Knowledge production and learning for sustainable forest management on the ground: Pan-European landscapes as a time machine

PER ANGELSTAM, ROBERT AXELSSON, MARINE ELBAKIDZE, LARS LAESTADIUS, MARIUS LAZDINIS, MATS NORDBERG, ILEANA PĂTRU-STUPARIU AND MIKE SMITH

Introduction

The sustainable forest management (SFM) concept appeared in the early 1990s as a way of describing what contemporary societies wanted from forests and wooded land (Loynhe Wilchie et al., 2003). SFM is a principle that focuses on both the stewardship and its economic, ecological and social outcomes on the ground (e.g. Forest Europe, 2011). In addition, policies in other related fields such as rural development (Bryden and Hart, 2004), conservation of biological diversity (European Commission, 1979, 1992), water (European Commission, 2000), bioenergy (European Commission, 2011) and landscape (European Council, 2000) are influencing expectations to be fulfilled by forests and wooded land.

As a consequence, it is vital for professionals involved with policy, governance and management concerning forest and woodland to be well-informed about the states and trends of different sustainability dimensions, based on criteria (i.e. values, goals) and indicators (i.e. quantitative and
qualitative variables) (e.g. Lammerts van Buren and Blom, 1997). Policies often also define, explicitly or implicitly, norms or performance targets that need to be satisfied in order for a particular indicator variable to be considered as sustainable. In addition, it is necessary to develop ways of establishing integrated multi-sectoral societal platforms for local and regional societal steering processes (e.g. Baker, 2006; IMFN, 2008). Altogether, criteria, indicators and norms provide a ‘map and a compass’, and the governance system a ‘gyroscope’ (see Lee, 1993), which ideally could contribute to making informed decisions based on transparent and reliable knowledge. Taken together, this is a prerequisite for innovation and adaptation to an increasingly uncertain situation by making legitimate decisions. This can be called an integrated landscape approach (World Forestry Congress, 2009).

While SFM policy formulation processes are well developed at the Pan-European level and in many countries, policy implementation on the ground remains a challenge (e.g. Lazdinis et al., 2007; Blicharska et al., 2011; Angelstam et al., 2011b). The recently published report State of Europe’s Forests (Forest Europe, 2011) identified four future challenges to realizing SFM:

1. to find and deliver the optimum balance among the various forest functions by mitigation and adaptation in the context of a changing climate and societal needs.
2. to mobilize more wood to meet the targets for bioenergy production, but also to reconcile this with the other dimensions of SFM.
3. to reconcile measures for biodiversity conservation with the more intensive forest management likely to be necessary to meet the expected higher demands for wood, including for renewable energy.
4. to achieve the potential of sustainable production and consumption patterns, green building, green jobs in the sector and the supply of renewable energy by strongly developing the ‘green’ features of the forest sector.

Given its long and complex history, Europe remains a very diverse continent in terms of its forest and woodland types and management systems (e.g. Puettmann et al., 2009). For long time, forest policy in the Europe has been solely a national responsibility. Since 1988, however, the European Community (EC) has attempted to adopt a more coherent approach to its forest-related projects, including a communication on a strategy and action programme for the forestry sector (Lazdinis et al., 2009). At the Forest Europe summit in June 2011, negotiations for a Legally Binding Agreement on Forests were initiated (www.foresteurope.org, visited 2011-06-16). Given the diversity among European landscapes, it is thus important to be aware of the local context in terms of ecological, economic and socio-cultural profiles, as well as governance arrangements (Angelstam and Elbakidze, 2006; Elbakidze et al., 2010) when implementing SFM policy.

The objective of this article is to outline an approach to knowledge production and development of learning processes related to SFM implementation on the ground that takes advantage of the diversity of forest and woodland landscapes on the European continent. The diversity of forest history and governance contexts in Europe’s natural forest and cultural woodland landscapes provide a unique resource for the development of knowledge about how to achieve both sustainable development as a process and sustainability as an outcome on the ground. We present European landscapes as the ‘time machine’ (Angelstam, 2001) which provides unique potential to allow a better understanding of the effects of the human footprint on landscapes and thus to define targets for sustainability (Vucetich and Nelson, 2010), approaches to forest and woodland landscape restoration (Mansourian et al., 2005) and adaptive governance (Elbakidze et al., 2010). This is possible due to the steep gradients in land use history whereby the gradual exploitation and intensive management of forest and woodland resources has spread like a tidal wave from areas of high demand to more and more remote regions (e.g. Gunst, 1989; Wallenius et al., 2010). Similarly, there are large regional differences in governance arrangements and social capital (e.g. Putnam et al., 1993; Lehtinen et al., 2004).

Firstly, we employ a biographic approach to Bergslagen in Sweden, the European boreal forest region with the longest history of still ongoing sustained yield wood production. Secondly, we use a comparative approach including five landscapes in Europe with different forest and woodland histories. Finally, we stress the need to study reference landscapes for natural forests and cultural woodlands and provide three examples. We discuss how suites of landscapes can be used as multiple cases for both (1) innovative production of knowledge and (2) social learning on the ground to achieve ecological, economic and socio-cultural goals through improved collaboration of stakeholders from different societal sectors at different levels.

