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Supplementary file S2. Description of the key operational environment factors that enable/hinder the implementation of NIFMS transfer to Karelia and that were selected for the interviews and further analyzes.

Strengths:

- *Improving quality and value of timber.* Regular thinning increases the quality and value of timber (Cameron 2001). Extension of the space between trees rapidly increases tree diameter (Ronco and Edminster 1985). Optimization of the forest structure allows an emphasis to be placed on valuable commercial tree species, such as conifers (Hokajärvi 2002). Utilization of dead and dry trees reduces the share of non-industrial firewood in the final harvest. In addition, appropriate forest thinning supports the mechanical properties of the timber, as a dimensional stability in drying, bending stiffness and bending strength (Macdonald and Hubert 2002).
- *Support for principles of sustained yield.* The main principle of intensive forest management and silviculture is the sustained yield of an optimum balance of quantity and quality timber, which would ensure the supply of wood products on a regular and on-going basis. Recently, this concept has been expanded to include other non-wood forest products and services related to cultural, social and environmental benefits (Wolfslehner et al. 2016).

- *Better forest road network.* Intensive forest management requires dense enough forest road network (Berntsen et al. 1971) to allow efficient exploitation and management of forest resources over a forest rotation. Based on the Nordic practice, the density of the road network that can be used all seasons should be around 10–15 m/ha (Gerasimov et al. 2013a). The roadbed must be able to accommodate the load of heavy trucks and have a minimum effect on the environment (Burton et al. 2003).
- *Improving forest health and fire control.* Regular tending and thinning contribute to the utilization of dried and infested trees, which often cause forest fires and spread insect pests and disease. In addition, a high-density forest road network, as a core principle of intensive forest management, also helps to control fire. Roads allow rapid access to fire fighting and prevent the spread of fire.
- *Employment development.* Intensification of forest management, i.e. silviculture, road construction and maintenance, cuttings, etc., will provide new areas of employment, especially in rural communities.
- *Contribution to municipal and regional economies.* (1) Higher quantity/quality forest resources may provide better raw materials for the wood processing industry, which plays an important role in the economy in Karelia; (2) The need for regular supply of wood and forest by-products may contribute to the growth of small and medium sized enterprises, which are able to support the municipal economy in small towns and villages; (3) Logging residues, non-industrial roundwood, small-diameter trees and other woody biomass from intensive tending, thinning and final felling, might be utilized for energy purposes, particularly in rural areas. For example, in small settlements in Finland, woody biomass is

used as an energy source for local heating plants, providing energy independence and supporting significantly the municipal economy (Enonenergia 2013).

Weaknesses:

- *High demand for skilled specialists.* Currently, the demand for personnel with proper education, training and skills exceeds the number of young professionals in Russia. In 2012, the northwest region had a deficit of more than 300 highly educated forestry specialists. Faced with a lack of trained specialists, some companies are forced to employ staff with no vocational training. The proportion of personnel with higher education is only 5-8%. The number of young specialists is low. The average age of working staff in the Russian forestry sector is approximately 60 years (State Council of the Russian Federation 2013).
- *The lack of investments in R&D.* Scientific forestry research, development and reviews of international experience are seldom performed in Russia. The level of local R&D in forestry should be taken into account when attempting to reform forest management in Karelia (State Council of the Russian Federation 2013).
- *Low market demand for energy wood.* Almost all woody biomass available on the harvesting site, such as logging residues, low quality round wood, small diameter trees, etc. are usually left in the forest because of low market demand for their utilization in Russia (Rakitova 2012). At least part of the available woody biomass could be used in heat generation plants as an energy source, although most of existing boilers in Karelia typically utilize fossil fuels.

- *Slow return on investments.* Most of forestry investments occur at the end of the rotation after the final harvest (Coder and Dangerfield 1990). Forests in Russia are state owned, and their management structure is based on leasing contracts. The longest possible forest leasing contract is currently 49 years (Forest Code of the Russian Federation 2006). Interest in intensive forest management investment is low, since the leasing period is shorter than the typical rotation period meaning that the outcome of the investment may occur after the lease ends.
- *High cost for young forest thinning* is due to the poor road network in Karelia and low market demand for the small-diameter wood, in particular deciduous.

Opportunities:

- *High potential of forest resource.* A significant volume (around 4-5 million m³) of the current forest resource in Karelia that could be exploited each year is unused. Soroka and Ananiev (2009) suggest that forest management in Karelia could be intensified with little or no loss to further reproduction. In addition, Karjalainen et al. (2009) simulated a range of management scenarios for forest resources in Karelia, which showed that the outputs from increased felling and thinning (similar to current practices in Finland) were largely positive, especially over the long term.
- *Wood-based energy development.* Public (Government of Karelia 2009) and private initiatives attempt to promote the utilization of wood-based energy in Karelia. Wood-based energy development could provide a market for woody biomass, and support thinning in Karelia. The potential for harvesting in the region is approximately 3.6 million

m³ of woody biomass could potentially be harvested each year (Gerasimov et al. 2013b). Many of the existing heating plants in Karelian municipal districts and rural areas are within the average transportation distance of between 50–70 km (see Government of Karelia 2009 for details), which makes wood-based energy costs competitive, at least in comparison to light fuel oil.

