Sustainable forest management and society: an example from the North-West of Russia

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Abstract

Sustainable forestry represents an important part of the sustainability concept and can be identified as a set of management plans, aimed to incorporate non-timber forest-related resources and values during timber production process. In the present paper an attempt was made (1) to build a theoretical model representing interactions among societal, economic and ecological factors affecting timber production, (2) to determine the most important factors responsible for the behaviour of the studied system, (3) to identify the main obstacles hampering development of sustainable forestry, and (4) to propose realistic solutions for the implementation of more sustainable forestry practices in Russian North-West.

The study highlighted the importance of interactions between intensity of forest operations and society's economic performance and weak links between these elements of the system in the real life. Absence of positive relationship between revenues from timber trading and society wealth prevents development of better people's attitude towards non-timber values, a crucial element of two balancing loops in the proposed system model. Specifically, within forestry, lack of investments seems to significantly lower efficiency of timber production. Outside forestry, economic crisis is the factor of paramount importance. Thus, there are two possible answers: (1) look at the possibilities to obtain more financial resources for the forestry, and (2) improve of country's general economic situation. Analysis shows that given proper legislation support, foreign investments present the only possible way to improve forestry operations and to promote sustainable forestry in Russian North-West.
Introduction and identification of objectives

Sustainable forestry represent an important part of the sustainability concept and can be identified as a set of management plans, aimed to incorporate non-timber forest-related resources and values during timber production process. Biodiversity (Zasada et al. 1997), ability of forests to buffer atmospheric properties (Gorshkov 1994), long-term soil fertility (Nihlgärd 1997), economical profitability and non-destructive impact of forestry on social development are the main targets of sustainable forestry.

Among different nature stocks, forests seem to be the most widely used one to satisfy a wide variety of human needs. For majority of today’s countries, forest primarily serves as an important source of economic income. As a result, acknowledged role of forests in maintaining natural ecosystem properties and their cultural and social importance are frequently coupled with their over-exploitation due to economic reasons. It leads to decrease in the quality of forest stands, lower species diversity and structural complexity of the landscapes, and deforestation. The later affects fundamental properties of Earth atmosphere (Gorshkov 1994). Subsequently, this development negatively affects cultural and social identities of the local populations. This makes the system nature - human population more vulnerable to endogenous disturbances that, consequently, decreases its sustainability.

The problem of forest resource depletion could be traced from increased consumption of forest-related products and increased human pressure on these ecosystems. More specifically, one can see a gap between actual productivity of the forest and current demand for wood. Many studies (e.g. Zasada et al. 1997, Gorshkov 1994) highlighted the negative correlation between increased consumption and ability of forest vegetation to recover. However, short-term economic targets provide little incentives to switch main attention from tactical problems of survival of forestry as an industry to strategic problem of biosphere preservation.

Increased environmental concern is forcing today’s forestry to optimise its activity. Although the need for changes in timber production process is clearly seen from global and national points of views, such changes are frequently hard to implement on regional and local levels. Economic and social considerations are the main obstacles in this case (case study for Russia - Nilsson 1997).

In this paper, I will consider applicability of sustainable forest management concept in North-West of Russia. Through formulating major factors driving development of the forestry and resources the it possesses, and by reviewing their the strength and "direction" it should be possible to identify main obstacles facing development of more sustainable forestry. I will also try to make a conceptual verification of the proposed system structure and its behaviour. The following objectives are identified:

1. To build a theoretical model representing interactions among societal, economic and ecological factors affecting timber production.
2. To determine the most important factors responsible for the behaviour of the studied system.
3. To identify the main obstacles hampering development of sustainable forestry.
4. To propose realistic solutions for the implementation of more sustainable forestry practices in Russian North-West.

The empirical data aimed to support the findings will come from
(1) analysis of history of coniferous stands located within one forest estate in St. Petersburg region, Russia,
(2) building up a model representing interplay between state of the forests (with the emphasis on the amount of old-growth stands) and pattern of forestry practices (with the emphasis on the intensity of clearcutting).
(3) data sets on economical and social development of St. Petersburg region and Gatchina administrative district (the area where the studied forestry is located).
(4) Available information on forestry operation in the other parts of Russian North-West.
Chapter 1. Developing a conceptual model

The most general assumption

In the modern world, any large-scale human activity inevitably affects three basic elements of today's environment - ecological properties of our surroundings, economical realities and societal development (Fig. 1). Forestry activities present an excellent example of these interactions. In brief, forest ecosystems ensure maintenance of atmospheric properties, species diversity, and landscape properties, while its utilisation provides for important sources of economic revenues and ensures social development of the whole regions (e.g. Siberia in Russia). As soon ecological properties of the forest will change (e.g. due to improper exploitation), the economic realities and associated social conditions may be affected. As a result of this simple reasoning, I assume that the conceptual model to be build should include all these three elements. In the following paragraphs I will gradually develop this the most basic assumption, considering forestry as one of such large-scale activities.

Interplay between economics and ecological values

Implication of timber harvest methods to plant and animal diversity provides an example of the interplay between ecology and economy (Reader and Bricker 1992, McComb et al. 1993, Reed 1993, Elliott and Swank 1994, Halpem and Spies 1995, Roberts and Gilliam 1995, Norton 1996, Sykes and Prentice 1996, Volin and Buongiorno 1996, Kaila et al. 1997, Zasada et al. 1997). Through (1) change in absolute and relative area of different forest type and forest age classes within a territory and (2) habitat fragmentation, timber management directly influences species abundance on stand and landscape levels. Indirect impact of forest exploitation are possibly changes in atmosphere gas concentrations, greater fluctuation of climatic characteristics and, as a result, decrease in biosphere stability (Gorshkov 1994). The current widely-accepted view considers old-growth forests as the most essential component of a boreal landscape, providing habitats for majority of species associated with this ecosystem. A range of case studies and simulation experiments highlighted this conclusion in many boreal regions (see Appendix 1 - Importance of old-growths in maintaining global sustainability).

The task to find out the optimised solutions for harvest policies can be further complicated by choosing different priorities even among "ecologically-sound" approaches. For example, study of management regimes for uneven-aged mixed-species forests in the Italian Dolomites (Volin and Buongiorno 1996) suggests that even simultaneous increase in tree size diversity and species diversity is hard to achieve under one cutting scenario, not mentioning dynamics of economic income.

As it was stated on many occasions, current silvicultural management provides little flexibility for the realisation of non-timber values (Go 1992). As a result, suboptimal
management practices are often implemented. Modelling management plans of mixedwood forests of northern Alberta in Canada showed that providing proper protection for wildlife species entail significant increases in operating costs or reductions in harvest levels (Cumming et al. 1994). The study also pointed out that protection of a species could imply habitat losses for others due to differences in habitat requirements among species. The general conclusion of this and similar studies is that landscapes organised for old-growth, biological diversity, habitats, and aesthetic values limit timber harvests and cash flows (Boyce and McNab 1994).

Interplay between economics and societal values

In Russia, the forest sector has been a significant employer and directly accounted for more than 2 million employees in this country (data for 1990 - Granåsen et al., 1998). In general, almost 10% of the work force and total population of Russia, could have been indirectly supported by activities in the forest sector in 1990. According to indirect estimations (Grigoriev 1995), the number of employed in the forestry sector have been decreased by nearly 300,000 just during 1995. Presently, a need to support employment in the conditions of severe economic crisis is heavily dependent on the ability of forest industry to properly manage existing resources (see examples for different Russia's regions in Grigoriev 1995).