European forest landscapes as a time machine

Biography of a forest landscape: Bergslagen (Sweden)

A dynamic forest product profile

Bergslagen is an informal region in central Sweden with a history of use of natural resources that began more than 2000 years ago (Nelson, 1913; Seebass, 1928; Berger et al., 2006; Isacson et al., 2009). Forest and woodland landscapes has had different roles over time in Bergslagen. The gradient between rural remote regions and more developed urban areas, including the Swedish capital Stockholm, coincides with the transition between Mälarvalley’s cultural landscape and forest lands to the north that eventually became known as Bergslagen (Nelson, 1913; Seebass, 1928). Upland areas in the northwest were permanently colonized by agriculture only during the late 1500s when immigrating Finns settled to practise slash and burn farming (Nordmann, 1888; Montelius, 1953; Emanuelsson and Segerström, 2002). Forests also provided grazing for cattle, fuel and materials for buildings, fences, tools and household items.
Small-scale production of iron began more than 2000 years ago in Bergslagen. Mining for copper started in the eighth century and in 1347, it was described how charcoal production at the mine in Falun, the main mining city in the region, was managed (Rydberg, 1982). Mining and metallurgical activities were important to the nation, and already in fourteenth century, the mining industry received rights to use 'all public forests and streams'. Industrial iron mining commenced during the early Medieval (Bindler et al., 2011). Germans saw the possibility of industrial mining activities during the early Medieval, and the Walloons from Belgium developed steel production during the 1700s (Magnusson, 1997). Mines, forests and streams in Bergslagen thus formed the base for economic development of the whole country for a long time.

The mining industry demanded three main types of forest products (Ryberg, 1982): (1) wood fuel to heat and crack the rock to allow extraction of iron ore, (2) wood fuel to reduce the oxygen content in the mined ore and (3) charcoal to melt the iron (Arpi, 1951). Additionally, wood was used for pit props, other mining constructions and shipbuilding. Due to intensive mining activities in Bergslagen, the need to produce a sustained yield of wood was recognized very early. Thus, Swedish industrial forest management was first widely introduced in Bergslagen (Brynte, 2002). Already during the seventeenth century, a discussion about wood shortage and what to do to solve it began (Wieslander, 1936). The establishment of the Swedish Board of Mines (Swe.: Bergskollegium) in 1637 and of Queen Christina's forestry legislation in 1647 were two early but important steps towards a sustained yield wood production. During the late 1700s, the fear of wood shortage was large (Wieslander, 1936), and regulations that required forest management plans to support sustained yield forestry were created. Already more than 200 years ago, the process of developing systematic forest planning and management began. This was an effort to meet the contemporary market needs for efficient wood production to provide charcoal as bioenergy for the mining and iron industry. An early example from Bergslagen was Garpenberg, where clear-felling with natural regeneration with or without prescribed fire and a 40-year rotation was used in 1767 (Almqquist et al., 1980).

Experiences from Germany, especially the Harz Mountains, where the challenges with sustained yield wood supply for the production of metals, glass and potash had been experienced earlier, became the basis of the first forestry training in Sweden (Brynte and Obbarius, 2002). Israel af Ström, who founded the Royal Forest Institute, and Carl Ludwig Obbarius, who founded the Bruksossefeten's Forest Institute in Bergslagen, were the two champions of sustainable yield forestry in Sweden. During the nineteenth century, Bergslagen experienced a transitional period from mining to forest industry as the main users of wood (Nyblom, 1959).

Initially, wood harvesting was done using dimension fellings, which means that big trees were felled and the rest was left behind. This produced forests with a low standing wood volume and poor growth rate, which forced the forest-dependent and nationally important mining and iron industry to recognize the need for efficient sustained yield wood production already in the late eighteenth century. An early example from Bergslagen was Garpenberg, where clear-felling with natural regeneration with or without prescribed fire and a 40-year rotation was used in 1767 (Almqquist et al., 1980). By the mid nineteenth century, foresters in Bergslagen had implemented the German model with clear-felling practices (Brynte and Obbarius, 2002). The short rotation time was due to the focus on the most important products – wood fuel for mining and charcoal for iron production. As a consequence, there were few stands older than 60 years (Figure 1). When the mining industry ceased to be the major purchaser of wood, the companies' focus gradually evolved to producing timber and pulpwod. The age distribution was thus shifted toward delivering tree dimensions that also satisfied the sawmilling industry and resulted in older forests than before (Figure 1). These older forests gradually became mature for logging. The proportion of young and middle-aged forests therefore has been increasing to the present day, and in addition, the areas of older forests set aside for biodiversity conservation has increased lately (Figure 1). Today, the main principle of forest management is to maintain a maximum sustained wood yield by using clear-felling methods, and the main end-user is the export-oriented forest industry. In addition, natural and cultural landscape values are emerging as providers of post-modern products in terms of tourism and amenity migration.

