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22 place-based multi-level collaborative learning concepts like Model Forest provide opportunity

23 for bridging the observed barriers.

24

25

26 Highlights:

- 27 1) Intensification of forestry requires understanding of social-ecological systems.
- 28 2) Frontiers of wood mining have led to regionally un-even stand age distribution.
- 29 3) Ideological dynamics has caused temporally unstable forest governance.
- 30 4) Barriers for intensification include institutional uncertainty, wood mining
- 31 history, and poor infrastructure.
- 32 5) Bridges include establishing predictable rules and norms, and zoning at
- 33 multiple scales.

34

35 Keywords: Wood production, intensification, Russia, boreal forest, environmental history,  
36 forest management policy

37

## 38 **1. Introduction**

39 Boreal forests have the largest area among all forest biomes in the world (McLaren &  
40 Turkington, 2013), and provide essential renewable wood resources used for value-added  
41 production of considerable economic benefits for businesses, the state and employment in  
42 rural areas. Growing markets at regional, national and international levels demand more forest  
43 products, including both wood and bioenergy. Boreal forests also provide other ecosystem  
44 services necessary for biodiversity conservation and human well-being (Молчанов, 1961;  
45 Ваганов *et al.*, 2005; Stryamets *et al.*, 2015). In addition, the sustainability of boreal forests  
46 for mitigation and adaptation to climate change has also been highlighted (Carlson *et al.*,  
47 2009). Satisfying this complexity of benefits is a challenge for implementation of sustainable  
48 forest management in boreal forests, of which Russia hosts the majority (Anonymous, 2012b).  
49

50 The development of forest management systems ranges from extensive to intensive (Duncker  
51 *et al.*, 2012). This gradient is uniquely well represented from West to East in the European  
52 continent's boreal biome. After initial wood mining in boreal Fennoscandia during the 19th  
53 century, intensive forest management has restored forest landscapes as wood production  
54 systems (Nordberg *et al.*, 2013). Being more remotely located, the wood mining frontier  
55 swept across NW Russia much later (Björklund *et al.*, 2000; Yaroshenko *et al.* 2001).  
56

57 Beginning with Peter the Great in 1719 (Редько & Редько, 2002), Russia's forestry consists  
58 of three distinct periods of societal change, which affected forest management. First, Russia  
59 developed into a major early provider of wood, amounting to about one third of world forest  
60 exports in the beginning of 20th century (Генверт, 1926), and encouraged sustained yield

61 forestry (Тюрмер, 1891). Second, after the Russian revolution in 1917, the socialistic  
62 ideology discarded economic factors (Knize & Romanyuk, 2006), which led to intense wood  
63 mining. Third, after the collapse of the Soviet Union 1991 market economy re-emerged which  
64 seeks to increase the yield of wood through intensification of forest management. There are  
65 thus two visions about forestry in Russia. The first is “wood mining”, i.e. harvesting where  
66 the timber volume is highest and leaving clear-cuts for natural re-growth. The second sees  
67 forestry as “agriculture of timber”, i.e. silviculture for maximum economical profit (Knize &  
68 Romanyuk, 2006).

69  
70 There is a growing interest in Russia to increase the productivity of wood per unit area and  
71 time in already harvested areas (e.g., Nordberg *et al.*, 2013). Russia’s forest industry aims for  
72 intensified wood production as an integrated part of sustainable forest management  
73 (Anonymous, 2013; Nordberg *et al.*, 2013). However, even if the ambition in Russia is to  
74 encourage intensive forest management (Elbakidze *et al.*, 2013) current Russian forestry  
75 practices can still be characterized as wood mining (Nordberg *et al.*, 2013). The Scandinavian  
76 model of intensive forest management is perceived by industrial forestry stakeholders in  
77 Russia as the best model for economically profitable forestry (Knize & Romanyuk, 2006).  
78 Consequently, there are attempts to introduce this forest management model in Russia. At the  
79 same time, Russia still hosts remotely located large intact forest landscapes (Yaroshenko *et al.*  
80 2001; Potapov *et al.*, 2008), and there is opportunity to conserve biodiversity at near-natural  
81 levels in such areas. Intensified wood production is thought to solve several problems: (1)  
82 sustained supply of sufficient raw material for forest industry (Holopainen *et al.*, 2006), (2)  
83 protect pristine boreal forests from human intervention (Fredericksen & Putz, 2003), and (3)

84 mitigate societal issues like unemployment in logging villages and thus increased  
85 urbanization (Becker *et al.*, 2012).

86  
87 Intensification of wood production has many definitions. The intensity of forestry may be  
88 described using both economic and ecological dimensions, which are generally inversely  
89 related (e.g., Bergseng *et al.*, 2012; Mönkkönen *et al.*, 2014). Economically, intensification is  
90 seen as a consolidation of all production factors such as soils, machinery, energy and  
91 manpower with the aim to get the highest financial net return from forest ecosystems  
92 (Sundberg & Silversides, 1988). Intensive forest management includes silvicultural operations  
93 aimed at increasing sustained yield wood production per area unit, e.g., scarification, planting  
94 or seeding, pre-commercial cleaning, fertilization and commercial thinning. The level of  
95 management intensity defines forest management approach (Duncker *et al.*, 2012), and can be  
96 sustained at multiple levels. Ecologically, intensification describes a higher degree of  
97 anthropogenic transformation of near-natural systems caused by forest management  
98 operations (Peterken, 1996; McRoberts *et al.*, 2012).

99  
100 Countries with transition economies (Myant & Drahokoupil, 2011), such as Russia, share  
101 several challenges regarding the reformation of their natural resource use, governance and  
102 management (Holopainen *et al.*, 2006; Nystén-Haarala, 2012). This requires that past  
103 trajectories in landscapes and regions are understood. Human impact creates path dependence  
104 effects on both biophysical landscapes and societal legacies (Wilson, 2012). A wide range of  
105 scholars has therefore stressed the need to consider both social and ecological systems when  
106 studying implementation of policies about sustainable development and sustainability (Berkes  
107 and Folke, 1998, Liu *et al.*, 2007, Redman *et al.* 2004). As a tool for extracting historical

108 lessons to help addressing today's challenges in forest landscape management and  
109 governance, Marsh (1864) very early stressed the need to study the transformation of the  
110 interaction of humans and the natural environment (Lowenthal, 2000). As an interdisciplinary  
111 field of research, environmental history is an appropriate framework for studying the  
112 dynamics of landscapes as social-ecological systems. The interest in understanding the history  
113 of landscapes as social-ecological systems has appeared in many contexts including studies in  
114 North America (Worster, 1994), South Africa (Beinhart, 1984) and in former European  
115 tropical colonies (Grove, 1989). Similarly, implementing sustainable forest management  
116 policy requires understanding the history of forest landscapes, including both their  
117 biophysical, anthropogenic and perceived dimensions (Angelstam *et al.*, 2013c). While there  
118 are numerous works on forest landscape history in different countries (Bürgi, 1999; Ericsson  
119 *et al.*, 2005; Hessburg & Agee, 2003; Steen-Adams *et al.*, 2015; Östlund *et al.*, 1997),  
120 practically no information exists on the historical dynamic of interconnections between  
121 ecological and social systems regarding Russian forestry.

