



# **Possibilities for using indicator percent for prioritization of stands for clearcutting in the russian federation**

**Nikolay Puteshov**

Supervisor: Mikael Andersson

Examiner: Ola Sallnäs

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## **ABSTRACT**

Planning is a very important part of forest management. In forestry, rational planning is needed for the effective use of forest resources for economic, ecologic, and social values. This study deals with tactical planning, especially with selecting stands for clear-cuts in Russia. At the tactical level, the problem of planning logging areas has two components: which stand to choose and when to cut it. This study shows how an economic way of planning can be introduced in Russia. A criterion for choosing stands for clear-cuts is indicator percent, which is used in Sweden on a wide scale. The work was done in a forest area, which is situated in Northwest Russia in the Republic of Karelia. Stands for clear-cutting were chosen according to all Russian rules of logging and indicator percent. Results of suggested plan were compared with actual clear-cuts made by a logging company in this area. Comparison was made for: harvested levels, indicator percents, net values and net values per one cubic meter of timber. The comparison showed that suggested plan was better than what had been done before in this area, but the difference was not significant. The discussion part is answering the following questions: a) why the difference in results is small? b) What could affect the results that were received? and c) what kind of problems can there be with introducing this way of planning in the Russian Federation?

**Key words:** forest management, forest planning, indicator percent, Russian Federation

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## 1. INTRODUCTION

Rational use of resources is one of the most important tasks for any kind of organization. To achieve this, the proper management and planning procedures are needed. In today's forestry the sustainable use of forests is emphasized and in this context forest management is playing a very important role. There are lots of different definitions of forest management e.g., Dunster and Dunster (1996) and Shindler and Cramer (1999), IUFRO (2009). Dunster and Dunster (1996, p. 137) define it as: "Forest management – is the practice of applying scientific, economic, philosophical and social principles to the administration, utilization, and conservation of all aspects of forested landscapes to meet specified goals and objectives, while maintaining the productivity of the forest..." If we consider other definitions of forest management, for example Shindler and Cramer (1999) or IUFRO (2009), it is necessary to say that they are quite similar, and the main point is that forest management stands for human activities in the forest for achieving specified goals (economic, social, and ecological).

One of the activities included in forest management is planning, which is the process of defining a problem, collecting data about the problem, formulating it, generating and evaluating different alternative solutions leading to the end of the process (Cohon, 1978). Planning includes lots of activities from defining a problem to the implementation of one of the several alternatives (Lämås, 1996). Planning is the most important step in any project. It means finding the best strategies and tactics to reach organizational goals and objectives. The necessity for correct planning is evident itself, but very often it is difficult to implement it in practice. Planning is a key management function because the other functions rely a great deal on correct planning. Good planning needs a big number of decisions on different questions (Hamzah, Gomez, 2009). The result of every planning process is a plan. Dunster and Dunster (1996, p. 242) defines the plan as: "A plan – is a course of action proposed to meet predefined goals, objectives and policies that lay out management directions, and an ordered set of decisions and actions to be taken to achieve these goals, objectives and policies..."

In Russian literature there is another definition of the plan: Shegelman (2008, p. 151) says: "A plan is a document, which includes the system of treatments for solving economical, technical, social and other tasks, aiming at reaching these goals. The plan shows resources, aims, tasks, treatments for achieving aims, and time and order of its implementation." There are some differences in these definitions, the main one is that in Russia the plan is like a detailed document, and in western countries it is more like a course of actions. But there are also some similarities, like in both statements the plan is a tool, which helps to define and achieve goals and objectives when decision makers choose the alternative.

In forestry, there is a need for rational planning for making effective use of economic and other values of forestry. It is a complex problem because it has both temporal and spatial dimensions. During the planning, the time horizon considered could be more than hundreds years and planning areas could be more than a hundred thousand hectares. To handle this problem the planning process should be systematized in a hierarchical structure (Thuresson, 1995). When hierarchical structure is used, it helps to solve the problem of time and space. At different levels there are different time horizons, different sizes of the area and different objectives and goals for planning. There could be different hierarchical structures; one of them was used by Weintraub and Cholaky (1991). It consists of strategic planning (allocation of resources), tactical planning (scheduling of operations) and operational planning (implementation of the goals set at higher levels).