Interplay between ecological and societal values

The relationship between ecological and societal values can be easily seen from several perspectives. Firstly, national, regional and local identities of human populations are closely connected to the forests as a source of food, other resources, spiritual inspiration and religions believes. A case study for the Siberia has demonstrated that damaging forest heritage of the region tends to speed up loosing people regional and local identities (Nilsson 1997). Secondly, in the case where society prioritise use of one forest product (e.g. timber) in expense of the others (e.g. medical plants or aesthetic values) the most probable outcome of this would be deterioration of the forests properties as an ecosystem (e.g. decrease in species diversity). Thirdly, and probably the most importantly, level of social development tends to positively affect attention people pay to non-timber forest values. This phenomena can be illustrated by the active development of forest certification systems in wealthy Nordic countries, which is aimed to decrease harmful impact of timber production on boreal ecosystem (Nordic Forest 1998). In turn, in crises-affected countries of the former USSR almost no real activities of this kind are going on (Grigoriev 1995).

The model formulation - bringing pieces together

Above discussion allows more formal approach to the problem that leads to formulation of causal loop diagram (Fig. 2). It is important to mention that for the sake of simplicity only one ecologically-based indicator (amount of old-growth forests in a landscape - Appendix I) of forest sustainability will be analysed. The author's believe is that the same structure holds for different ecologically-based indicators (e.g. biodiversity levels). Now, let's consider the proposed causal loop diagram (= model) in some detail.
First reinforcing loop: intensity of felling - revenues - societal prosperity

The intensity of felling positively affects revenues from timber trading (it is assumed that amount of timber extracted from the forest does not exceed overall timber increment - a rule stated in the Russian Forest Code and a general practice worldwide). Given the properly organised mechanism of wealth distribution, revenues from forestry should increase societal assets. This, in turn, provides a positive impact on our ability to utilise timber in the forest (Fig. 3).

Second reinforcing loop - taking old-growths in the consideration

Since old-growth forests are known for their low/absent exploitable timber increment, its elimination from a commercially-managed landscape should provide a place for young fast-growing stands. The latter are common for landscapes managed in the way to maximise profit from timber trading. Instead, presence of old-growths in the landscape limits timber increment and potential revenues. Thus, a desire to have more wealthy society negatively affects amount of old-growth forests though impact on felling intensity (this holds especially if a society did not accumulated the wealth yet) (Fig. 4).

Third reinforcing loop - taking non-timber revenues in the consideration

Since in the majority of cases, both timber-oriented and non-timber-oriented activities compete for the same land - it is reasonable to expect negative relationships between them.

Fig. 2. The theoretical model.
On the other hand, since utilisation of non-timber resources does not require felling, and frequently benefit from the presence of old-growth stands, one can expect positive impact on "non-timber" revenues on amount of old-growths (Fig. 5).

*First balancing loop - taking attractiveness of non-timber values in the consideration*

As soon as people basic needs are satisfied, there are more chances that greater attention will be paid to the forest-related values other than timber. Particularly, more efforts will be put to exploit commercial value of non-timber resources. Therefore, because of the potential increase in non-timber revenues one can expect greater amount of old-growths. This will lower timber-based revenues and, thus, will lower increase in prosperity associated with timber trading.

*Second balancing loop - direct impact of attractiveness of non-timber values (ANTV) on the intensity of felling*

There is probably another way ANTV can improve ecosystem properties (in our case - amount of old-growths). It looks possible that ANTV directly affects felling intensity by excluding certain stands from commercial exploitation (e.g. because of their high aesthetic value). As in the first balancing loop, this will lower timber-based revenues and, thus, will lower increase in prosperity associated with timber trading (Fig. 7). However, in the cases of well-developed balancing loops, accumulated societal assets will probably compensate for relatively minor "decrease in prosperity" (since at this point society is wealthy enough to consider all variety of forest values - see the previous paragraph).

Fig. 3. The first reinforcing loop.
Fig. 4. The second reinforcing loop.

![Diagram of the second reinforcing loop]

Fig. 5. The third reinforcing loop.

![Diagram of the third reinforcing loop]
Fig. 6. The first balancing loop.

Fig. 7. The second balancing loop.

What does it mean?

Now, it is possible to ask a question "Which factors drive this system"? The above discussion and the structure of the model itself suggest that the society wealth and/or revenues from timber-oriented forestry are the most important factors (Fig. 2). This conclusion may be incorrect since the proposed model depicts only key elements and impacts among them. Thus, a conceptual verification of the model is needed. In the following chapters, I will test this model by utilizing the data from St. Petersburg region, (Russia) one local forestry there, and by comparing forest statistics among countries.
Chapter II. Conceptual verification - a multy-level analysis of forestry operations

Testing the first reinforcing loop

Relationship between felling intensity and level of society wealth may be considered through dynamics of annual timber production and indicators of economical development. Both "within-country" and "among-countries" approaches are appropriate. In the first case, an attempt should be made to relate economical development with felling intensity for a certain time period. In the second case, comparison of felling intensities these parameters among countries with different levels of economic development should be helpful for testing this interaction at a larger scale.

Within-country comparison

Ability of a society support employment directly reflects its economic conditions. Therefore, consideration of employment dynamics is useful in assessing the changes in state of the country's economic potential. Although the presented data are incomplete, it shows that amount of logged timber and economical development are positively correlated. Both at the level of the region and at district level, one could observe decrease in economic parameters. It paralleled with decrease in the amount of produced timber. Table 02 also shows that Gatchina administrative district is representative for the whole St. Petersburg region in respect of economic development.

On the other hand, the general economic situation seems to guide development of forest industry. Support for this view comes from consideration of total harvests before and during perestroika time in Russia. In 1989 the total harvest was 439 million m\(^3\), and in 1994 the total harvest dropped to 175 million m\(^3\). Forest industrial production decreased in all parts of Russia as follows: lumber by 60%, panels by 52%, pulp by 58%, and paper and paperboard by 58% (Nilsson 1997). General economic crises resulted even in decrease revenues from timber export which dropped from 3869 down to 1262 m $ just during 1990-1994 period (Shitov 1996).

<table>
<thead>
<tr>
<th>Year/Period</th>
<th>Completion of annual timber production plan</th>
<th>Index of economical development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>St. Petersburg region</td>
<td>Gatchina administrative district</td>
</tr>
<tr>
<td>1970-80</td>
<td>52.9</td>
<td>-</td>
</tr>
<tr>
<td>1980-90</td>
<td>53</td>
<td>-</td>
</tr>
<tr>
<td>1990</td>
<td>50</td>
<td>18.57</td>
</tr>
<tr>
<td>1991</td>
<td>49</td>
<td>18.053</td>
</tr>
<tr>
<td>1992</td>
<td>-</td>
<td>17.34</td>
</tr>
<tr>
<td>1993</td>
<td>45</td>
<td>16.38</td>
</tr>
<tr>
<td>1994</td>
<td>38</td>
<td>14.33</td>
</tr>
<tr>
<td>1995</td>
<td>51</td>
<td>15.33</td>
</tr>
<tr>
<td>1996</td>
<td>49</td>
<td>-</td>
</tr>
<tr>
<td>1997</td>
<td>41</td>
<td>-</td>
</tr>
</tbody>
</table>
"Among-countries" comparison

To perform "among-countries" comparison, characteristics of forestry activities in Russia were contrasted with those of developed Nordic countries (Table 2). Finland and Sweden represented a group of developed countries with high rank of socio-economic development. Russia and Belorussia represented a group of developing countries. Level of economic development was assessed by simple ranking based on data from UN datasets (www.un.org). Proportion of annually felled forests in total amount of forest exploitable forest was used to estimate timber-oriented intensity of forest use. The table clearly demonstrate that although absolute numbers of exploitable timber differ greatly, proportion of forest felled annually (= intensity of timber-oriented forest use) is positively and strongly correlated with country's socio-economic performance. Therefore, within- and among-country comparisons supported the view that level of economy development is closely and positively connected with intensity of forest use. Moreover, the former appears to play a dominant role and directly affect the later.