122

123 The aim of this paper is to better understand barriers and bridges (see terminology in  
124 Gunderson *et al.*, 1995) for intensification of wood production in NW Russia by analysing  
125 past trajectories in a concrete representative region. Using regional and local logging frontier  
126 gradients from a large river to its headwaters in the Komi Republic as a case study we employ  
127 an environmental history approach for the period 1719-2014. First, we reviewed the forest use  
128 history, and re-created this in detail using spatial data for the period 1965-2014 when the  
129 timber frontier passed this region. Second, with a focus on the actors we reviewed the general  
130 forest use history during the entire period. Third, we analysed ideology behind the forest  
131 landscape history on international, state, regional and local levels for the same period. Finally,



132 based on the insights derived from the environmental history analysis, we discussed barriers  
133 and potential bridges for intensification of wood production in both social and ecological  
134 systems in NW Russia.

## 135 **2. Methodology**

### 136 **2.1 Framework**

137 To understand barriers and bridges for forestry intensification landscapes' ecological and  
138 social systems need to be analysed. We used Worster's (2005) environmental history  
139 framework to study a geographical area as space and place: (1) natural environments of the  
140 past, (2) human modes of production, and (3) perception, ideology and value. This approach  
141 reflects the landscape concept's biophysical, anthropogenic and perceived dimensions  
142 (Angelstam *et al.*, 2013a; c).

143

144 The environmental history is strongly influenced by the contemporary political regime.  
145 Therefore the analysis was divided into three epochs of development in what is NW Russia  
146 today (Мунчаев & УСТИНОВ, 1998). These are the Russian Empire from the appearance of the  
147 first administrative body for forest management in Russia (1719-1917), the Soviet Union  
148 (1921-1991) and post-Soviet Russia (1991-2014). Each epoch demonstrates different world-  
149 views having specific traits (see Table 1).

150

151 In the discussion we defined barriers to intensification as weaknesses and threats leading to  
152 ineffective forest management, and bridges in terms of current strengths and future  
153 opportunities to successfully intensify wood production. These barriers and bridges were  
154 defined based on the environmental history connecting ideology, actors and changes on the

155 ground in biophysical landscapes. One can thus see barriers and bridges (Gunderson *et al.*,  
156 1995) as a SWOT-analysis (Hill *et al.*, 1997), but without division into present and future  
157 factors. Barriers and bridges were then sorted into those relevant for social and ecological  
158 systems, respectively.

## 159 **2.2 Study area**

160 The NW part of the Russian Federation has the longest history of timber frontier development  
161 in Russia's boreal biome. Already in the late 17th century most of NW Russia's large trees  
162 near large rivers were selectively logged for ship-building. Timber was exported to Great  
163 Britain through the seaport of Arkhangelsk, and since 1704 also through St. Petersburg  
164 (Редько & Редько, 2002). Since shipyards were located in the estuaries of Northern Dvina  
165 river in NW Russia, the expansion of logging took place gradually as a moving frontier in the  
166 upstream direction. A good example of this is Northern Dvina's largest tributary, the  
167 Vychegda river in the Komi Republic. Here industrial logging for local use commenced in the  
168 18th century (Галасьев, 1961), and logging of large old trees and old-growth forests were  
169 intensified during Soviet period (Редько & Редько, 2002).

170

171 As a typical example of this moving logging frontier, we chose the Kortkeros rayon (an  
172 administrative unit of the second level in Russia) as a case study located in the catchment of  
173 the Vychegda river in the Komi Republic (Figure 1). The Vychegda river divides Kortkeros  
174 rayon into a northern and a southern part. The two tributaries of Vychegda in Kortkeros,  
175 Nivshera in the north and Lokchim in the south, both represent gradients in forest use created  
176 by a moving frontier of logging. Boreal forests in the Kortkeros rayon as in the Komi  
177 Republic are characterized by the tree species *Picea abies* (L.), *Pinus sylvestris* (L.), *Populus*  
178 *tremula* (L.), and *Betula spp.* Altitude ranges from 69 to 325 m a.s.l.

179

180 The Kortkeros rayon was established in 1939. The total area comprises about 1,970,000 ha  
181 (Турьева, 1989) which constitutes 4.7 percent of the Komi Republic. In 2012 population  
182 density was approximately 1 person/km<sup>2</sup> (Кудинова, 2012). Forest cover in the Kortkeros  
183 rayon is roughly 90 % and mires comprise about 7 % of the area (Anonymous, 2009). The  
184 whole rayon is one of six main logging territories in the Komi Republic (Шерстюкова,  
185 2012). Kortkeros rayon contains 35 protected areas, which cover 15 % of the rayon and 6.3 %  
186 of the forest area excluding wetlands (Anonymous, 2011). Detailed analysis of changes in  
187 forest age distribution among site types was made within one of the forest management units  
188 in Kortkeros (Figure 1) comprising about 10 % of the total rayon area.

## 189 **2.3 Methods and materials**

### 190 **2.3.1 What happened in nature**

191 First, we analysed the forest use history at state (Russia), regional (Komi Republic) and rayon  
192 (Kortkeros) levels. A literature review was conducted with focus on logging, silviculture and  
193 other forest activities in the study area. The historical forest data was collected from the state  
194 forest surveys since 1965, including forest management maps, from the local archive at the  
195 Kortkeros municipal administration. The surveys contain information on age structure,  
196 species composition and standing wood volume, and reports about silvicultural measures for  
197 the past 10 years. The maps provide spatial data about tree species composition and mean  
198 stand age. Additionally, to understand the recent changes in the landscape a local history  
199 expert was interviewed, and three focus groups with forest landscape's stakeholders were  
200 arranged.

201

202 To describe biophysical landscape changes we did a detailed change detection analysis of age  
203 class distribution for the selected forest management unit from its establishment in 1965 to  
204 2014. Östlund *et al.* (1997) stressed that forest surveys and maps from different time periods  
205 may have been done by different people with different methodology, knowledge and skills.  
206 However, forest inventories of 1965, 1979, 1981 and 1992 can be readily compared with each  
207 other. First, forest management maps for 1965 and 1992 were scanned and geo-rectified using  
208 2<sup>nd</sup> order polynomial transformation matrix with RMSE less than 10 m. Then, the maps were  
209 digitized using QGIS software (Quantum GIS development team, 2013). We used  
210 combination of dominant tree species and stand age as mapping category. The map of forest  
211 stands in 1965 was used as the base for the detailed analysis. The forest was divided into 4  
212 categories depending on age: (1) initial stage (0-10 yrs after clear-felling), (2) young (11-30  
213 yrs), (3) middle-aged (31-70 yrs), (4) final felling and old-growth forest (>71 yrs) (see  
214 Angelstam & Kuuluvainen, 2004). Second, in order to combine the data from forest  
215 inventories that were done according to different regulations, we used satellite images as a  
216 complement. Clear-cuts were visually digitized using forest management map (1965) as  
217 background and Landsat images (1975, 1986, 1993, 2006, 2014). Finally, age of initial land  
218 cover base map (1965) was re-projected to new map of 1975. At the same time the final stand  
219 age distribution of 1975 was adjusted to digitized clear-cuts, i.e. clear-cuts have stand age 0.  
220 This approach was applied sequentially for 1986, 1993, 2006 and 2014. In total we created 6  
221 age distribution maps.

222

223 The forest inventory data for 1992 was used to map the spatial distribution of forest site types  
224 along a soil fertility gradient (Сукачев & Дылис, 1964; Hägglund & Lundmark, 1999). The  
225 forest site types were re-classified into 3 coarse site types: poor, mesic and rich. Poor site

226 types represent forest cover with lichens, *Calluna spp.* and shrubs on wet sites with lower  
227 rates of tree growth, mesic sites with *Vaccinium myrtillus* and *Deschampsia flexuosa* and rich  
228 site types with low and tall herb vegetation and high productivity. Finally, in order to see  
229 development of different forest stages and structures at smaller scale, the information from  
230 age distribution maps was aggregated by site type and presented as proportion to the initial  
231 land cover of the base map 1965.

