Contrasting boreal forest landscapes in the central border region of Finland and Russia

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Abstract
This study describes landscape level forest conditions along the Finnish/Russian border by Viena Karelia, which harbors some of the most extensive old growth forests in Europe and contrast starkly the neighboring fragmented forest landscape on the Finnish side of the border. The Vienansalo forests have not known intensive, modern forest management practices until recently, and thus their current and future economic, conservation and ecological research potentials are high. A fifteen year time series of Landsat images documents phases of land-use change, including an increase in the rate of industrial clear-cutting at the periphery of the Vienansalo region’s core. Our field and remotely sensed surveys also suggest that the Vienansalo forest region will evolve forests of three distinct types: near-natural forests in the core Vienansalo region if the area will be protected, a patchwork belt area of multi-aged forest compartments created by a mix of Karelian and Finnish silviculture practices, and an area to the east characterized by the unmanaged maturation of large Soviet era cut-blocks.

Introduction
Some sections along the border region between Finland and Russia appear to show remarkably well in satellite imageries because there is a sharp discontinuity between two types of forest landscape between the two countries. In the Finnish side, vast clear-cuts and young regeneration stands extend to the border while on the Russian side, major extensions of old-growth forests are still present. This contrast was first noted in the early 1980s in a couple of polemic papers (Punkari 1984a, 1984b), which were based on the interpretation of low resolution satellite imagery. On the southern part of the border region near the former Finnish Karelia, the Russian side forests are to a great deal old managed forests which have been left to grow freely during the post-war period. In the middle and the northern border area relatively large extents of near-natural forest landscapes are also present, particularly in the region of Viena Karelia. With their sharp contrast to their neighboring Finnish counterparts, the presence of the two types of forest landscape can be considered as a unique ecological experiment and a special case for conservation (Lindén 2000).

In this paper we apply space-born Earth-observation data and field documentation to give a landscape level description of forests in this unique border belt. We focus on the Vienansalo region near the city of Kostamuksha in the Karelian Republic, Russia Federation. The extensive Karelian near-natural forests of this region have escaped intensive, modern forest management practices until recent times. We hope that by providing a broad description of the forest conditions found in this area, we will enhance the sustainable utilization of this exceptional landscape for cultural, economic, conservation and ecological purposes.
Material and methods

Study area

The region addressed in this study is located between the latitudes 64° to 65° North and longitudes 29° to 32° East (Figure 1). The border of Finland and Russia crosses this area in almost north-south direction. Most of our analyses refer to the Vienansalo ‘core’ area (marked by a ‘C’ in Figure 1) which has an extension of approximately 1500 km².

Climatically, the study region belongs to the middle boreal zone with long cold winters and dry cool summers. Western and south-western winds prevail, the average annual temperature is approximately one degree Celsius, annual precipitation is 550 mm and the average snow depth in February is 70 cm (Atlas of Finland 1987). Pre-quaternary rocks in the study region mainly include granitic veins in basement gneiss, which are in most places covered by gravelly and sandy ground moraine, glacifluvial sands or peat (Atlas of Finland 1990). Local geomorphology is characterized by glaciogenic landforms consisting drumlin fields and fine sediment plains in esker and sandur formations (Atlas of Finland 1990, Quaternary deposits…1993). The relief is shallow and gentle, with the highest elevations reaching 300 meters above sea level. The surface elevation of the major lakes is 100-200 meters above mean sea level, and relative elevation differences at the local scale usually vary close to 50 meters. The national border follows the Maanselkä drainage divide, separating the headwaters of the two major water systems flowing to the Baltic Sea and the White Sea/Arctic Ocean. The Russian side of the border belongs to the Viena Kemi’s river basin, and the Finnish side comprises sections of both Kemijoki and Oulujoki river basins. Lakes are abundant in both sides of the border, the most important including Lentua, Änättijärvi, Onto-järvi, Venehjärvi and Luvajärvi in Russia. The major rivers in the region include the Vuokkijoki, Venehjoki, Tollojoki and Kivijoki.