<table>
<thead>
<tr>
<th>Exploitable forest, * 1000 ha</th>
<th>Annual felling, in 1000 cubic meters, m³</th>
<th>Proportion of forest felled annually</th>
<th>Ranking of country's socio-economic performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>19511</td>
<td>55857</td>
<td>0.29</td>
</tr>
<tr>
<td>Sweden</td>
<td>22048</td>
<td>57543</td>
<td>0.26</td>
</tr>
<tr>
<td>Belorussia</td>
<td>6002</td>
<td>11618</td>
<td>0.19</td>
</tr>
<tr>
<td>Russia</td>
<td>676174</td>
<td>322361</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Testing the second reinforcing loop

Analysis of old-growth dynamics in respect with felling intensity was made by (1) retrospective analysis of stand age distributions in a forestry within St. Petersburg region, and (2) modelling of different felling intensities to predict state of these forests under different management regimes in the forest (see Appendix III for the model description).

Retrospective analysis

Since the middle of the century, area of coniferous stands of Svirski Les forestry increases. Concerning pine stands, the area increased from 6922 in 1949 up to 7572 ha in 1990. Corresponding numbers for spruce dominated stands were 4025 and 7845 ha. Irrespectively of the species, one can observe gradual accumulation of older (> 100 years old) stands (Fig. 8). This change paralleled with the decrease in forest use intensity. The dynamics was particularly pronounced during 90s, the time of dramatic collapse for the Russian economy.

Present situation represent a situation where ecological sustainability greatly benefits from absence of economic stability. As soon as one do not have to take into consideration
social and economic aspects - Russia's present situation can contribute a lot towards sustainability on the global scale (e.g., since more forested lands implies greater atmospheric stability - Gorshkov 1994), but the country itself can hardly benefit from it due to people's poverty and little believe in the country's political future.

Fig. 8. Area dynamics of old-growth stands (data are from the Svirski Les forestry - Project 1991, Inventory 1997) and annual timber production (data - for the St. Petersburg region, source - Lioubimov et al. 1998).

Results of modelling

For the modelling exercise, changes in the area of the old-growth was analysed in respect with different transitional coefficients (see details of sensitivity analysis in Appendix III). Intensity of felling was represented by amount of annual clearcut, the most common way of timber extraction in today's Russian forestry.

Clearcut rate appeared to be the most influential factor affecting amount of old-growths (Table 3, Fig. 9). Fully completed annual production plan should eliminate old-growth pine stands from the area but spruce old-growths appeared to keep increasing, apparently because of the higher transition rate of spruce clearcuts to deciduous stands (compared with pine clearcuts - 0.63 and 0.21 for spruce and pine respectively). Regeneration rate (bare land - coniferous stand) was among the least influential coefficients in the model. It indicated that transformation of deciduous to coniferous stands presented the major pathway for an area to reach old-growth state in the studied forestry. All transition rates involving bare land category had minor impact on amount of old-growth that was caused by relatively small amount of bare land within the area.
Table 3. The Spearman correlation coefficients between transition coefficients and area of old-growth stands after 250 years of simulation. In each case SD value was arbitrary chosen as 0.1 of a distribution average. The latter was estimated from 1980 - 1990 forest inventory data (see Appendix III for details of sensitivity analysis).

<table>
<thead>
<tr>
<th>Transition rates</th>
<th>Mean</th>
<th>Pine stands R</th>
<th>p level</th>
<th>Spruce stands R</th>
<th>p level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual clearcut rate</td>
<td>0.574</td>
<td>-0.98</td>
<td>&lt;10^-3</td>
<td>-0.99</td>
<td>&lt;10^-3</td>
</tr>
<tr>
<td>Clearcut stands - bare land</td>
<td>0.49</td>
<td>-0.96</td>
<td>&lt;10^-3</td>
<td>-0.97</td>
<td>&lt;10^-3</td>
</tr>
<tr>
<td>Clearcut stands - deciduous stand</td>
<td>0.51</td>
<td>-0.97</td>
<td>&lt;10^-3</td>
<td>-0.98</td>
<td>&lt;10^-3</td>
</tr>
<tr>
<td>Deciduous stand - coniferous stand</td>
<td>0.005</td>
<td>0.56</td>
<td>&lt;10^-3</td>
<td>0.67</td>
<td>&lt;10^-3</td>
</tr>
<tr>
<td>Bare land - coniferous stand</td>
<td>0.15</td>
<td>-0.15</td>
<td>0.34</td>
<td>-0.09</td>
<td>0.57</td>
</tr>
<tr>
<td>Bare land - deciduous stand</td>
<td>0.020</td>
<td>-0.22</td>
<td>0.16</td>
<td>-0.24</td>
<td>0.12</td>
</tr>
<tr>
<td>Deciduous stand - bare land</td>
<td>0.0077</td>
<td>0.18</td>
<td>0.24</td>
<td>0.32</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Fig. 9. An example of a sensitivity analysis output. Change in area of old-growth stands after 250 years of simulation under different clearcut intensities. The clearcut rate was allowed to vary from 0.2 to 3. Solid horizontal lines indicate the current amounts of areas covered by old-growth stands. Dotted vertical lines are the actual values of transition coefficients, estimated from 1980-90 data (except clearcut rate - data for 1993-97).

State age - exploitable volume increment

Finally, a well-known relationship between stand age and volume increment (Fig. 000) supported the assumption that higher proportion of old-growth stands decreases exploitable volume increment, and subsequently, revenues from timber trading.
Testing the third reinforcing loop and the balancing loops

Due to severe economic crisis and general poverty of the population it seems unlikely to find strong links between societal assets and attractiveness of non-timber values in today's Russia. Presently, it is far from agriculture-based country but still needs a lot of industrial development to become a wealthy state. Thus, only "among-countries" comparison may help identify the relationship between wealth and attention to non-timber forest resources.

"Among-countries" comparison - Russia as a whole and Svirski Les forestry

In Russia, promotion of non-timber uses of forests is suppressed by state policy to consider forest only as a source of timber (Forest Code 1997). Through activities of state-owned forestries and large companies (like Roslesprom a holding company established in 1993 and responsible for 60-70% of the logging in Russia - Grigoriev 1995), any attempt to limit felling faces their aggressive opposition (Quick cash 1993). An excellent example of lack of attention towards non-timber values is an official report on the state and utilisation of forests in St. Petersburg region (Lioubimov et al. 1998). Scrutiny of possibilities in timber productions left no room for analysis of non-timber values (an even more surprising fact is that the study was funded by The European Forest Research Institute, an organisation actively promoting concept of sustainable forest management).

Consideration of this problem at local level (that is, at the level of administrative district) reveals the same situation. An official forest inventory report, a document supposed to provide guidance for a forestry in its commercial activities, suggests only those non-timber forest uses which are associated with moderate or low investment effort (Table 4). Expert estimates consider recreational activities as highly profitable, however they are not proposed by this document.

A brief review of available options for Svirski Les forestry shows that the most profitable opportunity is associated with the highest investment effort (Table 4). Taking recreational
activities as an example, experts point to the lack of appropriate and costly infrastructure such as good road network and absence of accommodation facilities (Kochetkov 1998). Administrative workers also stressed the importance of transportation facilities (cars, minivans and buses) since the forestry would not be interested in flooding up the forests with private cars (Kozlova 1998).