### 232 **2.3.2 Who did it**

233 To identify the main actors that shaped the landscape, we reviewed regional and local  
234 literature about forest history in Komi as well as state statistical reports, forest management  
235 plans and archive documents. In order to collect information about local stakeholders we  
236 employed focus group interviews as qualitative method to understand opinions and extract  
237 knowledge about societal barriers to intensification of forest management (McLafferty, 2004).  
238 The method of focus group interviews implies that the organizer describes the topic in focus,  
239 then the role of the organizer is to facilitate the discussion among the participants, though not  
240 interfering in any way (Barbour, 2008). Three focus groups were organised with forest  
241 researchers and forest managers that represented the most active stakeholders of the Kortkeros  
242 rayon. Each group included 4-5 persons. Finally, we mapped decision-making actors, such as  
243 organizations who shaped the landscape history. There were two major actors who influenced  
244 the forest landscape history – the state and the private forest companies. Additionally, an  
245 interview with a local historian was conducted in 2013.

### 246 **2.3.3 Ideology**

247 Ideologies are linked to values and perceptions, which influence political and economic life of  
248 society. In our analysis we employed the left-right political differentiation to distinguish

249 between different ideologies. Ideology is often linked to a particular economic system, e.g.,  
250 planned economic system was supported by communistic (far left) ideology. This political  
251 gradient is believed (Jahn, 2010) to have roots in political theory and philosophy.  
252 Furthermore, left and right ideologies are divided by different attitudes towards equality  
253 (Bobbio, 1996). For example, left ideology seeks greater equality in society through action,  
254 and on the other hand right ideology presumes responsibility of individuals in society. Under  
255 left ideology the state tries to overcome inequalities in society by direct involvement whereas  
256 right ideology understands inequalities as a natural social phenomenon. However, no ideology  
257 can be distinguished as pure right or left. In our study it ranged from communistic (left) to  
258 liberal (right), as well as mixed. Analogously, liberalism promotes the primacy of the  
259 individual when freedom, individualism and rationalism constitute the most important values  
260 and beliefs. In contrast, communistic ideology emphasises community, equality and common  
261 ownership as keystones of societal development (Heywood, 2012). Analysis of the ideologies  
262 behind forest landscape changes was made using data from literature review, interviews and  
263 focus group discussions. The focus was on understanding (1) what interests different actors  
264 and stakeholders pursued, (2) what values the forest management decisions promoted, and (3)  
265 what market structure dominated in the study period (Table 2). Based on this we drew  
266 conclusions about left, centric or right wing ideology during the three different epochs.

## 267 **3. Results**

### 268 ***3.1 What happened***

269 Before and during the Russian Empire period (the first epoch; Table 1) large Scots pine trees  
270 along the rivers were harvested by single-tree selection for ship-building. Wood harvesting  
271 levels depended to a great extent on the availability of horses to transport logs to the river.

272 The average transportation distance was approximately 10 km from the river (Орлов, 1927).  
273 Season also influenced logging. Due to flat and boggy terrain in the study area, winter was the  
274 best time for logging, in summer the conditions were worse, and in autumn and spring terrain  
275 transportation was impossible (Ермилов, 1888). Timber logs were rafted on the main river  
276 Vychegda, then by the North Dvina river to the port in Arkhangelsk. Export of Russian timber  
277 began in late 17th century, when England began buying timber. Since that time companies  
278 from Great Britain, Sweden, Holland and Germany invested money into wood harvesting in  
279 Komi (Галасьев, 1961). In the second half of the 19th century direct foreign investments in  
280 forest harvesting started to take place in NW Russia, and thus the pressure on naturally  
281 dynamic forests by wood logging increased.

282

283 During the Soviet Union period (the second epoch) the land and forest were nationalized.  
284 Forest was harvested mainly for fuel-wood during civil war 1918-1921. A great increase in  
285 wood harvesting happened in the period from 1937 to 1940 when units in a prisoner camp  
286 system (GULag) were established in the Kortkeros rayon (A. Smylingis, pers. comm.). The  
287 wood was transported both outside of Kortkeros and the Komi Republic. Starting from the  
288 1930s the government introduced clear-fellings concentrated near transport infrastructures,  
289 which resulted in a moving logging frontier into wilderness areas (Галасьев, 1961). As a  
290 consequence, old Norway spruce forests were naturally replaced with birch and aspen on  
291 mesic and rich sites. However, Scots pine recruited well after large clear-cuts on sandy  
292 soils. Russia was involved into World War II in 1941. Logging slowed down and was  
293 concentrated near villages and rivers. After the war Russia aimed to restore the economy. By  
294 the end of the 1980s, just before the collapse of the USSR, the total harvest of wood in Komi  
295 peaked at 26 million m<sup>3</sup>/year (Figure 2).

296

297 During the post-Soviet Russia period (the third epoch) from 1991, after the collapse of the  
298 Soviet Union, the harvest level in Komi decreased rapidly, and dropped down by 81% to 5  
299 million m<sup>3</sup>/year in 1998. This coincided with the Russian financial crisis in 1998, also called  
300 the Russian Flu. Afterwards, wood harvesting recovered to about 9 million m<sup>3</sup>/year. Wood  
301 harvesting in the Kortkeros rayon followed the same pattern as in the entire Komi Republic  
302 (Figure 2 and 3).

303

304 Regarding the consequences of forest resources use for forest age distribution, our analyses  
305 show that the amount of middle-aged forest available for commercial thinning increased  
306 continuously since 1965 (Figure 4). Poor sites dominated (62 % of total area), followed by  
307 mesic (36 %) and rich (2 %). The age distributions on poor and rich sites were similar, but the  
308 area of forests on mesic sites changed less due to their remoteness from transport  
309 infrastructure.

### 310 **3.2 Who did it and how**

311 Noble persons and tsar servants employed peasants from nearby villages to cut the wood by  
312 hand. After creation of the Russian state forest service in 1719, the forest was managed for  
313 sustained yield in some central Russian estates, including logging under supervision of state  
314 officials (Table 1). Forest land was also sold to private companies who managed it  
315 themselves, usually including logging as the only forest management operation. In Komi,  
316 metallurgical factories in Kazhim (about 300 km from Korteros) and Njuvchim (about 90 km  
317 away) employed peasants from Kortkeros to harvest forest for the process of converting ore  
318 into metal (Галасъев, 1961).

319



320 In the beginning of the second epoch forests in NW Russia was a very valuable resource of  
321 wood for Bolsheviks because their foes – the pro-tsarist forces – controlled Donbass, which  
322 was the main coal reserve area in former Imperial Russia and located in today's Ukraine.  
323 Therefore, pressure on forests in NW Russia, and thus in Komi and Kortkeros, increased to  
324 satisfy industry needs. Political repression in Soviet Union in the 1930s facilitated further  
325 deployment of forest industry in NW Russia. Kortkeros in Komi was one of the centres in the  
326 GULag system that provided free labour, and was used as a role model (A. Smilingis pers.  
327 comm.). The GULag system existed until the death of Stalin in 1953 when the political  
328 leadership was changed. Starting from the end of the 1930s the forest industry in Komi and  
329 Kortkeros began to upgrade logging technology and improve organization. For example, the  
330 first tractors in Komi were introduced in the 1930s. However, forestry in Kortkeros was fully  
331 mechanized only by 1965 (Anonymous, 1966). Mechanization greatly increased wood harvest  
332 and facilitated forest work. The establishment of logging camps contributed to a strong forest  
333 industry. Some of logging camps formed the base for temporary forest villages where the  
334 logging was the main occupation of local population. Additionally, construction of pulp-mills  
335 in Kotlas (350 km downstream from the study area) and Syktyvkar (50 km from the study  
336 area) in the 1960s and 1970s has greatly influenced wood harvesting in the study area.