- *Proven Nordic expertise.* Finland and Sweden have a huge experience and proven over time solutions in practicing intensive and sustainable forest management (Kärhä et al. 2004; Mäkinen and Isomäki 2004; Äijälä et al. 2014).
- *Authority programs for forest sector development.* In March 2015, the Ministry of Natural Resources and Ecology in Russia launched a project to develop the concept of intensive management and reproduction of forests, with Karelia chosen as one of the pilot regions (Ministry of Natural Resources and Ecology of Russian Federation 2015). To support the concept, the federation level program “Forestry Development from 2013 to 2020” and “The regional strategy on energy production based on local energy resources from 2011 to 2020” could also be used, with the aim to increase actual harvesting by 50%, increase forest road construction to 1.6 million km annually (Ministry of Natural Resources and Ecology of Russian Federation 2012), and implement the reconfigure of 400 existing small and medium-sized heating plants to utilize wood chips (Government of Karelia 2009). Other programs can also be used to support the development of intensive forest management in Karelia.
- *Availability of new technology.* The market for forest technology has shown rapid growth. Ten years ago, many of the current technologies and methods in forest resource

assessment, forest planning, road construction and utilization of wood-based energy were unavailable on the global market. Yet today, they can be widely accessed, even in Russia.

Threats:

- *Insecurity of private investments.* Problematic renewal of forest lease contracts in Russia (see Gerasimov et al. 2013a for details), which takes into account the strongly bureaucratized functional mechanisms, ensures that long-term investments in state-owned forests are extremely problematic and might be critical for the transition to intensive forest management.
- *Low forest road density and quality.* The current forest road density is less than 2 m/ha. New roads are built mainly for winter harvesting, and existing roads are of low quality when heavy trucks quickly damage the road surface. The absence of drainage and trenches in most of the roads often causes floods and water stagnation, which leaves them out of use for extended periods. If this situation remains unchanged, then implementation of intensive forest management in Karelia might be in jeopardy.
- *Low profitability in forestry.* In 2005–2010, approximately 50% of logging companies in northwest Russia were unprofitable (Gerasimov et al. 2013a). Costs in forestry heavily exceed revenues in Karelia (Saramäki 2012). The average income from harvesting is slightly more than 60 euro/m³ (Kurilo and Nemkovich 2012) which is about half the income in Finland (Metla 2014). With low profitability in forestry, it is difficult to provide incentives for intensive management of forest resources on a stable and ongoing basis.

- *Forest degradation.* Intensive removal of living biomass (i.e. needles, leaves, and small twigs) will temporarily interrupt nutrient cycling, which may lead to a depletion of organic materials in the soil (Hacker 2005). Compaction of the soil by tractors and machinery may reduce air circulation and moisture movement in the deeper soil layers. Water stagnation prevents nutrient activity in plant roots. Therefore, intensive forest management and silvicultural activities may have a negative influence on biodiversity levels and future forest regeneration (Toral 2002).
- *Negative attitude to intensive forestry.* There is high skepticism among the different stakeholders in Russia, including policy-makers, towards a transition to intensive forestry. The reason for this is that intensive forest management is often perceived as a means to increase commercial wood harvesting, rather than providing a sustainable and on-going supply of valuable timber over a short rotation period. This raises concerns that environmental and social considerations in the intensive management of forests may not be fully taken into account by forest users and thus the practice may be limited in the long-term in Russia and likely to fail.
- *High investment cost.* Development of the forest industry in Russia, which depends on a reliable supply of wood, will require considerable investment (FAO 2012). Activities such as wood harvesting, logistics, wood processing etc. are capital-intensive activities, especially at the local scale. For example, the average cost of building forest roads with current machinery is over 25,000 €/km in Russia (Kotochigov and Kovalenko 2012), which is twice as high as in Finland (Metla 2014). The main source for such investments is bank loans. However, due to current interest rates of more than 10%, the investment

cost becomes too high and might not be economically viable for private business and investors.

- *Unprepared regulatory environment.* Forestry regulations currently applicable in Russia do not help in the transition to intensive forest management (Ray et al. 2013) because of the existence of several gaps in regulations. For example, current thinning provides only a weak silvicultural effect since the intensity of the thinning is often so low that only the tractor corridors can be cut. In other cases, thinning intensity may reduce a stand density below the minimum permitted limit (see Sinkevich 2013 for details). Moreover, as the timing of final felling depends on age rather than actual stand properties (e.g. stem diameter) this results in an expanded rotation period, thus making the forest older and the timber less merchantable. In other words, there is an urgent need for legislative amendments, without which it will not be possible to ensure the level of management and silviculture of forest resources for intensive forestry.