Strategic planning has a long planning horizon up to 150 years. In this plan we choose the main directions for developing the forest sector, while taking into account legislation and policy issues (Martell *et al.*, 1998). For example, making decisions about harvesting level, how much should be cut, and with what kind of species to regenerate (short rotation, medium, or long rotation), to increase forest area or to decrease it and use this land in a different way (agriculture, mining etc). Outputs from the strategic level are information about the level of harvesting in a 10-year-long period in clear-cutting and thinning and also information about economic output (Söderholm, 2002). Then this information is used for identifying harvesting volumes for the next 10 years. In Sweden, the Forest Management Planning Package has been developed as a tool for strategic planning of timber production. The main function of it is to maximize net present value (NPV) of the forest holding (Lämås, 1996).

In Russia, according to the new forest code the longest planning period is 10 years. This forest plan contains calculations of the harvesting volumes for the first 5 years and then for the second 5-year period. Calculations are made according to the forecast of the forest sector development and it also significantly depends on the annual allowable cut. It is strategic planning and the result is a forest plan for different regions in Russia.

In tactical planning we try to choose efficient treatments for forestry for achieving the objectives and goals which were set in strategic planning e.g. volume targets to be achieved (Andersson, 2005). The time horizon for tactical planning is from 3 to 10 years. The main idea of this planning level is to schedule harvest operations for specific areas (Martell *et al.*, 1998), i. e. which stand to clear cut, thin, regenerate etc. Other examples of decisions in tactical planning can be about: construction of new roads and restoration of existing roads (Davis *et al.*, 2001). Operational planning deals with sequencing of operations in the nearest future (up to 2 years), i.e. choice of machine systems, scheduling of labor force etc.

This paper deals with tactical planning and more specifically how to select stands for clear-cutting. When selecting a stand for clear-cutting in tactical planning one cannot only look at individual stands, since there are spatial relationships influencing the decision. One example is to create harvest blocks (Davis *et al.*, 2001), which are concentrations of areas of different stands which should be harvested at the same time. These blocks help to decrease costs for harvesting operations, such as transporting harvesting equipment etc. (Gustafsson *et al.*, 2000). The output of the tactical plan is the stands that should be surveyed in detail, and after that they should be passed over to the operative planning level. We can also find some directions about the development of the forest road network (Andersson, 2005).

At the tactical level the problem of planning logging areas consists of two issues: what stand to choose and when to cut it. There are different methods for selecting stands for clear-cutting. One way to make decisions about clear-cutting is to identify priorities according to economic criteria (forest rent, financial maturity). Other methods for example are: to choose stands according to relative volume growth, road net development, age etc.

In 1849, Faustmann developed a solution how to value forest land. It was a theoretical basis for economic planning in forestry (Thuresson, 1995). Faustmann valued forest land not from the position of currently available forest outputs, but he found that in forest management we can use cycles of accumulation and de-accumulation of natural capital. He found that we should take into account not only the value of forestland which is based on the current condition of forest capital, but we should also think that forest is a renewable resource. The main idea of his article was to reject the idea that the value of immature stand can be determined on the basis of the sales price (Ince, 1999). The main idea of Faustmann study was to investigate the “highest and best use” of the site, to compare different uses with different yields over different time periods and with

different costs. In his study he focused on finding the optimal rotation period for harvesting and for maximizing site rent (Gaffney, 2006). Finally he produced a formula for calculating Land expectation value or soil expectation value (SEV).

$$B = \left( \frac{A_u}{(1+p)^u} + \sum_0^u \frac{D_x}{(1+p)^x} - \sum_0^u \frac{V_x}{(1+p)^x} - C \right) \cdot \left( 1 + \frac{1}{(1+p)^u - 1} \right)$$

A = Net value from clear-cutting,

D = Net value from thinning,

V = Management costs etc.