337

338 During the third epoch private companies became responsible for forest management,  
339 including logging on forest areas that they have leased for 10-49 years (Anonymous, 2006).  
340 There are international forest companies operating in Komi such as Mondi international  
341 packaging and paper group as well as many small-scale forest businesses. The logging  
342 companies introduced modern technologies in forestry in terms of cut-to-length with  
343 harvester-forwarder logging groups. International and especially European markets influence

344 forestry in Russia. For example, forest certification was adopted by these private forest  
345 industries.

### 346 **3.3 Ideology**

347 During the entire three epochs the ideology behind the environmental history swung between  
348 right, i.e. liberalism and market economy, and left, i.e. communism and planned economy.

349 The very first industrial interest in wood harvesting was grounded in upgrading military and  
350 trade functions requiring wood products (Table 1). Thus, mainly state interests were  
351 addressed in the decision-making process. The tsar Peter the Great was interested in building  
352 a strong independent Russia with access to the European market for Russian products and  
353 foreign imports. Forests in Imperial Russia were mostly state-owned, only a small part  
354 belonged to noble people and private companies. Market economy that served the interests of  
355 the Tsar and the rich landowners (private sector) dominated. Thus sustained yield forestry was  
356 advocated (Орлов, 1927).

357

358 In contrast, during the second epoch in the 1930s the sustainable forest use concept was  
359 considered as foreign sabotage term aimed to stop industrialization in the Soviet Union  
360 (Knize & Romanyuk, 2006). As a result of a state campaign against the sustainability concept,  
361 courses in forest inventory were excluded from study plans in all universities. For Soviet  
362 economists forest had no longer value unless it was cut (Knize & Romanyuk, 2006). All  
363 forests became public, and market economy changed to planned (see Table 2). Industry  
364 enterprises were consolidated to increase logging efficiency, and in 1931-1935 forest  
365 management units (Russian term: lespromkhoz) were created (Редько & Редько, 2002). To  
366 protect the Soviet economy during World War II forestry changed its course to being military-  
367 oriented. Exported goods were reduced, wood was produced for the army and heating. In

368 1943 zoning was introduced, where forests were designated for protective, multiple-use or  
369 industrial production functions. The Soviet Union's economy underwent severe changes in  
370 1965, also called as the Kosygin or Liberman reform (Pejovich, 1969). This reform was  
371 characterized by introducing market economy methods of management when whole state  
372 enterprises were given rights to manage their own economy. Forest management units were  
373 reorganized into integrated units (Russian term: leskhoz) that fulfilled harvesting and  
374 silvicultural (planting, cleaning, protection from diseases and fire-fighting) functions. This  
375 was a clear step to decentralization of the economy, which resulted in further increase of  
376 wood harvest. The second epoch was characterized by state (public) interest in forest  
377 management.

378

379 During the third epoch the Russia's government changed its course to right-wing market  
380 economy and liberal ideology again. Today market forces steer wood harvesting and forest  
381 management. Focus groups revealed that values as individualism and rationalism dominate in  
382 the modern forest management in Kortkeros. The market economy principles were introduced  
383 into the Forest Code from 2006 and forestry regulations. State forest management units have  
384 just control and monitoring functions (Anonymous, 2006). All forest management operations  
385 were delegated to the companies who lease forest. However, the state still defines and controls  
386 its policy through plans to forestry operations using regional level forest management  
387 documents and also for each FMU. Thus, since the state still owns all the forest land in  
388 Russia, it promotes public interests along with private interests of forest companies.

#### 389 **4. Discussion**

#### 390 **4.1. A dynamic environmental history**

391 There are numerous studies debating intensified wood production, however, very often with  
392 an economic (Gerasimov & Karjalainen, 2008, Карьялайнен, 2009), social (Nystén-Haarala,  
393 2012) or biodiversity focus (e.g., Eriksson & Hammer, 2006; Шматков, 2013). Hence,  
394 economic, social and ecological aspects of intensification are considered independently from  
395 each other. By analysing empirically the environmental history of forest landscapes as  
396 integrated social-ecological systems, this study presents a holistic problem-solving approach  
397 to better understand barriers and bridges for intensification of forest management in NW  
398 Russia (Hadorn *et al.*, 2008). From a scientific perspective environmental history and  
399 integrated studies of social-ecological systems are two research approaches that allow  
400 simultaneous inclusion of social systems (based on for example institutional analysis) and  
401 ecological systems (based on thorough understanding of silvicultural improvements). This  
402 case study approach thus demonstrates concretely also the general scientific benefits of  
403 employing the approaches.

404

405 Our review shows the forest landscape history in the Komi Republic and its Korteros rayon  
406 has been complex, and has gone through at least three distinct epochs that differ by the  
407 governing ideology. The biophysical landscape was first shaped by the social system through  
408 relatively soft alterations in terms of single-tree selection harvest in the naturally dynamic  
409 forest (the first epoch); then with severe changes of forest cover due to intensive wood mining  
410 (the second epoch), and continued wood mining at a lower rate (the third epoch). The interest  
411 for wood production among actors (see Krott, 2005) remained constant across all three  
412 epochs, although the means were different. Our study shows that during the period of planned  
413 economy wood mining based on governmental subsidies to cover the costs of harvesting and

414 transportation, and with no investments in silvicultural treatments, was unsustainable and  
415 resulted in timber fall (Drushka, 2003). Thus, when the epoch of wood mining in landscapes  
416 dominated by old and old-growth forest was over, the sustained yield dropped.

417

418 We argue that ideological dynamics has caused temporally unstable forest governance.  
419 Political ideology does not reflect only interests of actors involved into shaping forest  
420 landscape in NW Russia, but inspire political action causing changes on the ground. With the  
421 formation of USSR and its communistic ideology the central government reached very high  
422 harvest levels which were impossible in decentralized tsarist Russia based on the sustained  
423 yield principle (Тюрмер, 1891; Орлов, 1927). As the main actor and the only owner – the  
424 Soviet state – was interested in maximizing economic profits. However, the Soviet epoch  
425 ended with the collapse of planned economy and, consequently, the forest sector. These  
426 ideological circumstances and new market forces had big effects on forestry. The harvest  
427 level began to drop even before the start of the third epoch (1991-2014) caused by political  
428 changes led by Gorbachev (Boettke, 2002). Today, the forest owner is state, but forest  
429 management and harvesting is done solely by private forest companies based on a leasing  
430 system. After the Russian financial crisis in 1998 forest companies gradually increased  
431 harvest levels, but at a much lower level that during the Soviet epoch.

432

433 The analysis of environmental history clearly shows the urgent need to understand not only  
434 technical aspects of forestry, but also past trajectories in social-ecological systems. Next, we  
435 discuss barriers and bridges to intensification regarding the ecological system in terms of  
436 silvicultural treatments after the wood mining logging frontier has passed in different

437 development stages after wood harvest, and the social system including transport  
438 infrastructure, norms and governance.