Presently, economic crisis makes unlikely large investments into production of non-timber forest-related products. However, resin tapping, utilisation of spruce bark and berry/mushroom harvesting may be appropriate choices in the situation where one can hardly expect massive financial support from the government. Forestry also offer timber handling services to local population, which totalled about 150000 rubles annually a decade ago (Project 1990). Indirect estimation suggests that this activity was of minor (but not negligible) economic importance compared with timber trading (Project 1990). According to Finnish forestry data, overall economic value of non-timber products may be app. 10 % of its value for timber production in the same vegetation zone (Salo 1994 - from Parviainen 1994).

Table 4. Non-timber forest uses and their potential economic importance in Svirski Les forestry. Data are for 10 year period (Project 1990). "Investment effort" refers to the amount of investments needed to ensure profitability of a particular activity. Relative estimations of investment efforts and potential revenues were based on literature sources and expert opinions (Pogrebniak 1968, Kozlova 1998, Kochetkov 1998).

<table>
<thead>
<tr>
<th>Non-timber forest uses</th>
<th>Total available resources</th>
<th>Proposed for exploitation during forest inventory</th>
<th>Investment effort</th>
<th>Potential revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin tapping, ha/tons</td>
<td>260/407</td>
<td>260/407</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Mushroom harvesting, tons</td>
<td>93.3</td>
<td></td>
<td>low</td>
<td>moderate</td>
</tr>
<tr>
<td>Berry harvesting, tons</td>
<td>190.7</td>
<td></td>
<td>low</td>
<td>moderate</td>
</tr>
<tr>
<td>Haymaking, tons</td>
<td>297</td>
<td>297</td>
<td>no</td>
<td>low</td>
</tr>
<tr>
<td>Cattle pasturage in forests, area in ha</td>
<td>7900</td>
<td>7900</td>
<td>no</td>
<td>low</td>
</tr>
<tr>
<td>Willow bark</td>
<td>no data</td>
<td>0</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>Spruce bark, m$^3$ *10^3</td>
<td>17.3</td>
<td>app. 10 % of timber volume</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Recreational activities</td>
<td>no data</td>
<td>0</td>
<td>large</td>
<td>large</td>
</tr>
</tbody>
</table>

* According to forestry regulations (Project 1990), this area belongs to the region where resin tapping is mandatory before clearcuts.

"Among-countries" comparison - example of developed countries

Attention to non-timber values in developed countries is much higher than in developing ones. However, it appears not to impede their economical development. Evidence for supporting this statement may be found by considering (1) popularity of forest certification programmes, (2) dynamics of timber demand, (3) effect of introduction of non-timber values to Gross Domestic Product (GDP), and (4) level of public participation and role of scientific community in identifying priorities in forest exploitation. In the following paragraphs, I will briefly discuss the above-mentioned aspects.
**Forest certification programs**

Forest certification programs are becoming increasingly popular in many developed boreal countries. One of the major players in this area is the Forest Stewardship Council (FSC), an independent international organisation. Its aim is to encourage the environmentally responsible, socially beneficial and economically viable management of the world's forests. An important characteristic of this program is its voluntary character. Another fundamental feature of this initiative is adoption of rules aimed to maintain various forest values.

In Sweden, for example, considerable amount of forests is already certified to comply with FSC regulations ([Nordic Forestry 1998](#)). In contrast, almost no real certification programme is going on in Russia ([Strakhov 1997](#)).

**Non-timber values and demand for timber**

According to the proposed model, greater utilization of non-timber products should limit demand for timber. Recent development of forest industries in different part of the boreal zone is in accordance with this assumption. For example, the most recent impact of non-timber demands has reduced sales of the US Forest Service by 40 million m³ since 1989 ([Nilsson 1997](#)). During the last decade, demand for wood production was reduced by 13 % in Europe. Studies in the Nordic countries show that current rates for forest certification will decrease long term wood supply by 15-20%.

**Non-timber values and GDP**

The overall goal of economic activities on a country level is usually to increase the country's wealth by increasing the Gross Domestic Product (GDP). Economic growth is normally considered as destroying the environment and depleting natural resources. In turn, more attention to environment (non-timber values in our case) should negatively affect economic growth (that is, lower increase of the GDP) and society's wealth. Fortunately, empirical evidence appears to be against this conclusion. It has been shown that a well balanced environmental policy would decline GDP by only 0.1 to 0.2 per cent. The costs of the alternative, which would be no action, would be far higher then this amount ([Schanzenbacher 1998](#)). In terms of the proposed model (see Chapter 1), it means that the fist two reinforcing loops should partly lose its importance in developed society. Instead, more weight will be given to two balancing loops. The later act to stabilise the whole system.

**Participation of public and role of research community**

Author's personal experience suggests that participation of public and role of research community is much higher in Nordic countries than in the Russia. Although Russian North-West represents one of the most economically and socially developed regions with high research potential, this conclusion holds there also. It is important to see that beside many differences between Russia and Nordic countries (e.g. differences in legal systems and in budgets of forest-oriented research projects), the attitude of general public appears to be very important. Since no qualitative data is presented it is hard to develop this point in further detail.

**Results of the theoretical model verification**

Lack of valid data ([Nilsson 1997](#)), and generally high measurement errors of Russian forest statistics make rather difficult any modelling exercise and question practical applicability of obtained results. According to expert estimates, the error can be as high as
15% (Shvidenko and Nilsson 1997, Lioubimov et al. 1998) that does prevent reliable estimation of forest dynamics. V. Gorshkov (with Komarov Botanical Institute in St. Petersburg, Russia) believes 50% to be a correct estimation of data error in forestry statistic data (Gorshkov 1998). It makes analysis increasingly difficult as one moves from one-forestry level up to the regional and state level.

Despite these limitations, available data supported well the proposed conceptual model. Thus, the assumption about major role of society economical development (= societal wealth) is also maintained. Since this moment it is possible to take a closer look at the third objective: Where are the drawbacks and undesirable interactions in the present situation? This will be the topic of the last chapter.
Chapter III. Identifying pits and falls in the present situation

In two previous chapters it has been shown that society wealth is the most important factor in determining dynamics of the studied system. Considering the situation in terms of the proposed model structure, one can reformulate this funding in the following way: "Poor performance of first and second reinforcing loops prevent development of first and second balancing loops." What are the reasons for the poor performance of the loops involving timber production and economy? Reviewed evidence points to (1) improper distribution of timber-related revenues and (2) lack of financial resources for the forest industry. The first factors deals with organisation of society, effectiveness of its institutions and is beyond the scope of the paper. Instead, nothing prevents the author from considering role of availability of financial resources for Russian forestry. Since in Russia foresties are allowed to gain revenues from commercial activities in the stands they manage (Forest Code 1997), this question can be divided into two parts: (1) analysis of economic efficiency of forest management (internal actor), and (2) what is the role of external (in respect with forestry) investments? In the following two sub-chapters I will consider these aspects, taking a local forestry in St. Petersburg region as an example again.

Efficiency of forestry operations at district scale

Optimising forestry practices may significantly increase timber production in Russian North-West. In respect with the local-scale forestries (leskhozi - see Appendix IV, Glossary), bad management can account for up to 40% in timber loss during felling and subsequent transportation in St. Petersburg region (Lioubimov et al. 1998). For Svirski Les forestry, amount of softwood "on-site" timber loss for 1980-90 totalled about 41,400 m³ (Project 1990, page 184-185). It corresponded to more than a half of timber production plan for this period. Later, up to 20 percent of the extracted wood may be wasted during the milling process (Petrov 1992). Non-optimum species composition of commercially managed stands may also be responsible for another considerable loss in revenues (10-20% according to Vettenrantta 1996). Thus, improvement in timber processing presents an enormous potential and may considerably increase timber production that won’t lead to higher felling intensity.