The biogeographic conditions have favored the formation of extensive coniferous forests and scattered small peatlands. Scotch pine (Pinus sylvestris) is the most abundant tree species in most areas. Norwegian spruce (Picea abies) occupies stands in valleys and is also common in those areas where the soils are formed of fine-textured deposits. Birch (Betula pubescens, B. pendula) and aspen (Populus tremula) are common in mi-
xed forests but do not form pure deciduous forest stands beyond human-disturbed areas. Scattered small mires are frequently found in valleys between the shallow hills while some flooded swamps occur in river margins and along lakeshores. The flora and fauna of the region represent species assemblages of poor forest and mire types, including species typical to both middle and northern boreal zones.

The human impact on the Russian side of the border is characterized by three types of activities: forest use, agriculture and mining. The largest population center in the region is the town of Kostamuksha, which was mainly constructed in the 1970s and has a population of 31,000 inhabitants. The city was established to support the exploitation of the large iron ore deposits that were found in the region. The industrial complex includes a large open mire area with high waste mounds, an extensive dammed lake and a large ore processing complex. Other population centers relevant to the Vienansalo core area include the traditional Viena Karelian villages of Vuokkiniemi, Venenjärvi, Tannonjoki, Vuonninen and Latvajärvi. Vuokkiniemi has 500 inhabitants, while the rest of the villages are occupied by only a few families. Conservation efforts in the region include the Strict Nature Reserve Friendship (see e.g. Lindholm et al. 1997) with its major component being the Kostamuksha Nature Reserve (Kostamuksha zapovednik, 47,569 ha). This reserve was founded in 1983 for the conservation of wild reindeer (Rangifer tarandus fennicus) populations and to compensate for the environmental damage the ore mine was to bring to the surrounding areas (Tynkkynen 1999). The Vienansalo forests are being considered for inclusion within the planned Kalevala National Park and since 1996 it has been temporarily removed from official forest management plans while delimitation of the proposed park boundaries are discussed. Despite the moratorium, forestry activities have continued in these areas, as we will discuss in a later chapter, and the area has not been removed from forest lands available for the calculation of annual allowable cut (Mr. Boris Kashevarov, personal communication in August 2000). The Vienansalo forests have also been included in a proposed ‘Green Belt’, an effort driven by non-governmental organizations to link patches of preserved forests along the Finnish-Russian border into a major protection system with high ecological value.

Data sources and analysis

The study is based on field surveillance and the use of space-born Earth observation imagery and cartographic data (Table 1). The digital spatial data analyses were conducted in the Laboratory of Computer Cartography of the University of Turku using image processing (ERMapper, Erdas Imagine) and Geographic Information System (Arcview) software. All the digital spatial coverages were rectified into zone 4 of the Finnish coordinate system (Kartastokoordinaattijärjestelmä or KKJ). Satellite data covering a time period of 13 years were used in the overall characterization of the landscape and in a time series analysis. Enhanced image products (color composites, hybrid images

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of two satellites) were prepared to facilitate visual interpretation of the landscape features. The elevation contour lines of the Russian topographic maps (10 m contour line interval) were digitized and gridded to create a digital elevation model.

Field work included extensive reconnaissance field surveys in the study region during the years 1997-2000, consisting of five field excursions of a few days duration. During these visits, virtually all trafficable roads and their nearby forests in the core study area were explored to assist the overall interpretation of the satellite images. Field plot locations were recorded on printed satellite images and by GPS (Global Positioning System) coordinates. Approximately 150 areas were delimited in the satellite images and documented in the field with simple descriptive information of their vegetation. Detailed surveys were made in 43 forest sites, which represented a subjective selection of all the major forest and mire types in the region. In these places, three observation points were established in 30 m intervals for relascope surveys, identifying the tree species counting separately healthy and standing dead individuals. The vegetation in each point was also described, regarding the forest site type and the canopy, shrub, dwarf-shrub and ground layers.