#### 439 **4.2. Barriers to intensification**

440 To increase the sustained yield of wood the current focus is to intensify wood production on  
441 areas which were previously harvested, and which are accessible. Regarding the ecological  
442 system this requires forest management that includes silvicultural methods in terms of for  
443 example scarification, planting or seeding, pre-commercial thinning and even fertilization  
444 (Elbakidze *et al.*, 2013). To pay for these costs, commercial thinning usually delivers  
445 inadequate financial net values (Brukas & Weber, 2009). Thus also sufficient amounts of  
446 forests available for final felling are needed to provide a sufficient net income that can pay for  
447 silviculture in younger stands. Our study shows that in Kortkeros, as in most of NW Russia,  
448 the uneven age forest distribution with domination of large areas of middle-aged forests is a  
449 major challenge (Figure 5). In addition, different developmental stages have particular  
450 barriers.

451  
452 Regarding young forests forest companies in the Komi Republic do not implement pre-  
453 commercial thinning in a way that increases the stand volume of commercially valuable trees.  
454 In Russia the pre-commercial thinning is done by the so called corridor method (Anonymous,  
455 2007). This means that 3-5 m wide corridors are cleaned, separated by un-cleaned strips of  
456 16-120 m. This silvicultural practice can be improved using experience of Nordic countries by  
457 introducing regular spacing of trees in the entire stand. However, at the national level there  
458 are legislation obstacles which do not allow adjust silvicultural norms to the regional  
459 conditions (Романюк, 2013). This may result in inefficient forest management and failure to  
460 intensify wood production on the ground.

461  
462 Regarding commercial thinning in middle-aged forests as an element of intensive forestry,  
463 innovative projects and demonstrations of commercial thinning do take place in Komi  
464 (Anonymous, 2012a). Nevertheless, more than 95 % of the wood delivered to the industry  
465 comes from final fellings (Козубов & Таскаев, 2000). For instance, area of cleaning and  
466 thinning never exceeded 1 % of total area of Kortkeros FMU (Naumov, 2014). The amount of  
467 middle-aged forest increased on all site types in the Kortkeros study area. The abundance of  
468 poor and mesic site types provide good opportunities for intensification, both by providing  
469 additional wood volumes today, but also improving the proportion of larger trees in the future.  
470 Unless used, this resource will partly disappear due to mortality and lost growth from  
471 competition among trees.

472  
473 Concerning final felling forests, those are today located far away from the current permanent  
474 road network (Aksenov *et al.*, 2002). Additionally, some forest areas are protected and  
475 therefore are not available for logging. These territories include protected areas and forests  
476 along rivers and wetlands. Due to extended conservation efforts in the 1970s the area of final-  
477 felling and old-growth forest has slightly increased on rich site types which are located along  
478 the rivers.

479  
480 Regarding the social system, the opportunity for introducing of active forest management  
481 based on cleaning and commercial thinning requires longer leases. This is possible only for  
482 financially strong and big businesses. Small-scale businesses have no access to this market.  
483 At the local scale, forestry in Kortkeros has experienced the same new trends. Intensified  
484 forest management requires also a permanent transport infrastructure, which is available not

485 only for harvesting (“lesovoznayadoroga” in Russian), including winter roads, rail-roads and  
486 river log floating, but also for silviculture during the snow-free season  
487 (“lesokhozyaystvennayadoroga” in Russian). Technically, there are opportunities for road  
488 construction of the latter type. In the Kortkeros study area there is much sand which can be  
489 used as building material for forest roads (Anonymous, 2009). In road planning hydrological  
490 conditions play an important role, therefore mapping of small rivers, creeks and bogs is  
491 needed. To find the best locations for roads it is necessary to make spatial analyses of the  
492 study area with both economic and ecological perspectives (Seiler & Eriksson, 1995). Finally,  
493 zoning of different road categories is highly relevant for the study area where natural  
494 conditions for forest growth are not homogeneous. Additionally, transport cost to remotely  
495 located, not yet harvested, areas need to be considered when investing in roads for harvest  
496 only, or also for silvicultural treatments (Кривошеин, 2013). However, the costs are high, and  
497 there are uncertainties regarding ownership and long-term maintenance. In Kortkeros rayon  
498 neither the stand age distribution, nor any history of value-added wood production beyond  
499 saw-milling, is favourable for intensification.

500

501 There are several other barriers that inhibit the process of intensification at the level of the  
502 Russian Federation. Legislation on wood production, debated regularly among practitioners  
503 and experts (Романюк, 2013), is another issue. Moreover, public participation has not been  
504 developed, thus creating conflict between forest industry and rural villages (Oksanen et al.  
505 2003). Pappila (2013) highlights that public participation, such as in forest certification will  
506 help to build trust in Russia’s forest sector. Lack of information on up-to-date national and  
507 international research and practices of intensified wood production is also considered as a  
508 barrier to intensification (Шматков, 2013).



### 509 **4.3. Bridges towards intensification**

510 So far, Russia's forest industry development has focused on the boreal regions as the focal  
511 ecological system. However, while the boreal biome was good for wood mining in landscapes  
512 once dominated by old and old-growth forests with large growing stocks, due to shorter  
513 vegetation periods and poorer soils, this biome is less suitable for intensification in the long  
514 term. Rather, more southern regions should be the focus for intensification because coniferous  
515 species such as Scots pine and Norway spruce grow faster in the south than in the north  
516 (Hägglund and Lundmark, 1977). Therefore, the main focus of intensification in Russia ought  
517 to be concentrated to south and hemi-boreal forest ecoregions at lower latitudes where for  
518 instance the Russian regions Pskov, Novgorod and Tver are situated. The shift in focus from  
519 wood production in north boreal to hemiboreal regions that took place in Sweden during the  
520 20th century provides valuable experiences (e.g., Nylund, 2009). Today, the highest volumes  
521 per hectare in Sweden are harvested in the southern part of the boreal biome (Skogsstyrelsen,  
522 2013). Indeed, after the first national forest inventory 1923-29 in Sweden Jonsson and Modin  
523 (1938) estimated how much, how and where the sustained yield of wood could increase. They  
524 concluded that by far the strongest increase could be achieved in southernmost Sweden, and  
525 not by intensification in northern regions that had been subject to the wood mining frontier.

526

527 To deal with barriers linked to poorly developed silviculture several social system bridges need  
528 to be addressed. For example, Nordberg *et al.* (2013) proposed to develop models to  
529 financially support intensified forest management of young and middle-aged forests. For  
530 example, when Sweden made the transition from wood mining to sustained wood production,  
531 economic and educational policy instruments were used in different stages of stand  
532 development after final felling, and financed both by private and state actors (Hagner, 2005).

533

534 Moreover, to satisfy economic, ecological and social dimensions of sustainable forest  
535 management policy, spatial planning of landscapes and regions are needed (Andersson *et al.*,  
536 2013). Fortunately, to some extent the combination of a history of landscape use with large  
537 variation between logged areas and intact forest landscapes (Aksenov *et al.*, 2002), and  
538 approaches to forest zoning to satisfy different functions, has made Russia pre-adapted to  
539 applying segregated approaches to derive multiple forest benefits on the regional level.  
540 Indeed, in 1943 a forest zoning concept by dividing forests into three groups was introduced  
541 in the Soviet Union (Галасьев, 1961; Козубов & Таскаев, 2000; Редько & Редько, 2002).  
542 The first group included protected valuable forests around cities, along rivers and roads; the  
543 second group forests in high-populated regions with restricted level of logging to annual  
544 increment; and the third group unlimited harvesting of final felling of old and old-growth  
545 forests was allowed. Indirectly this provided significant contributions to maintaining  
546 biodiversity by minimising harvests on rich sites near streams and rivers. In reality this was  
547 similar to the TRIAD concept whereby forests are separated into protected areas,  
548 multifunctional areas under ecosystem management, and intensive management (Seymour &  
549 Hunter 1992). Using the zoning concept, intensive forestry could be done on areas within  
550 economically acceptable transport costs. However, the new Forest Code from 2006 partly  
551 changed the logic for zoning. The first group became a protected forest zone with more  
552 detailed restrictions. It is still completely prohibited to do any logging in strictly protected  
553 areas. It is however now allowed to make clear-felling and selective cutting in protective  
554 forest zones, e.g. along streams, when it is necessary for infrastructure development, and  
555 mining of minerals, oil and gas. The second “equal growth – equal harvest” zone of forests  
556 was removed. Finally, the third zone remained the same. Reserve zone forests emerged in