Simulation modelling of different transition coefficients revealed another possibility to increase forest use efficiency (see Appendix III for detailed description). To illustrate this point, let us consider transition rate of coniferous clearcut to bare land category (Fig. 11) in respect with areas of old-growth stands. Currently observed rate equals 0.49. In other words, almost half of all clearcuts do not have proper sapling and seedling pools. At a country level, reforestation by planting trees takes place at 44% of deforested areas with successful outcome on 60% of the area. Thus, the actual reforestation involves only 25% of bare lands (Natsionalnyi Doklad 1991). Forest inventories in the studied forestry documented two negative factors associated with clearcuts: (1) almost complete destruction of sapling stratum (Project 1990), (2) difficulties with re-forestation (Project 1980, 1990). As soon as this transition rate will decrease, the amount of old-growth stands may be substantially increased. In the ideal case of no transition to the bare land, areas occupied by old-growth stands may double in size.

Transport problem presents a special case in problem of forest use efficiency. It deserves a separate sub-chapter.
Fig. 11. Change in area of old-growth stands after 250 years of simulation under different transition rate of coniferous clearcut to the bare land category - a result of sensitivity analysis. The transitions rate was allowed to vary from 0.01 to 1. Solid horizontal lines indicate the current amounts of areas covered by old-growth stands. Dotted vertical lines are the actual values of transition coefficients, estimated from 1980-90 data.

Transportation problem

Expert estimates consider road availability as important source of variation in forest use intensity among different forestries in St. Petersburg region (Kozlova 1998). According to the official statistics of Svirski Les forestry, no road construction occurred for the last two 10 years within forested areas. Almost no investments were made to maintain existing road network. Since 1970, the total length of roads decreased from 335 km in 1970 to 257.3 in 1980, and then slightly increased to 273 km in 1998 (Project 1970, 1980; Official statistics of Svirski Les forestry 1998). It makes road network coefficient equal 13 km per 1000 ha of forested land (273/21). Formally, this value is considered as optimal one for the region (Lioubimov et al. 1998). However, about 80 % of all roads lack proper gravel coating that make them hardly accessible for modern machinery, especially in spring, autumn and during rainy periods in summer (Project 1980). Thus, better road maintenance and building up new roads may considerably alter current forest use intensity.

Investment into forestry - which way to go?

No improvement in management can be accomplished without proper investment effort. One can classify the investments which can be available for forestries into two groups: (1) domestic and (2) foreign investments. The former appears to be unlikely and the later introduce considerable amount of uncertainty into the model and maybe potentially useless for improvement of the whole system. I will try to defend this thesis in the next two sub-chapters.

Prediction of timber harvest intensity based on within-country factors

Historically, investments in building up infrastructure (like roads, pipe, and communications networks) were made mainly by federal government which redistributed money, for example, from road-rich to road-poor regions at the country level. Today, economic crises effectively prevents any large-scale investments of this kind. On the other
hand, private timber harvesters are unlikely to invest into road construction due to economic reasons. Therefore, unless sudden and economically positive changes take place in St. Petersburg region and Russia as a whole, one can be rather certain about possible impact of domestic investments on forest use intensity in the nearest future. One can predict about the same level of completion of annual timber production plan, even with its probable slight decrease within next 2-3 years (due to fall of economy in the summer 1998).

Speculation on the impact of export-oriented timber harvesting

Experience of other researchers proves that data on foreign investments in particular forestries within St. Petersburg region are hardly accessible (Miroshnichenko 1998). Not all foreign companies are ready to discover even general statistics on their logging operations in Russia (an example with Finnish logging companies - Pötry et al. 1998). Forestry statistics for Karelian Isthmus (northern part of St. Petersburg region, most close to Finland) suggest that export trading accounts up to 200 % increase in timber production within a single district (Lioubimov et al., 1998, page 25 in Russian version). Communication with administrative staff of Svirski Les forestry revealed that timber harvesting for export trading may presently represent a significant amount of felling operations carried out by private companies in the studied estate although no valid statistics exist on this point (Kozlova 1998).

Changes in European timber marker may directly affect level of foreign investments in the forestry of the Russian North-West. Studies in the Nordic countries show that current rates for forest certification will decrease long term wood supply by 15-20%. It is clear that if we are to solve the biodiversity issue in a effective manner huge areas and volumes will be affected (Nilsson 1997 - see Non-timber values and demand for timber). Thus, demand for "imported" timber should increase and may be compensated through timber export from Russia. It proves export-oriented timber harvesting as potentially very important factor (for detailed analysis of foreign investment opportunities in pulp and paper industry - see Komlev 1997). Because of this, one can expect quite rapid changes in forest use intensity. On the other hand, annual timber production plan is, in fact, determined by Regional Government (namely - Forest Committee) that introduces political motivation in decision making process. The latter is a strong factor increasing uncertainly concerning dynamics of forest use in Russia (World Resources 1998).

Why foreign investments can be potentially useless?

Foreign investments are generally expensive (Komlev 1997). Most of the profit generated by them leaves the region/country. Legislation regulating these aspects is still under development in Russia (Shutov 1996). In such conditions even large-scale foreign financial contribution may be help in developing two balancing loops within the system. Instead, it can easily damage existing forest resources. Export-oriented timber harvesting is commonly known for its highly destructive impact on Russian forests (Grigoriev 1995, Miroshnichenko 1998). Coincided with the lack of effective legislation enforcement mechanisms, such timber harvesting already threatens forest heritage of the region, especially old-growth stands (Grigoriev 1995). It is clear that if one is to preserve large areas of such ecosystems in Russia, a strong and effective legislation support is needed on federal level.

The main problem - lack of financial resources

Analysis of the present situation suggests that lack of financial resources effectively prevents forest industry (1) to carry out its activities efficiently and (2) generate revenues available for the society. Absence of second phenomena does not allow development of the balancing loops. The question remained to answer is "What are the realistic solutions (if any) for the
implementation of more sustainable forestry practices in Russian North-West?" A brief statement of available options to improve the situation concludes this paper.

Time perspectives in the system

Consideration of the most basic assumption about interplay of ecological, societal and economic environments (Fig. 1) shows that loop-specific and impact-specific time frames differ. Thus, it should possible to assign the time estimates to the loops and to the single impacts (Table 5).

Comparison of time frames among different loops demonstrates that 1st reinforcing loop is dominated by shorter time frames than other loops. However, the most crucial element of this loop, a link between societal prosperity and outcome of forestry operations can take as long as half a century or more. Thus, even if all other links within this loop will act efficiently for a decade or so - the corresponding increase in society's assets will be achieved in a longer time perspective. This is a part of the system with seemingly low levels of uncertainty. Again, an exception is the probability of increasing society's assets with better performance of forestry - political development of the country fully determines the pattern of this link.

The second and third reinforcing loops include different ecological indicators of sustainability. Thus, there is a wide variation in possible time frames. Moreover, there are big differences in uncertainty estimates. This highlights one of the major difficulties facing sustainability concept (and sustainability of forest management, in particular) - lack of valid scientific information on ecological processes taking place at different spatial scales.

Analysis of interactions within balancing loops reveals that even under conditions of well performing reinforcing loops - more than a half a century may be needed to get working links between societal wealth and people's desire to take a look at non-timber values. Economic development of Nordic countries generally supports this conclusion. On the other hand, it takes about half a century for the new generation of people to come (new in the sense of values they were taught and education they got later).