C = Regeneration costs,

u = rotation time,

x = year of management treatment

p = interest rate.

Max Robert Pressler was one of the most important Faustmann's contenders. He introduced the concept about Indicator PerCent (Die Weiserprocent) (Pressler, 1860). This percent can be used for defining if the stand is mature for clear-cutting or not (Gong and Löfgren, 2009). In his paper "For the comprehension of net revenue silviculture and the management objectives derived thereof" he introduced quantity and quality indicator percent, and finally he found an indicator percent.

Indicator percent can be used for distinguishing mature stands from immature ones. If the indicator percent is bigger than our interest rate, the stand is immature and we should keep it, because the yield is higher in the forest than in the bank. If this percent is lower than our interest rate, it means that the stand has become mature and we should harvest it. It is one of the most important uses of indicator percentage. Very often it has been used in practical forestry and it is a very important invention in forestry (Gong and Löfgren, 2009). This percent can be used to find out when the stand should be harvested, but for defining optimal rotation age we should also know the correct land value. This indicator percent is useful for practical identification of the forest stand maturity, because error in defining land value will not significantly influence the optimal rotation age (Gong and Löfgren, 2009). Hence, we can finally say that indicator percent is the current interest rate from our investment, which consists of investments in the stand and land.

$$ip = \frac{\Delta V}{V + B} \cdot 100\%$$

ip = indicator percent

V = net value;

B = land value;

$\Delta V$  = value growth.

The stand develops; therefore, the growing stock volume increases each year, so we can calculate value growth as:

$$\Delta V = V_{i+1} - V_i$$

Land value is calculated using Faustmann's formula, which was shown above. Figure 1 shows an example how indicator percent is changing during the development of a forest stand.