557 1997 where no forest management is allowed for the next 20 years (Anonymous, 2006).  
558 Additionally, in the reserve forests it is allowed to harvest forest for geological tests and for  
559 the needs of local inhabitants.  
560  
561 Ultimately, improving silviculture and transport infrastructure, and zoning, alone are  
562 insufficient bridges to achieve intensification of wood yields. Additionally, several other  
563 social system legacies need to be addressed. The conservative political mindset of Russia's  
564 decision-makers, tending to use mechanisms of Soviet governance, needs to become adaptive.  
565 For instance, there are still multiple top-down regulations and plans, which have to be  
566 followed at lower levels. In Kortkeros governmental forest management units and forest  
567 companies are obliged to the forest management policy at regional level including  
568 performance indicators, such as the amount of wood harvested and the number of planted trees.  
569 This strong subordination hinders implementation of intensive forest management on the  
570 ground. To bridge this it is necessary first to include ideas of forestry intensification into  
571 national policy and then implement them at regional and local levels (Иматков, 2013).  
572 Additionally, innovations originating from bottom-up processes need to be encouraged. Yet,  
573 road networks development, investments in pulp and paper mills, bioenergy plants and other  
574 large projects cannot be handled at local level, therefore coordination at higher levels of  
575 governance is necessary. This has to be done by deliberating policy reforms by including all  
576 interested parties and moderate state support, e.g., for construction and maintenance of forest  
577 roads, as made in Sweden to support sustained yield forestry (Nylund, 2009). The process of  
578 transforming Russia's forestry should, however, not be done without implementing explicit  
579 analysis to determine the economically optimal decisions. Such analyses should include

580 infrastructure limitations, labour market constrains, forest machine capacity constraints,  
581 regional market constrains and other non-local conditions (Lohmander, 2007).

582

## 583 **5. Conclusions**

584 Implementing policy about forestry intensification requires understanding of past trajectories  
585 in social-ecological systems. Since the 18th century Russian forest history can be  
586 characterised as wood mining. Today's age class distribution in the study area in the Komi  
587 Republic confirms this. Here logging frontiers have led to regionally un-even stand age  
588 distribution dominated by middle-aged mixed forest. Nevertheless, old-growth forest is  
589 preserved along the rivers as a consequence of the zoning concept introduced in 1943. A key  
590 observation is that ideological dynamics in the social system has caused temporally unstable  
591 forest harvesting volumes, the profile of key forest actors and forest governance. Barriers to  
592 forest intensification include the wood mining history, poor infrastructure and institutional  
593 uncertainty. Coping with these barriers require integrated approaches ranging from policy  
594 change to economic reforms. Bridges for intensification include maintaining the forest zoning  
595 concept, establishing predictable rules and norms, and focus on sustained yield wood  
596 production in regions with the best biophysical conditions. To conclude, there is a need for  
597 research of potential effectiveness of the zoning concept, especially in terms of new  
598 regulations in Russia's forest policy, and assessment of balance between intensive wood  
599 production, social forestry and conservation of forest biodiversity in boreal Russia.

600

601 Forestry intensification in the context of implementing sustainable forest management policy  
602 requires solutions in both social and ecological systems, which need to be integrated at

603 multiple levels ranging between local forest management units and the policy level.  
604 Environmental history and social-ecological system are scientific concepts that benefit the  
605 application of a holistic problem-solving approach. Together they allow simultaneous  
606 inclusion of social systems (based on for example institutional analysis) and ecological  
607 systems (thorough understanding of silvicultural improvements) to better understand barriers  
608 and bridges for intensification of forest management in NW Russia.

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614

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876 научного центра РАН.
- 877

878 Table 1. Main trends of forest landscape history in the Komi Republic with reference to national-wide historical events, divided into broad epochs and  
 879 their internal phases.

Epoch	Time period	Characteristics	What happened in nature? (Harvest level)	Who did it? (Forestry actors)	Ideology? (Left/Right)
Russian Empire	1719-1850	Ship-building, local iron and salt industries	Low	State	Centric/right
	1850-1917	International export of wood products	Low	State and private forest enterprises ( foreign capital)	
Soviet Union	1930-1957	Industrialization and Gulag	Rapid increase	State (by prisoners)	Left (communism)
	1941-1945	WW2	Slowed down	State	
	1946-1975	Post-war reconstruction	Steady increase	State	
	1976-1989	Economic stagnation	Decrease	State	
post-Soviet Russia	1993-1998	Inefficient reforms towards market economy	Low	State and forest companies	Centric (in transition)

1999-2014

Gradual pickup

Small increase

Forest companies (also  
with foreign capital)

880

881 Table 2. Operationalization diagram (Mouton & Marais, 1988) of concept “ideology” used in this study

Concept	Variables	Operational definitions	Possible outcomes
Ideology	Interest	What interest did the forest managers pursue?	Private, public or civil
	Value	What values did the forest management decisions promote?	Freedom, individualism, rationalism – liberalism (right); Community, equality, common ownership –communism (left); and intermediate (centric)
	Market structure	What market structure dominated during the study period?	Planned economy, market economy

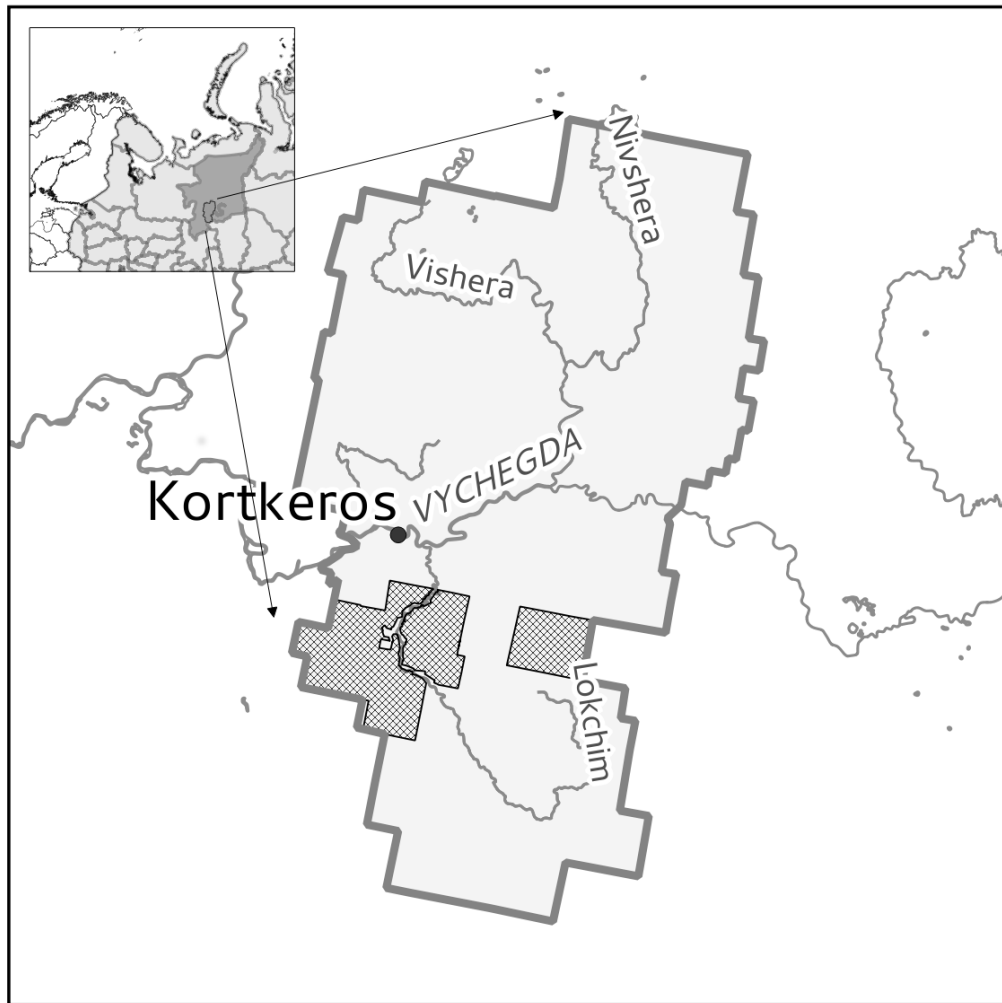
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903 Figure 1. Map of the Kortkeros rayon study area in the Komi Republic with the area (hatched