Results

Regional landscape pattern and change

The border between Finland and Russia is clearly discernible in the 1986/1988 Landsat MSS mosaic (Figure 2). Generally, the Russian side has larger and more uniform landscape entities than the Finnish side. Extensive clear-cut and regeneration areas prevail in the...
east (‘S’ in Figure 2), representing Soviet forest felling that expanded on a broad frontier in a progressive manner. The border belt (‘B’ in Figure 2), on the Russian de, contains major extensions of old-growth forests with smooth textured forest landscape pattern interrupted by water bodies and mires (Figure 2a). On the Finnish part of this image (‘F’ in Figure 2), a patchy sharp-edged landscape prevails (Figure 2b), composed of recent clear-cuts, even-aged regeneration stands, young plantation stands and scattered remnant patches of old-growth forest.

The southern part of the Vienansalo core area has been subjected to several phases of forest clear felling during the recent years (Figure 3). In the late 1980s the region was a vast forest area but the late 1994 and 1998 landscapes are characterized by heavy intrusion. Multiple small cutting areas can be found along the roadsides amidst the larger matrix of old-growth forests. Our most recent satellite image (Figure 3c) is a spring scene, with snow covering lakes and clear-cut areas are white against the dark coniferous forests. Panel ‘d’ distinguishes some major landscape types in the region.

Figure 3. Changes in the Vienansalo core area in satellite images from the 1980s and 1990s. The overall interpretation key for the imageries is the same as in Figure 2. The image from 1998 is a spring scene where snow covered lakes and clear cut areas are white against the dark coniferous forests. Panel ‘d’ distinguishes some major landscape types in the region.

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**Forest landscape types in the Vienansalo core area**

**Near natural forests**

The relatively natural condition of the Vienansalo forests is confirmed by Earth observation images where varying border and ecotone types are found in areas when one woodland type changes to another (Figure 4). These limits may be gradual or

*Figure 4. Details of the near natural forest landscape of the Vienansalo core area: a color composite hybrid image based on data from Landsat TM (RGB = principal components 1, 2, 3 from the bands 4, 5 and 7), and Spot panchromatic (intensity layer). Dark green areas are spruce or mixed forests, lighter green areas are pine forests, mires are yellow, clear-cuts are light pink or light green depending on age, roads are white and lakes and rivers are black. Triangles in large image show direction of 3D perspective image subsets a & b, which were created by draping the satellite image above over a hill-shaded digital elevation model. Subset a looks south along the main road into the 'core' area. Note the mire systems in the foreground valleys and the lighter green (pine) forests in the distance. Subset b looks north over Lake Venehjarvi. Note the lightening of the green color with elevation, as spruce forests change to pine dominated forests along the hill-tops.*
Figure 5. Forest structure as based on basal area in different forest types of the region. Black tops in each bar indicate dead individuals in standing volume. n = number of forest sites studied, in each site three relascope surveys were conducted.

sharp, corresponding to fire disturbance and local edaphic site factors such as topography, geomorphology and soil texture. Pine dominated forests are usually found on sorted sedimentary soils and on hilltops (Figure 4b), and spruces occupy valleys and finer-textured soils (Figure 4a). Deciduous trees are common in river margins and other areas where human disturbance has been intensive. Most of the forest sites studied were mixed and presented characteristics of self-thinning, as evidenced by frequent dying and dead trees in the standing volume (Figure 5). Usually, the trees are also notably uneven sized, gaps are common, and coarse wood debris on the ground abounds. Late successional features are apparent in many stands, i.e. with large aspens and pines present, yet with younger trees mainly consisting of spruce (Figure 6a-c). Charcoal was frequently found in the humus and topsoil of all forests, and multiple fire scars on old pines confirm the re-occurrence of fire in these woodlands.
Although the above characteristics confirm that much of the woodland landscape structure expresses natural condition and processes, these forests are not untouched by humans. Scattered stumps resulting from selective cutting are abundant in many places, especially near waterways. In addition, pine resin tapping has been practiced at an industrial scale from the 1920s and it has been obligatory prior to final felling until the late 1980s (Strakhov & Pisarenko 1996). The commonality of tapped pines throughout the Vienansalo region suggest that massive forest felling operations were planned for the area in the late 20th century.