Consequences and lessons learned

Over the past two centuries, forest landscapes in the Bergslagen region have methodically been developed from local multiple use into efficient wood production systems, first for mining and then for the forest industries. However, this long history of industrial production, that once provided many jobs, resulted in relatively low levels of entrepreneurship and education among local people compared with regions with more diversified livelihoods (Bergdahl et al., 1997). The long history of mining has also led to a legacy of polluted water, soils and remaining sludge deposits (Bindler et al., 2009; Sartz, 2010). Natural resources still continue to be a base for commodity production based on wood, metal and water in Bergslagen, but immaterial values are becoming increasingly important for the evolution of new products connected to the landscape, culture and nature (Vail and Hultkrantz, 2000) and thus for rural development.

Forest landscape actors continuously need to adapt to new situations. Economic globalization, energy production (biomass, water and wind) and climate change are current issues that affect forest landscape management and governance. Additionally, with increasing mineral prices internationally, there is a renewed interest to resume mining operations in Bergslagen. Cultural and ecological values of forest landscapes in Bergslagen are attractive to people. This has led to a wave of seasonal and weekly amenity migration of people seeking recreation and better quality of life. Some move permanently from densely populated
regions in Europe, while others split their time between recreation in Bergslagen and work remotely in Stockholm and other cities in central Sweden. There is thus a need to adapt present management to maintain and develop cultural and natural values of forest landscapes in Bergslagen. However, to maintain the biodiversity of natural forests and cultural woodlands by protection, management and restoration is a major challenge. What, where and how much? These are three central issues for conservation of viable populations of all the natural forest species as required by the Swedish forestry and environmental policies. ‘What’ is about representation of all natural and culturally caused forest habitats in Sweden. ‘Where’ is about how patches of these forest habitats are located in relation to each other for species to survive in the short term. ‘How much’ describes the need for a certain amount of large enough areas together forming functional networks of different forest habitats that meet the requirements for long-term species survival. Much remains to be done to achieve biodiversity policy objectives (Angelstam et al., 2011a). (1) Protection of forest habitats on productive sites are underrepresented among both protected areas and in the managed landscape as a result of forest history and current forest use (Nilsson and Götzmark, 1992; Angelstam and Andersson, 2001). (2) Protected areas are few and often located as isolated islands in the used landscape, resulting in poor functionality of habitat networks (Angelstam et al., 2003a; Manton et al., 2005). (3) The proportion of forest land reserved for species conservation is still low in relation to science-based policy targets (Angelstam et al., 2011a, b). (4) Protection, management and restoration measures of various kinds, and collaboration for ecological landscape planning among landowners and other stakeholders is insufficient (Eriksson and Hammer, 2006; Angelstam et al., 2011a, b).

Thus, as illustrated by the Bergslagen region in Sweden, SFM is an evolving concept and concerns entire landscapes as integrated social-ecological systems. A current challenge is to develop collaboration models that allow different forest stakeholders to work together locally, regionally, nationally and internationally to achieve their desired diversified and intensified but still sustainable use of goods, services and values of forest landscapes across Bergslagen (Andersson and Angelstam, 2008). Regions and countries with a shorter history of forestry than in Bergslagen, such as in Russia and Canada, which want to develop an economically sustainable forestry, and analyse the consequences of this can thus learn much from Swedish historical experience. This applies both to what worked well and the negative effects.

The overview of the Bergslagen region’s forest history reflects a general forest historical fact, namely that people and communities at various times have had different profiles of use of forest landscape goods, ecosystem services and values (Agnoletti and Anderson, 2000). Similarly, landscapes in different regions and countries are located in different historical phases of forest use and have different governance arrangements (e.g. Wulder et al., 2007).

Figure 1. Age distributions in the Skinnskatteberg forest management unit of the Swedish state forests for the years 1903, 1935, 1967 and 2010 (data from Ek (1995) and the state forest company Sveaskog Co.’s data base; normal age distribution according to Ek (1995)). The contemporary aims of Sveaskog Co. are to develop economic, social and ecological values. To maintain biodiversity Sveaskog Co. aims at setting aside 20% of the productive forest area in each ecoregion and considers other stakeholders’ needs. This has effect on both the expected development of harvest levels (lower) and the age class (broader) and tree species (more diverse) distribution.
European forest landscapes with different histories

Scotland – forest landscape restoration (UK)

The westernmost boreal forests of Europe are located in the north of Scotland and have a long history of deforestation and conversion. The pine-dominated forests in the Scottish Highlands that previously covered more than 1.5 million ha currently occupy only about 16,000 ha, of which over half consists of very open park-like pine woodlands. Human use of this region started at least 4000 years ago when pastoralists used the land for grazing (Davies and Tipping, 2004; Froyd and Bennett, 2006). Subsequently, forest cover declined dramatically, probably due to a combination of climate change, felling and grazing by domestic stock with pine becoming dominant. The advent of refrigerated meat from Australia out-competed sheep production and conversion. The pine-dominated forests in the region have been reforested after wind damage and bark beetle infestation. As a consequence of both ecological problems (Jansen et al., 2002; Hauhs and Lange, 2010) and changing values in society (Lehman, 2001), the forest administration in Lower Saxony took an initiative to transform forest practices. Protection, conservation and recreation are today coordinated in an ecological planning process called Löwe (Langfristische Ökologisches Walderneuerung) in an area of 74,000 ha in the Harz, divided into 54,000 ha of state forests managed according to Löwe-model, 17,000 ha national park with low forest management intensity and 3000 ha with municipal forests where the Löwe-model is not mandatory but recommended.