What is the time perspective for the sustainable forestry? It should be based on time frames of the system elements (Fig. 1): forestry operates within a society, relays on existing economic mechanisms, and takes advantage of the ecological phenomena (namely, biomass production in the ecosystem). Average stand rotation age in boreal zone is about 80-100 years, substantial changes in the ecosystem and atmospheric properties can occur within a decade, and recent development of Russian society proves that almost any speed and any direction are possible. Thus, to adequately address different aspects of forestry, a multi-scale time perspective appears to be the most appropriate approach. In each case, a time frame should be chosen on the basis of particular indicator/parameter.
Table 5. Time perspective for the system's elements. Single impacts are grouped in respect with loops they participate in. Impacts involved in the several loops are positioned with the loop of their "origination". Three possible ecological indicators of forest use sustainability are presented in the 2nd reinforcing loops. Question mark indicates high uncertainty associated with time perspective of a particular impact. "Higher resolution" estimate of uncertainty (the last column) is based on subjective evaluation of literature data (Gorshkov 1994; Kobak et al. 1993; Kuusela 1994) and analysis in this and previous chapters.

<table>
<thead>
<tr>
<th>Loop</th>
<th>Impact</th>
<th>Time frame, years</th>
<th>Uncertainty estimate, rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st reinforcing loop</td>
<td>Felling intensity → &quot;timber&quot; revenues</td>
<td>few decades</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>&quot;timber&quot; revenues → prosperity</td>
<td>several decades - half a century</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>prosperity → felling intensity</td>
<td>several decades</td>
<td>low</td>
</tr>
<tr>
<td>2nd reinforcing loop</td>
<td>Felling intensity → area of old-growths</td>
<td>one decade or less</td>
<td>very low</td>
</tr>
<tr>
<td></td>
<td>Felling intensity → structural complexity of landscapes</td>
<td>from less than one decade - to few decades</td>
<td>very low</td>
</tr>
<tr>
<td></td>
<td>Felling intensity → species diversity</td>
<td>from one to few decades</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Felling intensity → global atmospheric properties</td>
<td>from several decades - to ?</td>
<td>very high</td>
</tr>
<tr>
<td></td>
<td>an ecological indicator → timber revenues</td>
<td>from one decade - to ?</td>
<td>low or moderate</td>
</tr>
<tr>
<td>3rd reinforcing loop</td>
<td>&quot;timber&quot; revenues ↔ &quot;non-timber&quot; revenues</td>
<td>several decades - half a century</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>&quot;non-timber&quot; revenues → an ecological indicator</td>
<td>from several decades - to ?</td>
<td>moderate</td>
</tr>
<tr>
<td>1st balancing loop</td>
<td>prosperity → attractiveness of non-timber values</td>
<td>half a century or longer</td>
<td>low</td>
</tr>
<tr>
<td>2nd balancing loop</td>
<td>attractiveness of non-timber values → felling intensity</td>
<td>half a century or longer</td>
<td>low</td>
</tr>
</tbody>
</table>

Conclusion - is there way out of the situation?

The previous chapters highlighted the importance of interactions between intensity of forest operations and society's economic performance (Chapters 1 and 2), and weak links between these elements of the system in the real life (Chapters 2 and 3). In other words, absence of positive relationship between revenues from timber trading and society wealth prevents development of better people's attitude towards non-timber values, a crucial element of two balancing loops in the system. Specifically, within forestry, lack of investments seems to significantly lower efficiency of timber production (Chapter 3). Outside forestry, economic crisis is a factor of paramount importance (Chapter 3).

Thus, there are two possible ways to promote sustainable forestry in Russian North:

1. look at the possibilities to obtain more financial resources for the forestry, and
(2) improve of country's general economic situation.

It seems that search for financial resources is currently limited to foreign investments (Chapter 3). As soon as the strong legislation support for effective link (timber production)- (society's wealth) will be established, the foreign investments may be helpful in making the whole system working. On the other hand, improvement of country's general economic situation heavily depends on political will of Russian authorities to put market-oriented reforms into practice. Latest development (devaluation of the rubble, increase in communist influence in the Russian parliament and in regional governments) seriously questions optimistic expectations about development of Russian economy. This fact forces the forestry to look not at domestic resources, but at foreign timber industry. Analysis shows that given proper legislation support, foreign investments present the only possible way to improve forestry operations and to promote sustainable forestry in Russian North-West. Otherwise, slow development of ineffective and costly-for-society forest industry will continue.

Analysis of the different time perspectives within proposed model shows that current situation has a time-mediated "fix-that-fails" structure. Particularly, better performance of ecological indicators of sustainability (an example of old-growth forests was analysed) reflects the general collapse of Russian economy. If only ecological indicators are to be included in sustainability assessment - Russia would probably be among the first ones both in Europe and in World. A more comprehensive assessment forces us to address the failure of the present system to deal with long-term goals of economic and social development. Again, the results of this study point to the necessity of investments to increase positive impact of the forestry as an industry on the development of society.

Finally, it is important to realise that that if movement or people of the country/region do not consider forest as an important economical resource (due to present of other more profitable businesses) and want to preserve it in its present state - the need for sustainable forestry almost disappears.

References


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Appendix I. Importance of old-growths in maintaining global sustainability

Forested lands exceed twenty percent of the total area of the Russian Federation and cover more than 40% of the territory of the north-eastern part of European Russia. Between 70 and 75% of Russian forests are considered mature or over-mature (Lakida et al. 1996). That ensures existence of majority of species within boreal biome. Role of boreal forests as possible sink of carbon has attracted attention during last decades (e.g. Kobak et al. 1993). This is particularly true for Russian boreal forests: Lakida et al. (1996) have showed that between 1966 and 1993 European Russian forests were a net sink for carbon and stored an average of about 87 Tg of C annually. Old-growth forests (that is stands with trees older 120-140 years in the canopy) are also known for their high biodiversity levels, i.e. tremendous information flows (Gorshkov 1994). Because of these considerations, logging of old-growths have been seriously questioned during last decades. It is absolutely unlikely that any management plan can successfully mimic actual old-growth in partially logged stands. Although aspects like disturbance size distribution and amount of dead wood can be regulated during harvesting operations (e.g. Seydack 1995), other features (e.g. uprooted areas, genetic and species diversity) are almost impossible to simulate artificially. Thus, better silvicultural methods should not in any way be used as an excuse to cut old-growth stands (Runkle 1991). The only sustainable alternative is to keep old-growths undisturbed by logging and other human activities. How much these stands should be protected? Estimations and actual values vary (e.g. Parviainen 1994, Gorshkov and Makarieva 1998) and depend on the ultimate aim of preservation. As a rule, more global targets imply greater portion of old-growth to be saved. Under certain scenarios all currently available old-growth stands are to be excluded from commercial use (Gorshkov 1994).
Appendix II. Study area

The Siversky Les Forestry is located 70 km to the south of St. Petersburg in Gatchina administrative district. It occupies about 23,000 ha and is located at 59° 20’ NL and 30° 10’ EL. The area belongs to south taiga vegetation zone. The landscape is characterised by lowland poorly drained plain (with mainly 70-80 meters above sea level) allied with the subterranean slope of the Baltic shield. The later is overlaid by the layers of mid-Devonian red sands and sandstones. The main relief and soil forming rock is quaternary decarbonated moraine 5-10 m thick, mostly abrased, washed out, overlain by sands and covered by thin sands and sandy loams.

Vegetation growth period of the territory lasts for 140 days on average, with the maximum July temperature being 16.7 C. Annual precipitation typically varies between 610-708 mm, major part of which falls in July-August.