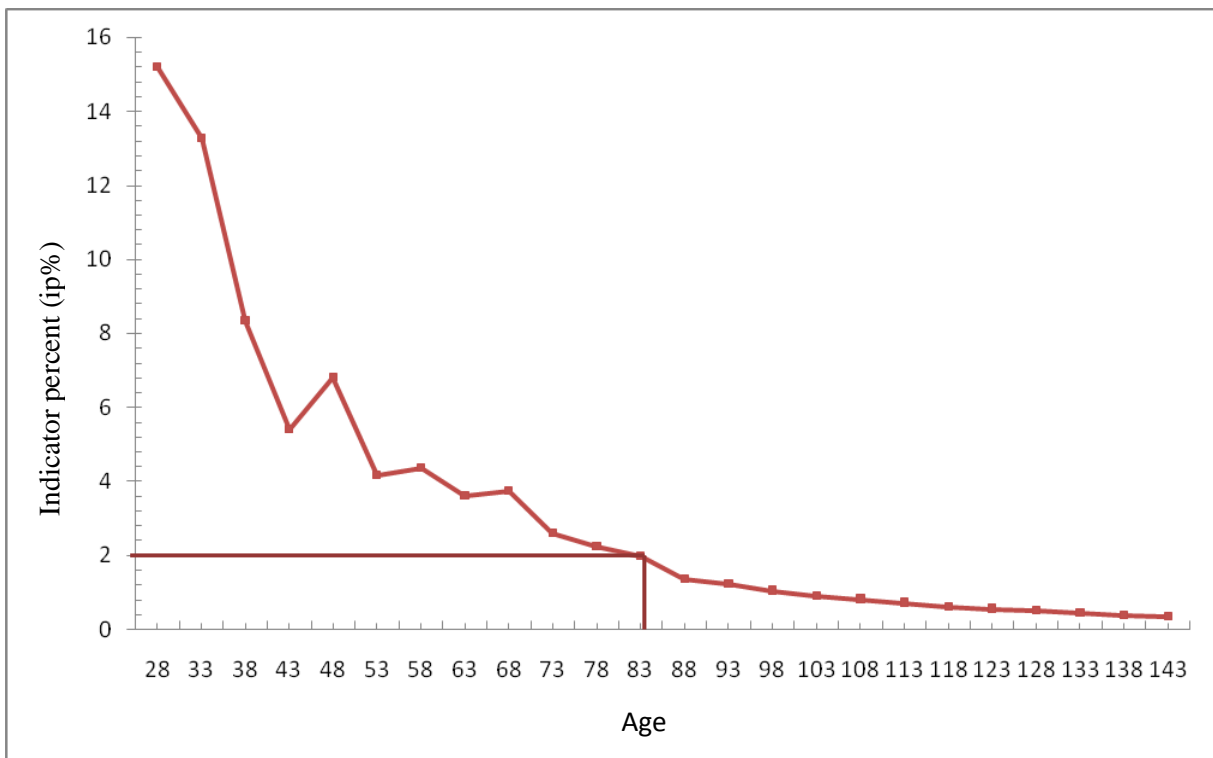


Figure 1 – Example of how indicator percent changes during stand development

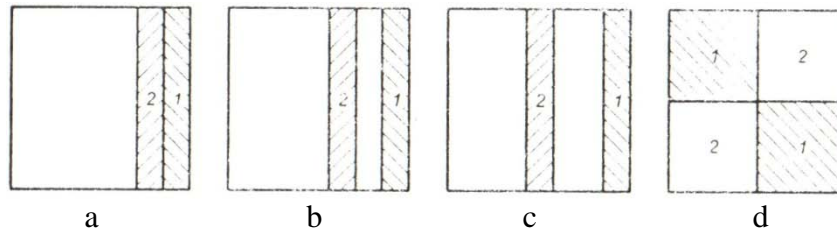
As you can see from figure 1 indicator percent is decreasing during the time. There are two reasons for that. The first and the main reason is that every year the stand increases its volume, and it means that value growth each year becomes less and less comparable to the net value, which also increases each year. The second reason is that with age the stand volume growth becomes lower, especially if we are talking about a long period of time, and it affects the value growth. In figure 1 you can also see that at the age of 48, 58, 68 indicator percent increases, because the stand is thinned. When thinned, the net value of the stand decreases, but value growth is more or less the same, which leads to the increase of the indicator percent. If the interest rate is 2%, then according to figure 1 this stand should be clear-cut at the age of 83. Indicator percent can be used not only for estimating the optimal rotation period, it could be used for other purposes, e.g. in tactical planning for selecting stands for clear-cutting. In this case it is possible to use indicator percent for ranking potential stands for clear-cutting when selecting them to achieve the target volumes. A stand with low indicator percent gets a higher priority for clear-cutting compared to the stand with higher indicator percent.

In Russia, before the year 2008, all planning of clear cuts had been carried out by state forest management companies. In Karelia the name of this company was “Karellesproekt”. They were using the recommendations of private logging companies for planning clear cuts such as: areas of road network development, access to forest, allocation of opencast mine for road construction materials, distance of forest transportation and etc. They also were following all rules and restrictions about allocation of clear cuts and taking into account the function of forest protection and conservation. But from the year 2008, when a new forest code was introduced, the situation changed. Now private logging companies are responsible for planning. It means that they will not only be interested in all the things that were mentioned above, but they will also be interested in maximizing their income, not only for short time period, but also for the future, because if they manage forest well, the state will help them to receive those forests for a longer lease. In Russia, there are a lot of different rules and restrictions about choosing areas for logging. Examples of these restrictions are: clear cut cannot be bigger than 50 hectares, its width from the



west to the east can not be more than 500 meters, and the length from the north to the south should be not more than 1 kilometer.