Figure 6. Pictures illustrating details of the Vienansalo forest region; a. old pine-rich mixed forest, b. spruce dominated mixed forest, c. mixed forest landscape of successional nature, d. large-scale Soviet clear cuts near Kostamuksha, e. Russian clear cut area with remnant trees of the understorey and an untouched forest island, and f. Russian/Finnish clear-cut prepared for forest regeneration.
Soviet clear-felled areas

Vast clear-felled lands from the Soviet era are present in the eastern part of our study area (Figure 2). These areas are extensive open landscapes that extend over hills and valleys, interrupted only by thin remnant forest patches by rivers, brooks and lakes, and by scattered island-like untouched tree groups (Figure 6d). Abundance of previously suppressed trees that are left as the de facto canopy is a characteristic feature of Russian clear-felled areas (Figure 6e) and coarse woody debris is often found in large quantities. Wood transportation from the forest has been performed in the form of tree-length hauling, which has disturbed the forest undergrowth. Especially near sawing sites, logging waste and abandoned wood piles are common.

In none of the Soviet clear-felled areas that we visited did we record regeneration silviculture measures, rather they were as a rule left to regenerate naturally. The former undergrowth trees often do not show obvious signs of increased growth speed, even in those areas where the felling operation took place more than a decade ago. Rather, the forests regenerate naturally by mostly broad-leaved species (birches, aspen) that often seem to form low-value stands where polycormic trees and sprouting bushes are common. In these areas, the forest develops toward a mixed forest type characterized by a remarkably patchy distribution of trees, including both dense thickets where self-thinning takes place and areas of relatively sparse wood cover.

Post-Soviet clear-felled areas

In the late 1990s, logging operations near the border have been practiced by mainly Finnish/Karelian companies. Logging areas within an old growth forest matrix have given rise to an archipelago of clear-felled areas surrounded by near-natural primary forest (see Figure 3b & c). Modern harvesters have been used in the logging where also undergrowth trees have been removed before mechanical soil preparation and nursery stock seedling plantation (Figure 6f). Also burning has been used to prepare some soils for the planting. Waste wood of rotten stems is abundant and drainage dikes are rarely encountered. Another contrast to typical clear-cut areas in Finland in the 1990s is the occurrence of patches of intact forest (seed patches) left inside the clear felled areas.

Discussion

Contrasting forest landscapes near the border

We have utilized satellite imagery to illustrate details of one of the most dramatic vegetation frontiers in Northern Europe. This frontier is mainly created by differences in the utilization intensity and methods of forest management between two countries. Due to major changes in forest management and use in the Russian Karelia, the patterns documented in our Earth observation imageries will soon disappear.

Anthropogenic disturbance has a long history in Fennoscandian forests. For example, the clearing of the most productive land for agriculture during the 19th century has significantly altered the boreal forest landscape. Forest fire frequency has fluctuated due to the human influence and it has favored the growth of broad-leaved trees over vast areas in Fennoscandia (Heikkinnen 1988, Lehtonen et al. 1996, Parviainen 1996). The extraction of tar, saw wood and other forest products has also been intensive in many forest areas, yet their impact has never been as comprehensive as that of the modern forestry. During the late 20th century, Finnish forest management has relied on the use of particularly intensive management techniques including clear-cutting, soil preparation, artificial regeneration of trees, thinning, optimal rotation of stands, drying of
peatlands and fire suppression. The cumulative effect of these techniques at the landscape level (Sigurdsson 1999) is now clearly discernible in space-born earth observation data.