904 polygons) where spatial analyses summarised in Figure 4 were made. The inset map shows

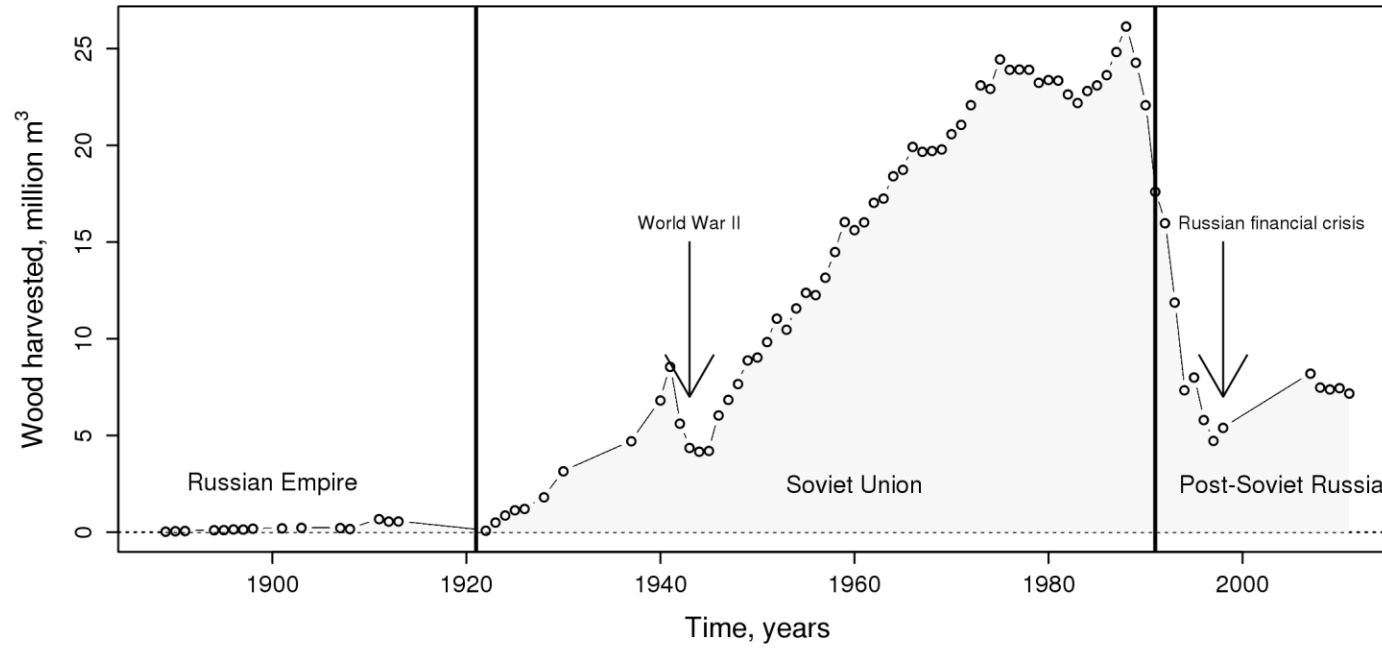
905 the location of Kortkeros rayon in NW Russia (Source of spatial data:

906 [www.openstreetmap.org](http://www.openstreetmap.org)).

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912 Figure 2. Wood harvest in Komi Republic during the period 1889-2014. The forested area is 36 million ha. (Козубов & Таскаев, 2000; Юшкова,

913 2001; Шерстюкова, 2012).