Progressive coupes on contiguous strips are one of the most important restrictions, in Russian forestry affecting how clear cuts could be spatially allocated. The basic rule is that clear-cutting of an area adjacent to a clear cut is allowed after a specified green-up period. Duration of this period depends on reforestation method. Figure 2 shows how clear cuts could be spatially allocated. In examples *b* and *c* it is possible to cut areas 1 and 2 the same year, but in example *a*, green-up period is needed between clear-cutting areas 1 and 2. In example *d* clear cuts are allocated in chess order, first area 1 is cut and then after the green-up period area 2. Example *d* has been the most popular method during the last 10 years (Kovyazin *et al.*, 2008).



source: "Basics of forestry and forest taxation" 2008

Figure 2 – Spatial allocation of clear cuts according to progressive coupes on contiguous strips

The aim of this thesis is to test the use of indicator percent for identifying priorities for selecting stands for clear-cutting for a ten-year period at a territory leased by the logging company "Karellesprom". The results from the ten-year plan of clear-cutting are then compared to the result from clear-cutting activities carried out by the company. Variables compared are indicator percent and economic result.

## 2. MATERIALS AND METHODS

### 2.1 General description of area and description of data

The study area is situated in the Russian Federation in the Republic Karelia. It is a part of Rimskoe forest enterprise. The study area is about 25000 ha. It includes 691 mature and over mature stands with the total area of 10767 ha. The main tree species for this area are Norway spruce (*Picea abies*), Scots pine (*Pinus silvestris*), and Birch (*Betula pendula*). All inventory data was received from the state company “Karellesproekt” and logging company “Karellesprom”. All data is from the year 1998, so the plan was made for the time period from 1998 to 2008, for 10 years. Most of the mature forest stands are mixed and uneven aged. All stands are old (Figure 3). Site index of the area in general is very low. It means that the volume increment is quite low in this area. Average growing stock volume in the study area is around 170 m<sup>3</sup>/ha.

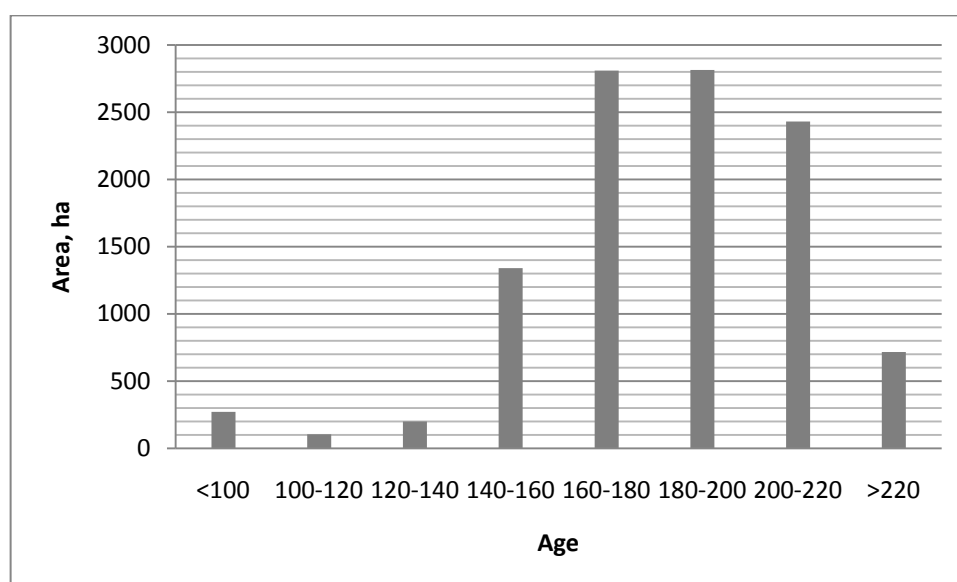


Figure 3 – Area distribution of age classes as of the beginning of the planning period for all potential clear cut stands

Inventory data included the following variables: the age of each species in the stand, species composition, diameter of each species, height of each species, site productivity class, area of the stand, relative basal area, standing volume per ha (table 1). Site productivity class (in russian “bonitet”) is a taxation characteristic of a forest stand, which defines its productivity. It accounts for the average age and average height of the stand (Anuchin, 1982). There are 5 classes of bonitets. I – is the best, and V – is the worst. But sometimes there are such bonitet classes as Ia or Ib that are better than I; there can also be Va and Vb, and they are worse than V. Relative basal area is a ratio between basal areas of real forest stand and a model stand which has relative basal area 1. It shows in portions from 1 (Shegelman, 2008).