Eastern Carpathian mountains – forests for local livelihood (Ukraine)

The Ukrainian Eastern Carpathians cover 3.5 per cent of Ukraine’s area and 10.3 per cent of total area of the Carpathian Mountains. This part of the Carpathian ecoregion has been part of Austria-Hungary, Poland and the Soviet Union (Hensiruk et al., 1998). The character and intensity of the use of forest resources intensified during the nineteenth century. As a result of high demand for wood in West European countries, the forest industry began to develop (Hensiruk, 1964). The demand for spruce (Picea abies) wood on the market prompted the Austrian owners of the forests to replace the natural forests with spruce in the late nineteenth century (Hensiruk, 1964). A complete change of political, social and economic relations in Ukraine that had profound influence on the ways in which natural resources were used was initiated in 1939 when also the Western regions of Ukraine became part of the Soviet Union. Forests owned by state, private plots of land were joined into collective farms, and there was a shift towards industrial use of forests.

The dynamic history of the Carpathian Mountain region with a range of different governance and management systems has influenced the forest landscape in many dimensions (Soloviev and Keeton, 2009; Bjornsen Gurung et al., 2009). At present, the strategic objectives of the Ukrainian national forest policy are related to SFM according to international agreements. Implementation of SFM on the ground in the Carpathian Mountains region requires (1) protection of ‘a unique natural treasure of great beauty and ecological value, an important reservoir of biodiversity, the headwaters of major rivers, an essential habitat and refuge for many endangered species of plants and animals and Europe’s largest area of virgin forests’ (Anon, 2003); (2) maintenance of traditional village systems (Elbakidze and Angelstam, 2007) and (3) development of multiple economic use of forest resources for local, regional and

Harz – the cradle of sustained yield forestry (Germany)

The German Harz Mountains are divided into three different states: Lower Saxony, Saxony-Anhalt and Thuringia. From 1952 to the reunification of Germany, Harz was divided between West and East Germany. The natural vegetation consists of beech and oak up to 700 m above sea level, then mixed forests of spruce up to 800 m after which Norway spruce dominates. The highest point is the Brocken (1142 m). Harz is just as the Bergslagen region rich in minerals, forests and streams (Hauhs and Lange, 2001). Mining has been conducted since the eleventh century. The main forest products were firewood, timber and charcoal. Forest management started in 1712. Until about year 1800, only beech and oak were used, and coppice forestry dominated. From the 1790s, spruce began to be planted.

Management of the forest landscape in Harz is currently focused on how to deal with heavy metal depositions from nearly 500 years of intensive mining operations, returning some of the planted spruce (which represents almost 90 per cent) to deciduous forests, browsing damage on trees caused by red deer, reforesting after wind damage and bark beetle infestation. As a consequence of both ecological problems (Jansen et al., 2002; Hauhs and Lange, 2010) and changing values in society (Lehman, 2001), the forest administration in Lower Saxony took an initiative to transform forest practices. Protection, conservation and recreation are today coordinated in an ecological planning process called Löwe (Langfristische Ökologisches Walderneuerung) in an area of 74,000 ha in the Harz, divided into 54,000 ha of state forests managed according to Löwe-model, 17,000 ha national park with low forest management intensity and 3000 ha with municipal forests where the Löwe-model is not mandatory but recommended.

The current aims of management are to promote natural processes and foster the return to more natural woodland, a priority habitat within the UK Biodiversity Action Plan (Anon, 1995), and with targets set for establishment of new woodland in addition to the expansion, restoration and improvement in the condition of the surviving remnants. There is an aim within this policy to increase the woodland cover of Scotland from 17 to 25 per cent of the total land cover (Forestry Commission, 2006). This would see an increase in all forest types and management alternatives, including rehabilitation, restoration and regeneration. The challenge is to convey a long-term vision of the desired forest structure for the future and to identify silvicultural options that achieve these aims while maintaining biodiversity and landscape values.

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national development (Anon, 2003; Soloviy and Keeton, 2009; Elbakidze and Angelstam, in press).

Pskov oblast – introducing sustained yield forestry (Russia)

Forests in the Pskov region, located in the westernmost part of the Russian Federation, immediately east of Estonia and south of St. Petersburg, have been used for traditional farming and animal husbandry for a long time, just as in Bergslagen. Forests were cleared for agricultural purposes since the seventh century. For long time, Pskov was a regional economic centre. The abolition of serfdom in 1861 eventually led to more intensive forest management for sales at local markets. New free farmers who acquired land paid for this by cutting forests, leading to increased deforestation between 1906 and 1914. After the revolution of 1917, wood removal rate increased further and was concentrated to easily accessible parts of the landscape. During World War II, the intensity of forestry decreased sharply. In 1950s, forests were harvested using a method called ‘concentrated felling’, i.e. a frontier of clear-felling, which led to over-harvesting and deforestation of large areas (Koldanov, 1992; Knize and Romanyuk, 2005). The main role of forests and forestry at this time was to support the industry with cheap raw material. Intensive logging and the lack of silvicultural activities led to a major alteration of forest age and tree species structure.