Pine-dominated stands occupy 35.8 % of the area. Spruce, birch and aspen stands growth on 29.4, 27.2, and 7.6 % of the territory respectively. Generally, forest of the area is high productive with the average productivity class being 1.9 (on 5 point scale with 1 as the maximum productivity class). The average volume increment is 4.0 m³/ha, the average yield is 260 m³/ha, the average yield of mature and overmature stands is 338 m³/ha. The average characteristics for the area exceed those for the region on the whole (there average productivity class is 2.7, the average yield for 1 ha of mature stands is 250 m³, and the average annual growth is 3.1 m³/ha) (Zhigunov 1995).

According to the Russian classification framework for commercially managed forests, the forests of the estate are classified into Group I and Group II stands (occupying 9874 and 10681 ha respectively, see Forest groups in Appendix IV, Glossary).

The main types of forestry operations are clearcuts and selected cuts. They constitute approximately the same portions in annual timber production plan. According to the forestry regulations for this area, the clearcuts not exceeding 250x250 m² in size are allowed (Project 1991). No significant changes in land property ownership are observed within the estate. For example, changes in the property rights of coniferous forests did not exceed 1 % for 10-year period (Inventory 1970).
Appendix III. Model description

Outline of the model

In the present model the ecological criterion to evaluate the different management regimes was area of old-growth stands. Impact of economical development on forest used intensity was evaluated through analysis of stands dynamics under various levels of annual allowable cut (ALC or lesoseka in Russian - see Cuts in Appendix IV, Glossary). The modelling exercise was primarily intended to assess current logging practices in respect of most ecologically valuable forests - old-growth coniferous stands.

The model considers four land categories within the estate - Scotch pine (Pinus sylvestris L.) and Norway spruce (Picea abies (L.) Karst.) stands, deciduous stands and bare lands (Fig. 12). Just first two categories were analysed in detail. For pine, spruce and deciduous stands the term "forest type" will be used later in the text to refer to stands with dominance of one of coniferous or deciduous species. Deciduous stands include birch (Betula pubescens L.) and aspen (Populus tremula L.) - dominated stands.

Area distribution of ten age classes represent pine and spruce forest types in the model. One age class covered 20 years of stand lifespan, except class 10 representing stands older 200 years. Over time a stand moved from one class to another one with the probability of 0.05 annually (1/20 = 0.05). As soon as coniferous stand reached class 5 it could experience partial felling or clearcut. Although official felling instruction advise preferential cutting of mature and old-growth stands due to lower volume increment (Zagreev 1992), examination of empirical data (Project 1991) suggested that probability of being cut did not become higher as stand aged. After being cut, a coniferous stand could

1) move to deciduous stands category,
2) move to the bare land category.

There were also flows of area between bare land category (BL) and deciduous stands (LS), as well as between these two categories and pine/spruce age class 1.

Computationally, the model used transition probability matrix for each age class and LS and BL categories. I assume the matrix to be a finite Markovian matrix. The state of a system at the moment n can be found out by multiplying vector of system states at n-1 moment to the transition matrix :

\[ V_n = V_{n-1} \cdot M \]

where M - is transition matrix, Vn and Vn-1 - states of a system at moments n and n-1.

Sources of data errors

Lack of valid data (Nilsson 1997), and generally high measurement errors of Russian forest inventories make rather difficult any simulation exercise and seriously question practical applicability of obtained results. According to expert estimates, the error can be as high as 15 % (Shvidenko and Nilsson 1997, Lioubimov et al. 1998) that does prevent reliable estimation of forest dynamics. V. Gorshkov (with Komarov Botanical Institute in St. Petersburg, Russia) believes 50 % to be correct estimation of data error in forestry statistic data (Gorshkov 1998). It makes situation increasingly difficult as one moves from one-forestry level up to the regional and state level. Although some large-scale modelling studies report surprisingly accurate correspondence between generated results and those obtained in forest inventory records (Lioubimov et al. 1998) it does not prove raw data reliability: both model and verification data typically come from the same inventory records. The model presented here was based on the data from state-owned estate and managed by St. Petersburg Forest Research Institute (StP NIILH). This fact should make one more optimistic about data
precision. At the same time, chosen scale of consideration was believed to reduce errors due to data generalisation.

Fig. 12. Model outline. Number of age classes modelled in the model - 10 in each coniferous category. Size of boxes does not reflect actual area occupied by a category in Svirski Les forestry. Flow names are shown only on left portion of the figure. Vertical dashed lines represent stand ageing.

Model assumptions

In the present paper, considerable levels of uncertainty were present both at the level of model formulation and at the level of input parameters. To treat uncertainty at the model formulation level, the following assumptions have been made:

1. Model did not consider spatial distribution of forested areas, spatial autocorrelation during natural or cutting disturbances, nor landscape properties (e.g. connectivity among different landscape elements - e.g. Turner et al. 1994, Boychuk and Perera 1997).
2. Model ignored long-term events that occur at the time scale of centuries to millennia e.g. climate change and floodplain dynamics due to lack of high variability of potentially available data. Model also regarded pine- and spruce-dominated stands as successional entities and does not allow direct transition of land from one such category to another. However, an area without forest vegetation (bare land) or a deciduous stand could become a coniferous stand. Absence of pine-spruce transition was caused by length of simulation runs (250 years) and the way a forest type was defined in the model (a single-species dominant classification).
3. No variation in natural mortality rate was present in the model. This assumption was made because of the absence of readily available data sets in the forestry estate.
4. Model ignored the impact of possible atmospheric pollution. Obtained data revealed rather minor impact of this factor on estate's forests, namely - 0.015 % annually for the period 1980-90 (Project 1990, p. 167).
5. Differences in land use regimes between forest of 1st and 2nd groups were not taken into account (see Forest Groups in the Appendix IV, Glossary). Although differences between 1st and 2nd groups have been declared in the newly adopted Forest Code (Forest Code 1997), experts questioned actual difference in stand treatment (Kozlova 1998) in this estate.
6. Timber volume per ha was assumed to be constant among stands subject to clearcuts (that is, mature and old-growth stands) and there was no variation in the amount of clearcut due to variation in timber volume. Model did not consider this factor because of the possible large data errors. According to studies of forest typology in St. Petersburg region (General principles 1994), average volume per ha in the same forest type may show 25 % variation.
(7) No difference was made between selected cuts and clearcuts (i.e. both were considered as clearcuts). Although official regulations do not allow removal of more than 40% of timber volume during a single selected cut, this rule is not always observed. This assumption was partly justified by rather little differences between simulated and real areas of older age classes subject to felling operations (Fig. 13).

(8) No environmentally driven dynamics of conifer's regeneration were tackled. Parameters of conifer regeneration may vary from 25% to 85% within the same forest types (Project 1991). Analysis of regeneration possibilities was done while studying model sensitivity to various transition coefficients (see Model testing and sensitivity analysis later in the text).

(9) In the situation where data on conifer harvesting were available but no species-specific information was present, I assumed pine and spruce stands to be equal in these respects. According to current price lists of the Svirski Les forestry, the proportion (average pine timber price)/(average spruce timber price) was 41/36 that supported this assumption. However model reflected the fact that for last several years pine clearcut rate was twice as much as that of spruce (Project 1991).

(10) I assumed 0.57 to be average AAC completion level during simulation period. The value was obtained as average of ACC values for 5 year period (1993-97, Table 1).

(11) Clearcut area was assumed to become a bare land or deciduous stand. In other words, there was no automatic transition of clearcut pine/spruce stand to the youngest age class within the same forest type. Given empirically estimated transition coefficients from bare land to deciduous and coniferous stands (0.2 and 0.15 respectively), it should take about three years for an area to recover after clearcut.