Table 1 – Example of inventory data used in this study

District №	Stratum №	Species Composition	Age	Diameter, cm	Height, m	Site productivity class	Area, ha	Volume, m <sup>3</sup> /ha	Relative basal area
1	4	5P2S3B	150	18.4	13.9	V	4	90	0.4
1	6	5S5B+P	170	17	14.5	V	32	140	0.6
1	7	8P1S1B	150	20.4	13.7	V	4	90	0.4
1	11	4S2P4B	170	18.4	14.8	V	10	120	0.5
1	12	4S1P5B	170	18.8	15.6	V	4	130	0.5
2	1	6B4S	80	18	15	IV	5	90	0.5
2	7	10P	150	22	14	V	3	70	0.3
2	9	6S4B+P	170	19.2	16	V	29	160	0.6
2	10	5S5B	170	18	15	V	4	140	0.6
2	11	5S5B	170	18	15	V	6	140	0.6
2	13	4P3S3B	170	19.2	14	V	17	120	0.5
3	1	6B2A12S	70	15.6	13.6	IV	4	90	0.6
3	4	5S2P3B	170	17.6	14.2	V	4	110	0.5
3	5	5S5B+P	170	18	15	V	2	140	0.6
4	9	6S4B	170	16.8	14.8	V	34	140	0.6
4	15	6S4B	170	18.8	15.8	V	14	160	0.6

Species composition is interpreted as follows: 5P2S3B reads 50% pine, 20% spruce, 30% birch and 5S5B+P reads 50% spruce, 50% birch and less than 5% of pine.

## 2. 2 Description of ProdMod

The computer software ProdMod was used to simulate stand development. It is Swedish software for estimating growth and yield (Eko, 1985). The growth functions used in ProdMod are based on data from 17500 different sample plots in the Swedish national forest inventory. With this program we can make forecasts for both monocultures and mixtures.

The input data needed in ProdMod includes: the number of stems per hectare, basal area, age and site index for each species. It also needs latitude and altitude. Output data is given for 5-year-long periods. For each tree species the output is described with the number of stems, basal area, volume, volume increment, diameter, height, and biomass. In this study the output data used is: volume increment, diameter, height, basal area, and number of stems.

## 2. 3 Data transformation

There are some differences regarding variables collected in forest inventory in Russia and in Sweden. Thus, for using ProdMod, there is a need for some data transformation. For example, in Russia the number of stems per hectare is not in this data, also instead of site index another criterion is used, i.e. Site productivity class. Instead of basal area, in Russian forestry, relative basal area is used. In this study I have used a special table to transform Russian site productivity classes into Site indexes according to the Swedish definition (Hägglund, 1979). Site index is a criterion for defining site productivity. It shows dominant height at the age of 100. For example

S32 means that spruce stand at the age of 100 will have dominant height of 32 meters. Below you can see a part of this table (table 2).

Table 2 – Site productivity classes scale for average rotation species

Age, years	Name of site productivity classes		
	III	IV	V
	The lowest boarders of height, m		
10	2.4	1.8	1.3
20	5.0	3.7	2.6
40	9.9	7.4	5.6
60	13.9	10.7	8.3
80	16.9	13.2	10.4
100	19.0	15.0	12.0
120	20.5	16.3	13.1
140	21.6	17.2	14.2
160	22.4	17.9	14.8
180	23.0	18.4	15.2
200	23.3	18.7	15.3

Source: USSR norm for forest taxation, 1990

For example, a Pine stand at age of 180 has site productivity class V. Then in this table we find the height of this stand at the age of 100 and then it is possible to find the site index. It is T12. This table is used for average rotation species.