At present, middle-aged stands dominate in Pskov, and natural regeneration without silviculture has resulted in a dominance of deciduous trees (birch (Betula spp.) and aspen (Populus tremula)) instead of coniferous (pine and Norway spruce). At the same time, the human population declined in rural areas, and a gradual abandonment of fields and meadows began. Only in the 1960s, a new forest inventory was done and forests began to be replanted after harvesting (Knize and Romaniuk, 2005). During the latter half of the 1990s, logging increased again due to international demand for wood. Since 1998 collaboration between Sweden and Russia has resulted in the development of the Pskov Model Forest. The aims were to introduce an intensive forest management system based on Swedish and Finnish experiences but adapted to the local and regional conditions and to develop landscape planning for biodiversity conservation (Romanyuk et al., 2001, 2005).

The Dvina-Pinega in Arkhangelsk Oblast – a large intact forest massif (Russia)

While forests have a very long history of dimension felling along the watercourses in order to obtain raw materials for shipbuilding that took place in Arkhangelsk city, founded already in 1584 (Redko and Babich, 1993), Arkhangelsk Oblast was dominated by old-growth forests still into the 1970s (Trubin, 1985, 2009). During the Soviet period, large forested areas were clear-felled, and what remains today in remote places forms a large part of Europe’s last remaining large intact natural productive boreal forest areas (Yaroshenko et al., 2001). One example is the massif of pristine boreal forests located between the Dvina and Pinega rivers in Arkhangelsk Oblast in north-west Russia (Dobrynin and Stolpovskiy, 2008). In an European context, conservation of this forest is recognized as an efficient way to sustain biodiversity in terms of species, habitats and ecosystem functions (Yaroshenko et al., 2001; Spidsø and Sorensen, 2009). The debate among different stakeholders from local to international levels regarding these intact forest landscapes and how to find a balance between use and conservation is intense. On the one hand, conservation of these large intact forest areas is crucial according to international guidelines on the conservation of biological diversity in the European boreal forest from the Atlantic to the Urals (e.g. Dobrynin and Stolpovskiy, 2008). On the other hand, these areas could supply large volumes of timber for forest industry and bioenergy production. The rapid harvesting of old-growth forest without secured regeneration during the Soviet period has led to large areas of young forest not yet ready for harvest and thus a constant pressure on remaining old-growth areas.

Reference landscapes for natural forest and cultural woodland

Pechora-Ilych in the Komi Republic – a strict nature reserve (Russia)

Even if vast, Russia’s boreal forests host only few areas where forests’ natural dynamics are controlled by coarse-grained natural disturbances such as fire and wind as well as fine-grained disturbances caused by flooding, insects and fungi (Syrjänen et al., 1994; Kuuluvainen et al., 1998; Yaroshenko et al., 2001). Some of these areas are protected in a form that is called zapovednik (Shtilmark, 2003) in Russian or strict nature reserve, excluded entirely from any kind of human use. The aim is to protect biodiversity and
monitor different aspects of natural ecosystems over time. Pechora-Ilych, the European continent’s largest protected area, is located in the Komi Republic on the west side of the Ural Mountains and covers about 1.3 million ha with its buffer zone. Pechora-Ilych is thus a reference landscape for studies of natural boreal forest dynamics on a large scale as a basis to implement the vision of ecologically sustainable forest management (Angelstam et al., 1997, Jasinski and Angelstam, 2002; Torlopova and Il’chukov, 2004; Van der Sluis et al., 2003).

The ecological values of forest landscapes in the buffer zone around the protected area are currently seen by the regional administration as a great resource for the development of ecotourism that could become an important part of the regional economic development (V.A. Shirotov, personal communication). Badenkov (1998) stressed the need for a comprehensive plan for sustainable development of Russia’s mountain regions. These included participation by residents, protection of natural resources and the environment, recognition of the Ural Mountains as a social and natural heritage.

Dehesa and montado – agroforestry cultural landscape (Spain and Portugal)
Land management systems incorporating combinations of trees, grasslands and rotation cereal cropping around villages have created key elements in European landscapes throughout historical times (Heaton, 1948; Stevenson and Harrison, 1992; Eichhorn et al., 2006). The Mediterranean Spanish dehesas and Portuguese montados are agro-silvo-pastoral savannahs covering about 5 million ha (Joffre et al., 1999; Plieninger et al., 2003). As such, they form reference landscapes for cultural woodlands. Under the impact of rural communities on forests, dehesa and montado systems integrate use of forest, grasslands, fields and landscape (Costa Tenorio et al., 2005; Pardo and Gil, 2005; Vicente and Alés, 2006). According to Clément (2008), the durability of the Spanish wood pasture can be explained by insecurity along the regional borders (the word dehesa comes from the word defence), that transhumance was the most important industry in Spain for many centuries and the protective laws adopted by the rural communities to protect dehesas. These open man-made woodlands exhibit ecological integrity (Moreno Marcos et al., 2007) and maintain a high diversity of several groups of plants and animals (see Aragón et al., 2010). The combination of grazing, shrubs and maintenance of oak trees promote diversity of birds (Godinho and Rabaça, 2010) and mammals (Rosalino et al., 2009; Pereira and Rodríguez, 2010). Maintaining the patchiness of natural and cultural processes of the landscape appears crucial for many wide-ranging species (Pereira and da Fonseca, 2003). Additionally, to regenerate holm oak (Quercus ilex), episodes without grazing may