Model testing and sensitivity analysis

After Lin et al. (1996), the approach to verify model was to test model predictions against post-sample observations for short-term (8-year period) and long-term (steady-state) accuracy. Several parameters have been checked in respect of the model sensitivity to their fluctuations. Available data were not enough to estimate actual variation of model parameters (=transition coefficients). However, their values were generally of the same order and it was unlikely that differences in statistical variation of transition coefficients were large. As a result of this reasoning, variation of each parameter was subjectively chosen to be equal to 1/10 of the distribution mean. Areas of old-growth stands were then contrasted with values of model parameters to assess relative importance of different transition coefficients. Finally, impact of the coefficients was studied in detail: each parameter (except annual clearcut rate) was allowed to gradually change from 0.01 to 0.99. As to ACR, it values ranged from 0.3 up to 3.

Term "sensitivity analysis" as it used in this paper should be viewed in its formal sense since no information on actual variation of transition rates was available. Because of this, model-based classification of transition rates as more/less important for stand dynamics may not reflect reality of forest operations. Nevertheless, informal discussion with forestry workers provided no indication that one could expect "significant" changes in land use intensity of the area (Kozlova 1998).

Confirmation of the model

To ensure that the model did produce reasonable results, confirmation has been carried out and the data generated for the year 1997 were contrasted with the actual values (Fig. 4). Although there were deviations as high as 23% and 18% (young pine stands and spruce stands 40-80 years old, respectively), other estimations were within 12% error from actual values. One can suggest two factors responsible for rather high errors in young pine and
middle-age spruce classes. The data might be collected less carefully than data on older classes being the most important for timber harvesting in the nearest future. As a rule, forestry statistics automatically moves clearcut areas to youngest age category within existing-before-cut forest type. Discussion with forestry workers (Kozlova 1998) seemed to support this argument. Model overestimated amount of area under stands 40-80 years old, especially areas of spruce stands (with 18 % error). As to the middle-age class (80-100 years old) older, model performed better with maximum error of 7.3 % (spruce stands). For stands experiencing felling activities (> 100 years old) model produced results which were very close to the actual values. In majority of cases, model correctly showed trend in area dynamics of a land category.

Model predicted well total values for particular forest type. In the case of bare land, quite high deviation from actual data (19 %) was apparently due to small size of this land category (about 300-400 ha, an order of magnitude smaller than total areas of coniferous or deciduous stands). Generally, given the possible initial error of used raw data (between 15 and 30 % - see Outline of the model later in this Appendix), the model results were considered satisfactory.

Model steady state

250 year period was found sufficient for the model to reach a steady state (Fig. 14). Later, this period was used to evaluate the model sensitivity to variation in transition coefficients. Given empirically estimated transition coefficients, area of old-growth spruce forests should increase from 256 ha up to 1004 ha at the end of this period. Increase in the area of pine old-growths were much less pronounced (from 322 to 375 ha, respectively). Amount of bare land remained approximately the same, and area under deciduous stands decreased from app. 5000 to 4000 ha.

Fig. 14. Estimation of the model steady state. Length of simulation - 250 years. OX - years, OY - area, ha. 1 - bare land, 2 - deciduous stands, 3 and 4 - pine and spruce old-growth stands, respectively.
Fig. 13. Model confirmation for 8 year period. Actual data for 1990 (start of the simulation), 1997 and generated values for 1997 are presented. Differences (in %) between generated and actual data for 1997 are indicated above bars representing simulation results. A - spruce and B - pine stands, C - overall changes in the total land area, area of bare land and deciduous stands.

A.

B.

C.
Appendix IV. Glossary

Where indicated, the definitions are exact citations from the respective sources.

*Annual Allowable Cut (AAC)* - The AAC description identifies the level of AAC for different quality classes as well as for tree species in these classes. Normally, AAC should be equal to the annual net volume increment of the forested.


*Coniferous trees* - Trees classified botanically as Gymnospermae. Their wood is generally referred to as softwood.

*Criterion* - A criterion represents a strategical direction of a practical operation aiming at implementation of accepted principles. The criterion on sustainable forest management should be assessed by a set of indicators. (Nilsson 1997). See Indicator.

*Cuts* - In Russian forestry, all cuts are classified into two categories: main cuts (Rubki glavnogo pol'zovaniya in Russian) and preliminary cuts (Rubki promezhutochnogo pol'zovaniya in Russian). Main cuts actually refer to clearcuts, and preliminary cuts stand for any selective (partial) cuts. Russian Forest Code (Forest Code 1997) does not allow forestries (state-owned in Russia) to conduct main cuts (MC) and preliminary cuts (if there is another company willing to carry out this operation). Instead, a forestry should employ other companies and control their activities.

*Forest groups - Group I forests* - Forests with mainly protective functions, namely water-protecting, health-protecting functions and forests of specially protected areas. Group II forests are forests in highly-populated areas with developed road networks, with various protective functions, and having limited value as source of commercial timber. Group III forests are forests of regions sufficiently covered by forest vegetation, being important mainly as a source of commercial timber and other forest-related products (translation from the Forest Code of the Russian Federation, in Forest Code of Russian Federation and the problems of nature protection. Nature Protection Bulletin 1(6), 1997). According to Russian Forestry legislation, group I forests should be subject to less intensive forestry operations, compared with groups II and III (e.g., concentrated clear-cuts may not be allowed in the group I forests).

*Forest industry enterprise (lespromkhoz in Russian)* is a private or state-owned industrial company responsible for the harvesting and/or processing of fiber products into marketable goods, i.e. lumber, pulp, paper, or furniture (Nilsson 1997).

*Forestry enterprise (leskhoz in Russian)* is an independent management unit of the Federal Service of the Forest Management of the Russian Federation, which manages the state Forest Fund area and is primarily responsible for fiber production, silvicultural activities, and management of the state forest resources (Nilsson 1997).

*Indicator* - An indicator is a quantitative and descriptive characteristic related to a criterion or criteria on sustainable forest management. A set of indicators makes it possible to assess trends of changes in the forest management with respect to a specific criterion. Consistent tracing of indicators over time makes it possible to discover the trends of changes in forest management (Nilsson 1997).

*Deciduous trees (=non-coniferous)* - Trees classified botanically as Angiospermae. These are generally referred to as broaddeciduous /smal-deciduous or hardwoods.

*Old-growth forests* - Foster et al. (1996) provide an useful discussion on what should actually be called "old-growth" forests. In the present paper I follow their unformal but pragmatic
definition of old-growth stands as forests having old trees in the canopy and without history of human disturbance.

*Productivity* in a classical forestry sense has been measured by the construction of growth and yield tables of volume increment. Such tables based on previous growth accurately predict yield for forest management. They have been associated historically with current levels of utilization and customarily disregard components on non-commercial materials such as stumps, small branches, etc. Since utilization has increased with time, and as wood supply has diminished, full and whole-tree harvesting and utilization require adjustment in yield tables (Zasada et al. 1997).

*Sustainable harvesting* - <here implies that> similar amounts and types of products (dimensions, quality, species) continue to be harvestable at periodic intervals in perpetuity (Seydack 1995).

*Uncertainty* - imperfect knowledge regarding aspects of a model. Uncertainty regarding model variables is usually specified by a probability distribution or by a sample of measured values (an empirical probability distribution); sometimes it is specified by a set of possible values. We adhere to the probabilistic concept of uncertainty, and we use variances as measure of uncertainty (Camase News, November 1995; retrieved on Nov. 14th 1996 from http://www.bib.wau.nl/camase/modguide.html ).