The border region addressed in this study has witnessed a variety of forest use practices according to different cultures but it still contains some extensive near-natural forest areas. Given the baseline conditions described here, some implications for future forest succession become apparent. While the intensely managed Finnish border forests will eventually grow up to larger cohort of mature coniferous stands, the Russian border forests are likely to evolve along three distinctive paths. Some of the forests will escape logging due to nature protection, and we anticipate two kinds of forest succession for the clear felled areas in the Vienansalo region. The Soviet clear-felled areas will grow patchy mixed forests with abundant woody debris. Another type of succession will result in those areas which have been clear felled and planted according to Finnish standards modified by Russian silviculture regulations, but which may suffer from lack of post-harvesting silviculture measures. Since licenses for forest land are commonly not granted for longer periods than 5 years (Piipponen 1999), the incentive for long term management of the planted compartments is absent. In consequence, replacement plantation, elimination of undesired broad-leaved trees and artificial thinning are not likely to occur until the Russian forest sector is reformed and land tenure issues are addressed.

**Turbulence in forest management in Karelia**

During the period from the 18th to mid-20th Centuries, Karelia was a poorly developed region of the Russian periphery. Local processing of timber was small-scaled until industrial saw mills began to develop. Later, northwest Russia developed an increasing strategic role in the Russian forest sector. In the mid 1990s about half of the Russia’s pulp and paper products and about one fifth of the sawn goods were produced in this region (Anon 1996). The most important forest use practice was logging of mature and overmature coniferous forests. The volume of annual wood harvested in the Republic of Karelia was at its highest at the end of the 1960s, when about 20 million m³ were harvested annually. It was quite common that the annual allowable cut at this time was exceeded by 20-30% in old coniferous forests, whereas about 60% of the hardwoods were left unharvested (Piipponen 1999).

Related to the political turbulence in the transition from Soviet to Russian state, the forest industry sector in Karelia has undergone drastic organizational changes, including ministerial reorganizations, corporatisation and reorganizations of regional sectors and enterprise units (Piipponen 1999). Under the current conditions there are severe malfunctions in the institutional setting impeding the attempts by forest industry actors to restructure towards a better capability to function in international high quality- and certification-oriented forest product markets. This situation is problematic from the point of view of sustainable forest management and biodiversity conservation. Although forest regulations in Russia contain strong of biodiversity protection measures the forests suffer from high rates of illegal logging and negligence (Piipponen 1999).

In terms of geographic location and forest resources, Karelia could develop a competitive forest industry comparable to those of the Nordic Countries. This requires that the wood should be largely processed in the region. Only in this way can capital for reinvestment (i.e. silviculture) be accumulated. However, a significant decline in timber harvesting by Karelian firms has taken place since the beginning of the Perestroika in 1986 (Piipponen 1999), which has strongly favored foreign companies working in the area, particularly Finns. Finnish forest companies have been quick to purchase logging rights to any mature forest area, the institutional vacuum and subsequent lax controls
existing in Karelia making it possible for them to obtain cheap wood supplies. The opening of new possibilities to log wood from Russia was particularly welcomed in Finland because most mature forests in its own border region had been already cut and conservation pressures concerning the remaining ones was increasing. The possibility to log on the Russian side may have been considered by some as a rare opportunity that should be utilized as fast and comprehensively as possible, realizing that public opinion might put a stop to the whole log removal activities in the area (Tynkkynen 1999).

Our field observations from the Vienansalo region evidence a high rate of cutting during the late 1990s and booming round wood export to Finland. Modern harvesters worked almost uninterruptedly and only non-rot parts were selected for their transportation to Finland. Finnish timber trucks constituted the most common type of vehicle on some roads of the region and even some significant road maintenance and construction work was conducted by timber companies.

In spite of these developments, the Vienansalo region still possesses a unique opportunity to combine economic development with the protection of an ecologically and scientifically important forest landscape (Lindén et al. 2000). Wood harvesting should be directed to areas of low natural and cultural conservation value and avoided in areas which have a high value for biodiversity conservation or which constitute part of a major undisturbed forest matrix. The unique values of these forests as a biodiversity store and landscape-level research area are significant and their potential as an European level tourist attraction is apparent. Two questions remain. Can and will the Karelian and Russian forest sectors restructure quickly enough to embrace ecologically and socially sustainable forestry? The corollary of this is, of course, whether Finnish (and other European) actors are motivated to participate the sustainable development in this region through economic investment and political pressure.

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