Figure 2. Satellite image showing the forest harvesting gradient south of Karpagory in the Pinega catchment in Arkhangelsk Oblast, NW Russia, with four strata: (1) young forests (without silviculture and with potential for development of sustained yield forestry in the future if cleaning and bioenergy harvesting is commenced), (2) harvested areas with corridors along streams according to previous rules (thinning is now allowed in previous set-asides), (3) partly harvested areas in chequer-board pattern outside large intact forest areas and (4) not harvested areas inside large intact forest areas. The white line is 10 km.
be needed (Pulido et al., 2001). Trends of land abandonment and intensification of land uses both form threats to dehesa and montado systems (Pinto-Correia, 2000; Plieninger, 2006).

According to Plieninger et al. (2004), the loss of these cultural woodland systems is an effect of urbanization, rural abandonment and the EU Common Agricultural Policy (CAP). Also Fragoso’s et al. (2011) results based on modelling of farmers’ incomes indicated negative effects of CAP resource allocation. There is thus a need to reinforce and promote alternative agricultural and non-agricultural economic activities in rural areas (Fragoso et al., 2011). New functions include leisure and recreation (Pinto-Correia, 2000; Garzia Perez, 2002; Surová and et al., 2011). Indeed, Gaspar et al. (2009) showed that mixed livestock dehesa farms, i.e. the closest to the traditional systems with a highly diverse production, made optimal use of resources and had little dependence on external subsidies. To conclude, the maintenance of the dehesa and montado systems by management is a good example of how traditional silvicultural ideas need to give way to a diversity of forest and woodland management regimes that take into account goods, services and landscape values (Linares, 2007). However, Pinto-Correia (2000) and Plieninger et al. (2004) pointed out that this requires a holistic landscape approach including conservation incentive schemes, environmental education and technical assistance.

Transylvanian Alps in the Carpathians – two references in one place (Romania)

This case study focuses on the Southern Carpathians (also known as ‘Transylvanian Alps’), which have the highest coverage of virgin forests (Biriş and Veen, 2005) and were less impacted by deforestation during the post-communist period (Rozylowicz et al., 2011). This area includes reference landscapes for both natural forest and cultural woodland. From the perspective of the time machine, the two models correspond to different historical trajectories.

The natural forest reference includes most of Retezat National Park, areas in the Domogled-Cerna Valley National Park and the Hăţeg Country Dinosaurs Geopark. Here, large parts of the remaining natural beech forests in Europe are located (Biriş and Veen, 2005). The historical conservation of this intact forest landscape is explained by the fact that the western part of Southern Carpathians represents a mountain ‘citadel’. Due to the topography, this area was never fragmented by access roads. In 1935, Romanian authorities decided to set-up in Retezat the first national park in Romania (Drăcea, 1945). Today, in this region, almost 90 per cent of the intact forest landscape is already included in existing protected areas (Stanciu, 2008).

The cultural woodland reference includes mountainous massifs separated by the main transcarpathian axes of communication: the Olt Valley and the Rucăr-Bran Passageway (both used since the Roman period), respectively, the Prahova Valley (used especially after the construction of the royal summer residence, in the late nineteenth century). The presence of human settlements had, over time, a greater impact on forest cover. Very ancient tradition of wood processing can be recovered in the traditional architecture of houses or in the household objects (Giurescu, 1980). During the nineteenth century, as a consequence of the new policies introduced in the Austrian Empire, significant afforestation occurred. This phenomenon is similar to that reported in other regions of the Carpathians (e.g. Kozak, 2003). However, the economic pressure on forests has increased both at macro-level, due to wood industry development, and at micro-level, due to the large utilization of wood for fuel by locals (Borlea, 1998). During the communist period, despite the industrialization policy, afforestation campaigns were launched (Ungur, 2008). After the collapse of the communist regime in 1990, massive landowners transfer occurred, thus leading to large scale and uncontrolled deforestation. In the Southern Carpathians, such deforestations were reported mostly in the eastern part.

To conclude, in the context of SFM, maintenance of natural forest and cultural landscape requires application of differentiated planning policies. In the western part of the Transylvanian Alps, it is suitable to establish a network of functional bio-corridors between adjacent virgin forest sites (Veen et al., 2010). In the eastern part of the Transylvanian Alps, it is necessary to implement an updated forest legislation related to the afforestation program (Romanian Government, 2008) with a focus on the management and conservation of the cultural landscape.

