. Development of Adaptation Policy within Forestry and Related Actions

As with forest policy, climate change policy is addressed at multiple governance scales. The Climate Change Act (2008) governs the UK's compliance with the Kyoto Protocol, notably through setting the target of reducing emissions of all six greenhouse gases to at least 80% below their 1990 levels by 2050. Only Scotland has passed its own Climate Change Act, in 2009, under which Scottish Ministers have developed an adaptation programme [93]. This summarises the key risks and opportunities for the forestry sector as: increased problems of windthrow and drought, wildfire, pests and diseases, and possible increases in productivity in tree species that are matched to the new conditions. In the Programme, the aspiration for forestry is that "we need a move towards planned adaptation in woodland creation and management, as well-structured and diverse forests that can better withstand change and extreme events" [84]. Actions are focused on promoting standards (the UK Forestry Standard, see below) and decision support tools (such as Ecological Site Classification (ESC), which help planners to choose suitable species, and GALEs, which helps to manage wind risk), as well as supporting research to enhance resilience.

An overview of silvicultural components of adaptation concludes that silvicultural recommendations for more resilient and adapted forests focus on three dimensions: species composition, stand structure (which is often linked to silvicultural system) and adaptive management, and that two of these feature in Scottish policy [94]. The current Scottish Forestry Strategy (2006) refers to adaptation in only the broadest terms. One of seven key themes is "Using forestry, and adapting forestry practices, to help reduce the impact of climate change and help Scotland adapt to its changing climate" [95] and includes:

- Improving understanding of climate change impacts on woodland ecosystems and silviculture and implementing precautionary measures, such as forest habitat network creation.
- Maintaining preventative measures and ensuring readiness for pests, diseases and other threats, such as fire and wind.

With the shift in emphasis to the Land Use Strategy, and the new wider focus on ‘sustainable land management’ indicated in the Forestry Bill, climate and forestry work does not appear to be focusing more specifically on adaptation, and the main current policy driver is the continued expansion of new forests.

This leaves something of a vacuum in the relationship between policy and practice. Silvicultural researchers tentatively advocate species diversification, mixtures and stand diversification [96–99]. Three pieces of recent research suggest that the private sector is doing little or nothing to adapt (beyond compliance with the UKFS), and the public sector is struggling to adapt without clear scientific or policy guidance. First, a study of private sector advisors in Wales (where, for the purposes of this analysis, advisory systems and ownership are similar to those in Scotland) found that forest managers are not generally convinced of a need to adapt, have little confidence in climate change predictions and are more concerned about the current high levels of tree disease [100]. A second study focused on the public sector in England and Scotland, and again highlighted a disjunction between science and practice [42]. Without clear policy and operational guidance, foresters are tending to apply their own silvicultural knowledge and, through observation and local experiment, finding ways to diversify the conifer base. However, they are impeded by resource cuts, reorganisation, poor record keeping, increasingly top-down policy control and drivers to maintain timber production (despite policy headlines indicating multi-objective management).

The question of species diversification has generated much debate in industry and professional contexts in recent years, and a third study looks beyond the forest managers, to the whole supply chain on which species choice depends [85]. It focuses on the perceptions of nursery managers, forest managers from private and public sectors, and sawmill managers. The study highlights the dependence of forest management on both nursery supply and sawmill demand. Nursery suppliers are private businesses, which have suffered some acute financial losses through attempts to provide a wider range of conifer species. Sawmills, on the other hand, claim to be diversifying ahead of their reputation. The picture is complicated by regional variations and by competition between sawmills driven by recent over-capitalisation, but underlying the reluctance to shift is the over-riding focus of the private sector on high returns on investment, short rotation lengths (which allow forest managers to defer choices until climate change is more evident) and lack of policy tools. Traditional mixed estates tend to favour a wider diversity of species, but some focus their economic and cultural priorities on deer stalking. Scotland suffers from an excessive population of deer, and voluntary measures to control the problem have not been successful [101]. Many forest managers see the deer density (particularly of red deer) as the single greatest threat to commercial cultivation of a wider range of conifer species [85], and the factors underpinning the problem are cultural (i.e., the influence of the landowning sector).

3.2.3. Structural Positions and Adaptive Spaces of Forest Owners

The comparison between ‘public’ and ‘private’ forestry presented so far (and in official statistics) is a blunt instrument. Scotland has a range of different types of owners, and attitudes and modes of action vary according to cultural and ecological context [100,102]. Analysis of ownership in Scotland is confounded by two problems with data. First, land registration is not universal; the owners of any given piece of land may be buried in historical documents, or may be hidden behind a complex set of trusts and companies set up to obscure tax obligations [103]. When an owner applies for a grant, or sells the land, ownership must now be recorded, but this record is far from complete [104].