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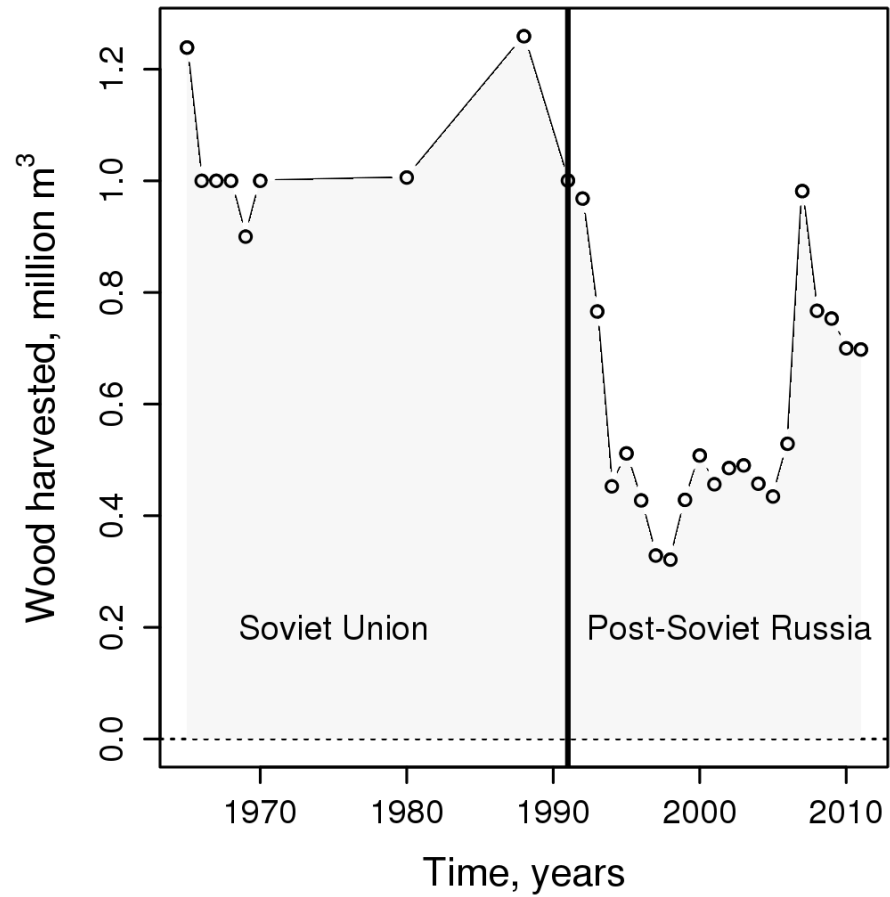
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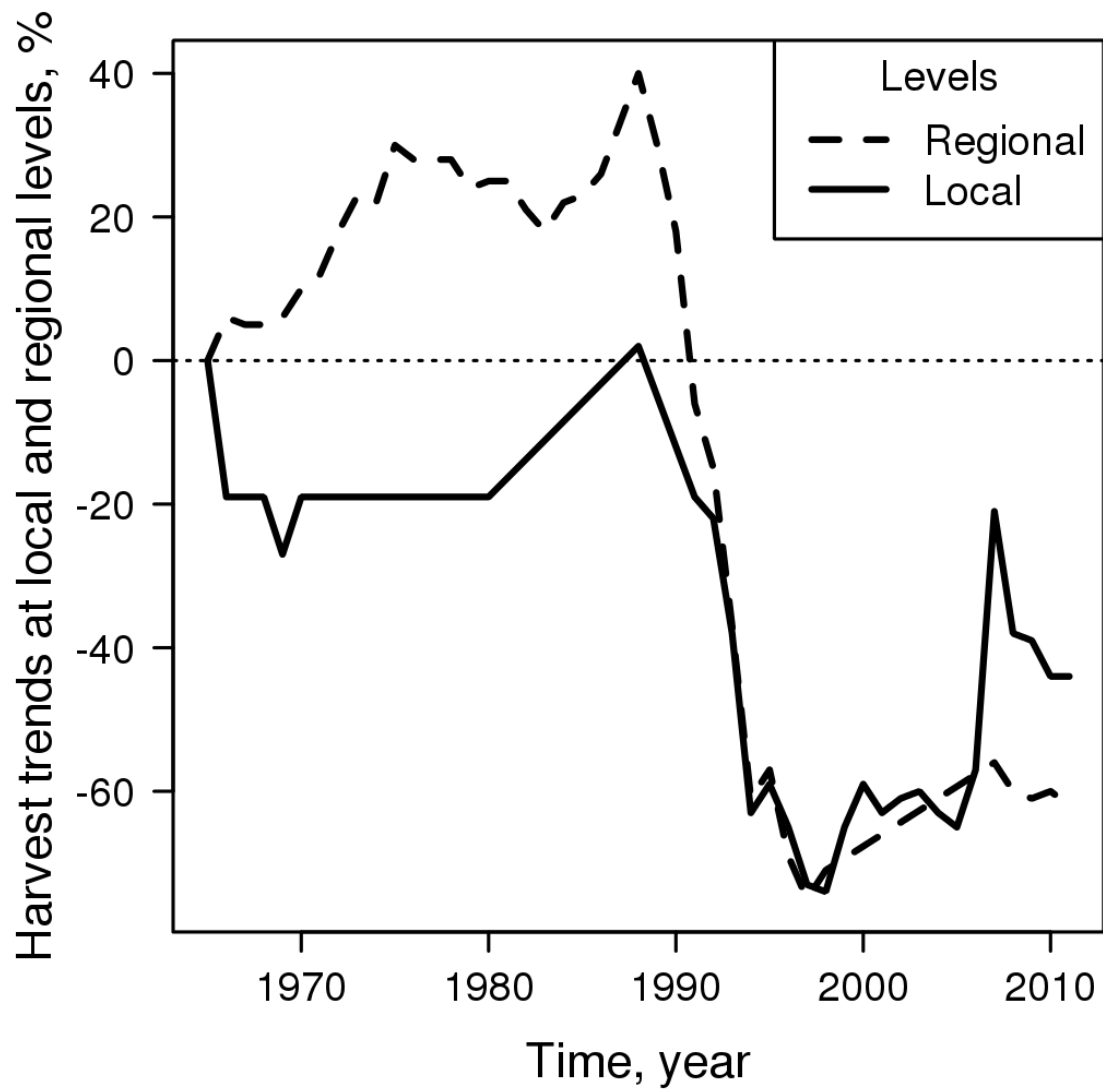
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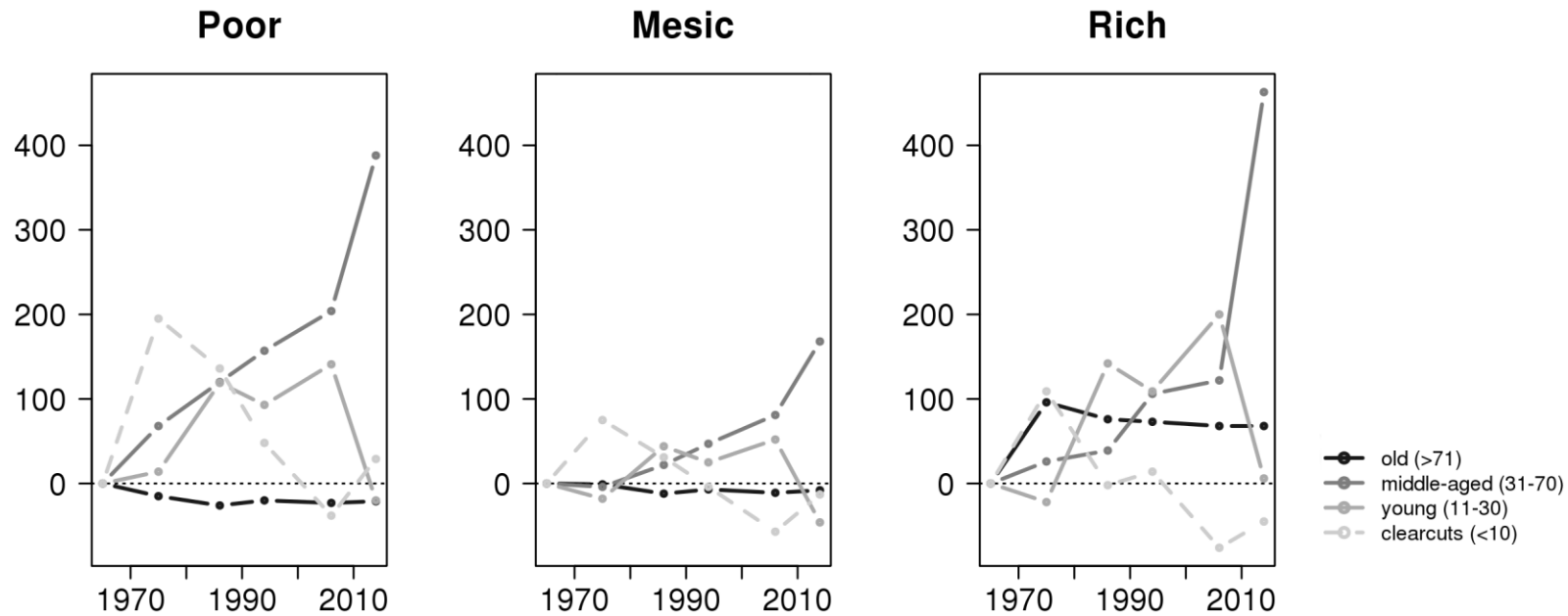
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929 Figure 3. Wood harvest in Kortkeros rayon during the period 1965-2006 covering the end of the Soviet epoch and post-Soviet Russia. The forested  
930 area is 1.8 million ha (Anonymous, 1971, 2014; Турьева, 1989; Шерстюкова, 2012).



931 Figure 4. Harvest trends at local and regional levels relative to the reference 1965 year.



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938 Figure 5. Trends in the area of different age classes on poor (62% of the study area), mesic (36%) and rich (2%) site types from 1965 to 2014. The y-

939 axis shows the area change relative to the initial cover in 1965. The analysis was performed on a total area of about 160,000 ha.