Discussion

Multiple case studies of landscapes for knowledge production

Forests and woodlands provide goods, ecosystem services and values, the profiles of which vary in time and space (Kennedy et al., 2001; Merlo and Croitoru, 2005; Wulder et al., 2007). Both with Pan-European and EU perspectives, the diversity of forest landscapes is an asset for knowledge production based on compilation and comparison of local knowledge and perspectives on sustainability of forests and woodlands and sustainable development processes in different regions. Put simply, comparative studies of multiple landscapes provide short cuts to developing both knowledge and societal learning processes toward sustainability in forest and woodland landscapes. This is endorsed by FAO’s forest definition, which includes not only high forest but also other wooded lands (FAO, 2010). Consequently, the borders between traditional sectors such as forestry, nature and cultural heritage conservation, agroforestry, agro-silvo-pastoralism and rural development have become blurred. The same applies to natural and cultural aspects of cultural woodlands (Saltzman et al., 2011), which are both important elements of rural development and biodiversity in many parts of Europe (Angelstam, 2006). In addition, non-industrial private forest owners’ attitudes are changing from goods to services and values as the profile of forest owners and their norms change (e.g. Fischer et al., 2010;
Nordlund and Westin, 2011). To implement contemporary policies related to natural forests and cultural woodlands, and if deemed necessary to develop them, it thus becomes necessary to focus on both social and ecological subsystems. The term landscape captures this.

The overview of Bergslagen’s forest history over time, and comparisons of forest and woodland landscapes with different histories, as well as reference landscapes, confirm the general pattern of how societies at different times have had different profiles of use of forest landscape goods, ecosystem services and values, and the importance of accessibility for economic use. Currently, the Bergslagen region is in the process of finding new ways for rural development based on forest goods, ecosystem services, including ecological and cultural values. The traditional forest management system is currently contested by actors who advocate uneven-aged or cohort systems for both ecological and socio-cultural reasons (Axelsson et al., 2007; Siiskonen, 2007; Tahvonen, 2009; Axelsson and Angelstam, 2011), at least in urban forests, and an increased interest in viewing forest and woodland landscapes’ natural and cultural capital as an infrastructure for tourism and recreation (Vail and Hultkrantz, 2000).

The suite of regional case studies clearly illustrates how anyone who is interested in contributing to the implementation of guidelines on SFM, and forestry education, can learn from each other by using Europe’s forest landscapes as a time machine. Thus, even if the entire world is always in the same calendar year, different regions and countries may be located in different forest historical phases (Table 1). Finally, knowledge about reference landscapes providing a vision (c.f. the terms Leitbild in German and etalon in Russian) for natural forest (e.g. Pechora-Ilych zapovednik in Russia), cultural woodland systems (e.g. Iberian dehesa and montado systems) and both (e.g. the Transylvanian Alps in Romania) are vital.

Production of knowledge about SFM implementation requires evaluation of outcomes in terms of ecological, economic and socio-cultural dimensions and of the policy implementation process by society’s governance actors (Rauschmayer et al., 2009). It is thus necessary to combine methods from natural and social sciences (Tress et al., 2006; Fischer et al., 2010). Regarding the ecological dimension of SFM, systematic analyses of the functionality of different types of ecosystems in actual landscapes for a given level of ambition need to be made (Angelstam et al., 2003b; Lazdinis and Angelstam, 2004). This includes (1) estimation of regional gaps in the amount and representation of ecosystems; (2) analyses of the functionality of the habitat networks, for example in terms of hosting viable populations and delivering ecosystem services and (3) understanding of how operational protection, management and restoration measures can be combined in practice at different spatial scales. The social dimension concerns the implementing actors, stakeholders and institutions in a selected actual landscape or region. This includes (1) identification of the landscape’s actors and mapping of policy and sector networks, (2) evaluation of the implementation process to learn about issues of concern and (3) evaluation of policy implementation outputs by relevant actors in terms of understanding of policies, ability to act and attitudes in the defined social-ecological system.

It is challenging to adjust forest and woodland landscape goods, services and values to contemporary societal demands and it is therefore sometimes necessary to revisit, adapt and improve the situation. An international term for this is forest transition (Mather, 1992; Grainger, 1995; Mather and Needle, 1998; Rudel, 1998; Perz, 2007). In Sweden, for example, the wood production capacity was restored, after centuries of exploitation and lack of forest management, by a combination of state funding, responsible forest industries as well as advice and assistance to private forest owners from conservation groups, forest agency and forest owner associations (Utterström, 1979; Hagner, 2005; Enander, 2007). Similarly, in Scotland there is a desire to increase the forest cover by 50 per cent by restoring existing and creating new forests and woodlands. Rehabilitation, restoration and recovery (WRI, IUCN, UNEP, 1992; Aronson et al., 2006) are three key concepts in landscape restoration (see also Table 1). The term landscape restoration, ‘a planned process that aims to retain ecological integrity and enhance human well-being’, cap-