Second, of those owners who are known, little has been done to sort them into useful categories. The new National Forest Inventory provides greatly improved data on forest volumes and content, but data is currently presented only at the level of “Forestry Commission” and “Other”. The latter is extremely diverse, being defined as “Land not owned or leased to the Forestry Commission”. Thus, “private individuals, private forestry or timber businesses, other private businesses, local authorities, charitable organisations and community ownership or common land” are all combined in the same category, which also includes government departments other than the

Forestry Commission (such as the Ministry of Defence) [105]. A number of studies have attempted to develop typologies of private forest owners, but these cannot be modelled on the approaches used in the USA or Scandinavia where (a) all owners are known and (b) non-industrial family owners are the main focus of the typology. There have been many calls for segmentation of landowners to understand better those most amenable to woodland creation or management [106] and a very detailed study has been produced for England [107], but nothing comparable for Scotland.

The most detailed data currently available on Scotland's forest ownership are summarised in a privately-funded study [108]. Based on a sample of 17% of Scotland, Wightman concluded that over 91% of Scotland's non-FC forest area is owned by landed estates (46.2%) or investment owners (45.5%), and that 32% of the owners of Scotland's privately-owned forests live outside Scotland. So, while there are other owner types, a basic analysis of ownership must include public (33%), landed estate (27%) and investment forestry (27%).

It is a significant handicap in the study of forest decision-making and planning in the UK, that the commercial sector is almost invisible in statistics and literature. A Web of Science search produces only two papers that discuss the composition of commercial forests, and only one of these mentions landowners; the only paper which mentions investment forestry is dated 1992 [109].

Within the Land Use Strategy, ownership is mentioned in two contexts: a growing policy commitment to community ownership, and a public and political concern with the rights and responsibilities of landowners, being addressed in the Land Reform Bill [84]. Within the SFS, different types of forest owner are implied by the statement "Forestry businesses are characterised by large-scale timber processing based on just under 7 million m³ of timber production each year. Many woodland owners are struggling to obtain sufficient direct returns from their woodlands and this is impacting on their ability to undertake desirable silvicultural operations, such as thinning" [95]. What the strategy does not do is identify the characteristics of "forestry businesses" and "woodland owners", which are implicitly different in this statement. One indicator that the strategy seeks to change is "Just over 65% of woodlands are in non-state ownership and 28% are covered by approved, long-term forest plans" [95]. However, this "non-state ownership" is so diverse as to provide very little information in itself.

One study examining constraints on new conifer afforestation provides further information on the different priorities of different types of private landowners [110], and highlights the more mixed objectives of traditional estate managers compared with investment forestry. That study also shows that the advisory systems, which support the different owner types (particularly estate owners, investment forestry companies, and farmers), are quite different. Climate and forest policy do not as yet distinguish between these different owner types in modes of incentive or outreach. Private forest agents (consultants) make management decisions on behalf of the invisible majority of commercial/investment forest owners, and are constrained by their profit-orientation to focus largely on the fast-growing and market-friendly Sitka spruce.

Political goals for forestry adaptation are aspirational and are not strongly supported by incentives or information and advice. An important aspect of Scottish forestry (and indeed all British forestry) is that governance is weighted towards incentives and voluntary regulation (e.g., certification). Many have described the UK forestry sector as being relatively liberal, but stakeholders within the industry do not tend to agree. Government regulation can be summarised as the requirement for a felling licence (to fell more than 5 m³/year) and to regenerate or restock.

This leaves certification as potentially the strongest policy tool to support adaptation, although it is not focused on climate change per se. It is underpinned by compulsory regulation, which is the component of certification that influences species choice. All public forestry, and most commercial forestry, is certified in the UK under the UK Woodland Assurance Scheme (UKWAS; which is in turn supported by both the FSC and PEFC). The UKWAS criteria include guidelines on structural and species diversification, which are based on the regulatory standards provided by the UKFS. As with other policy tools, certification affects different owner types differently. The large traditional estates

sometimes complain that their forests are too diverse, and their objectives too varied, to comply easily with certification, while farmers find the costs too high for the area of woodland.

4. Discussion

The two countries reviewed in this study differ widely with respect to their forestry traditions and in terms of the parameters reviewed here (Table 1). The contribution of the forest sector to GDP is almost eight-fold higher in Sweden than in the UK (UNESCO) (although the economic significance of forestry in Scotland is much higher than in the rest of the UK). Although statistics on forest ownership are differentiated only into ‘public’ and ‘private’ categories, the majority of Scottish forest is owned by landed estates or investment owners. Sweden, together with its Nordic neighbours, has the largest average size of private forest holdings, while Scotland has the most inequitable forest land distribution [111,112]. In Sweden, production and profit incentives are still high among private forest owners, while the values and incentives among forest owners in Scotland are more diverse, ranging from farmers who planted trees to obtain subsidies to more intensive investment forestry. About 60% of Sweden is covered by forest, while the corresponding figure for Scotland is only 18%. In the Scottish case, this has increased nearly four-fold over the last hundred years and, as a result, the majority of the forest cover is plantation dominated by exotic conifers with commercial management objectives [89,90]. Swedish forest can be regarded as semi-natural and is dominated by Norwegian spruce. As a result of the stronger economic focus overall in Swedish forestry, it can largely be seen as related to maximising production rather than, for instance, maximising resilience under climate change [77]. In modern times, this is also the case in the investment forestry sector in Scotland where research indicates that most decisions are driven by profit maximisation, with little willingness to diversify under current conditions. High returns on investment in forestry are underpinned by a raft of tax incentives, which have been described as “overgrown” [112].