<table>
<thead>
<tr>
<th>Landscape case study</th>
<th>Reference conditions</th>
<th>High-grading</th>
<th>Forest management</th>
<th>Rehabilitation</th>
<th>Restoration</th>
<th>Recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland (UK)</td>
<td>Pre-Medieval</td>
<td>Medieval</td>
<td>1600s</td>
<td>1800s</td>
<td>1900s</td>
<td>Today</td>
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<tr>
<td>Harz (Germany)</td>
<td>Pre-Medieval</td>
<td>Medieval</td>
<td>1700s</td>
<td>1800s</td>
<td>1800s</td>
<td>Today</td>
</tr>
<tr>
<td>Bergslagen (south-central Sweden)</td>
<td>Pre-Medieval</td>
<td>Medieval</td>
<td>1700s</td>
<td>1800s</td>
<td>1800s</td>
<td>Today</td>
</tr>
<tr>
<td>East Carpathians (Ukraine)</td>
<td>Pre-Medieval</td>
<td>Medieval</td>
<td>1800s</td>
<td>1800s</td>
<td>1800s</td>
<td>Today</td>
</tr>
<tr>
<td>Pskov oblast (NW Russia)</td>
<td>Medieval</td>
<td>1800s</td>
<td>Today</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinega river catchment in NW Russia</td>
<td>1900s</td>
<td>Today</td>
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<td>Natural forest in Pechora-Ilych</td>
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<td>zapovednik in NW Russia</td>
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<td>Cultural woodland in Iberian</td>
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in the Transsylvanian Alps
In the context of climate including preserving existing forest carbon (Bradshaw et al., 2009), carbon sequestration (Koca et al., 2006), frost (Rammig et al., 2010), wind (Blennow et al., 2010a, b), water, nutrients and biotic disturbances (Kalén, 2005) all involve new challenges. However, the picture is complex and Shanin’s et al. (2011) modelling of forests in Russia demonstrated that forest harvesting has a greater effect on the carbon dynamics of forest ecosystems than the expected climate change. Similarly, Schröter et al. (2005) showed that European regions show large variability in terms of the relative importance of ongoing management versus climate on land cover development trends. Concerning social systems, the increasing interest in bioenergy (Larsson et al., 2009) including whole-tree harvesting (Levin and Eriksson, 2010) to replace oil products, rural development and globalization have made the governance process more complex. As a consequence, rather than focusing on teaching best practices, both multi-disciplinary (Fischer et al., 2010) and integrative approaches to knowledge production are needed (Axelsson, 2010). However, while policies have a top-down origin, implementation and feedback in most governance contexts need to originate from stakeholder collaboration from below (Hiedanpää et al., 2011).

The World Forestry Congress in Buenos Aires in 2009 concluded that there is a need for an ‘integrated landscape approach’ (World Forestry Congress, 2009). In an effort to operationalize this concept, Axelsson (2009) and Axelsson et al. (in revision) defined the following characteristics. (1) A sufficiently large area that matches management requirements and challenges in both social and ecological sub-systems; (2) multi-level and multi-sector stakeholder collaboration that promotes sustainable development as a social process; (3) a commitment to and understanding of sustainability including criteria, indicators and norms or performance targets as an aim among stakeholders; (4) integrative production of knowledge which is socially robust and quality assured and (5) sharing of experiences, results and information as explicit knowledge, as opposed to tacit (Tress et al., 2006), through education, communication and public information. The collaborative nature of the landscape approach suggests a shared responsibility among stakeholders, even if the government in most countries is a major actor. There are different efforts to address landscape level sustainability: the EU Leader method for rural development (Bryden and Hart, 2004), the Biosphere Reserve concept to address mainly sustainability and conservation (UNESCO, 1995) and Model Forest addressing SFM and community sustainability (IMFN, 2008).

Despite the need for a landscape approach, it is unclear what actors are responsible for initiating its development. There are many other both international and national examples (Axelsson et al., 2008). The landscape approach and different landscape approach concepts provide important examples from which one can learn, provided that researchers and practitioners in different countries collaboratively evaluate these efforts (Sandström et al., 2008; Daugstad, 2009; Stenseke, 2009; Elbakidze et al., 2010).

Conclusions

We view the European continent’s natural forest and cultural woodland landscapes as a time machine and thus a tool that can help to stimulate mutual learning and knowledge production locally and at the Pan-European level. Systematic use of this time machine can support both successful SFM processes and outcomes on the ground in forest and woodland landscapes. This approach is also consistent with scholarly work on how to improve adaptive capacity of social-ecological systems (see Elbakidze et al., 2010) as well as international and EU level policies linked to forests and woodlands. A prerequisite for a successful sustainable development process in line with SFM is that related policies and reference conditions are reflected in relevant education programmes (see Lawrence, 2009; Rekola et al., 2010). The proposed approach fits well and is an opportunity for the ongoing Bologna process aiming to internationalize and standardize European university education to make it more competitive. In actual operational forest management and governance, there is a need for landscape managers who are capable to collaboratively lead sustainable development processes, including but not limited to forest management to produce a wide range of products, ecosystem services and values. These professionals would be key actors in as different areas as rural development, public health, conservation, cultural heritage management, bioenergy production and timber production (Parkes et al., 2010). This requires a comprehensive understanding of how to implement an integrated landscape approach, i.e. sustainable development as a collaborative learning process (Baker, 2006) and sustainability as measurable objectives (Vucetich and Nelson, 2010). To conclude, there is a need for both (1) transdisciplinary knowledge production that use landscapes as sampling units (Roux et al., 2010) and (2) encouraging local collaborative learning processes involving researchers, practitioners and other stakeholders.
on the ground and in education. Ideally, networks of case study landscapes should be developed, representing different forest use phases and governance arrangements and different collaborative learning approaches to develop locally adapted SFM solutions.

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Conflict of interest statement

None declared.

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