In summary, Scottish ownership is diverse, but poorly represented by statistics; the academic focus on owners’ motivations and decisions has often concentrated on smaller-scale and farm forestry, whereas more than 90% of private forests are owned by large estates and investment clients and more than 50% are owned by non-residential owners and managed on their behalf by forest agents. In investment forestry in particular, but also more widely in commercial forestry, the motivations and willingness to adapt among owners and managers are poorly known.

For these two case studies, therefore, it can be argued that different policy tools are working against each other. In both Sweden and Scotland, the conception of forest owners within adaptation policy is quite limited and mainly understood and addressed in more general terms, even as broad as “land owners”, without clear acknowledgement of the various diversities within this wide group, e.g., in capacity, incentives and vulnerability. The general low awareness of climate change adaptation among forest owners [21] and the inequality of knowledge between individual small-scale forest owners and the forestry professionals/organisations [83] highlight potential structural constraints to adaptation and the realisation of capacity in both these contexts. The lack of integration of climate change adaptation in certification schemes and the high dependence, in both contexts, on private advisory services, often dominated by production-orientated logics [12,17,77,100], further underline these challenges on both a local and policy level.

5. Conclusions

To conclude, much of the variation in forest systems can be viewed as a result of historical developments. Historically, Swedish forests and forestry became an integral part of the welfare state at an early stage (both in terms of the economy and employment), due to the combination of e.g., the historical landscape of forest-owning small farmers and various land reforms during the 19th century. In terms of both politics and livelihood, the first Forestry Act in 1903 contributed to the construction of forest as a common interest. Landed estates and high concentration of land ownership have dominated the Scottish landscape, and this has contributed to low public interest in forests and

conflicting relationships between farmers and forest. The unequal distribution of land, combined with political focus on reforestation, forest professionalism (private agents) and increasing economic dependence on investment forestry and timber-demand from industry, have shaped the political space of Scottish forests and it's the present structure, dominated by landed estates and commercial forestry managed on behalf of absent investors. Swedish forest and forestry early on became a common interest and the structure of the industry was segmented, and therefore the sector has developed to comprise multiple groups of forest owners within the 'Swedish forestry model' and systems to govern these groups (e.g., through social norms, advisory systems or technologies such as forest management plans) [49,50].

In the deregulated conditions characteristic of forest governance in both contexts, the lack of integration of climate change adaptations in the social regulatory practices and performative spaces of voluntary regulations (e.g., certification) constitute a major challenge for the epistemic and normative authorities that these contexts depend upon, and in turn contribute to the structural barriers to change. Given the weak integration in both countries, vulnerability of different groups of forest owners potentially becomes interlinked with their adaptation capacity and their specific structural and institutional conditions, e.g., resources, knowledge, traditions, etc. (cf. [77]). The persistence of these structures means that more common rationales and norms, primarily focused on production and motivating activity by forest owners, have been established and have shaped the process of defining good management and forest ownership [51]. In the Scottish case, the lack of data on forest ownership is evidence of a forestry structure which contrasts with that of Sweden, in its modes of representation and governing. This is partly manifested in a research focus on public land and the lack of visibility of commercial forestry [100,102,112].

In terms of adaptation measures, specific situations thus produce both a specific set of political spaces and policy tools that are interlinked within the context, and determine the logics that shape policy and adaptation processes: the aspects that are seen as manageable [38], negotiable [18,19] or practical in a logical sense [36] (e.g., replanting of spruce after a storm [12] or fast growing species [77,90]). This relationship emphasises the need to explore these issues on the contextual basis of different forestry structures and forest governance systems. It also indicates that greater attention needs to be paid to the specific agencies that these different systems provide, in order to better understand the adaptation logics of different groups of forest owners. Moreover, it reveals how different logics and rationalities hinder effective climate change policy and adaptation (cf. [113–116]).

Given the types of economic logics prevalent in both countries, a potential way to include more groups of forest owners in climate change adaptation could be to include adaptation requirements in the central planning and support systems (e.g., [117,118]), such as in felling regulations, or forest certification guidelines (e.g., [119]). However, a more diverse, inclusive and successful approach to adaptation may require the creation of space for alternative thoughts and actions by various actors (cf. [120]) to develop a more transformative approach to the challenge of climate change in forests [42,79].

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