There is a special table, which transfers relative basal area into basal area. The table was used during calculations (Table 3). Part of this table is shown below.

Table 3 –Basal area depending on dominating tree species, relative basal area and average height.

Height, m	Pine, Larch								Spruce							
	Relative basal are								Relative basal are							
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
12	9	12	14	17	20	23	26	29	7	10	12	15	17	20	22	24.5
13	9	12	15	18	21	24	27	29.9	8	10	13	15	18	20	23	25.5
14	9	12	15	18	21	24	28	30.6	8	11	13	16	19	21	24	26.7
15	9	13	16	19	22	25	28	31.5	8	11	14	17	20	22	25	27.8
16	10	13	16	19	22	26	29	32.2	9	12	14	17	20	23	26	28.9
17	10	13	16	20	23	27	29	32.7	9	12	15	18	21	24	27	30
18	10	13	17	20	23	27	30	33.3	9	12	16	19	22	25	28	31
19	10	14	17	20	24	27	30	33.8	10	13	16	19	22	26	29	32
20	10	14	17	21	24	27	31	34.3	10	13	16	20	23	26	30	33
21	10	14	17	21	24	28	31	34.7	10	14	17	20	24	27	31	34

Source: LenNIILH, year is unknown

To get the basal area for each stand, linear interpolation between height classes was made. For example, we have pine dominated stand with relative basal area 0.5 and average height 17.7 m. A stand of 17 meters high has basal area of 16, and for stand of 18 meters high the basal area is 17, so the interpolated value can be calculated as follows:

$$16 + \frac{(17 - 16) \cdot 7}{10} = 16.7 \text{ m}^2/\text{ha}$$

Since many stands in the study area are mixed the species composition must also be accounted for when calculating the basal area:

$$TBA = \sum_{i=1}^n X_i \cdot B_i$$

TBA = total basal area of stand

$X_i$  = volume proportion of specie i in stand

$BA_i$  = basal area of specie i

i = number of tree specie

For example, if the stand consists of 40% pine with a height of 19.6 m and 60% of spruce with a height of 16.4 m and has a relative basal area of the stand 0.6, then to calculate the basal area of the whole stand the basal area for each species was used and then each species was multiplied by its share in the species composition in the stand and then summed up as follows

$$\left(20 + \frac{(21 - 20) \cdot 0.6}{10}\right) \cdot 0.4 + \left(17 + \frac{(18 - 17) \cdot 0.4}{10}\right) \cdot 0.6 = 18.7 \text{ m}^2/\text{ha}$$

To get the number of the trees per hectare the calculated basal area was used, as well as the average diameter, which is given in the stand database, and this formula:

$$Nt = \frac{4 \times BA}{\pi \times d^2}$$

Nt = number of trees per hectare

BA = basal area,  $\text{m}^2/\text{ha}$

d = average diameter, m

After all transformations I got a data set that could be used for simulations in ProdMod. A part of this data set is shown in table 4.

Table 4 – Example of transformed stand data (gray background) ready for use for simulations in ProdMod

District №	Stratum №	Species composition	Age	Diameter, cm	Height, m	Site productivity class	Area, ha	Volume, m <sup>3</sup> /ha	Relative basal area	Site index	Basal area, m <sup>2</sup> /ha	Number of trees per ha
1	4	5P2S3B	150	18.4	13.9	5	4	90	0.4	T12	10.6	399
1	6	5S5B+P	170	17	14.5	5	32	140	0.6	G12	14.5	639
1	7	8P1S1B	150	20.4	13.7	5	4	90	0.4	T12	11.5	352
1	11	4S2P4B	170	18.4	14.8	5	10	120	0.5	G12	12.8	482
1	12	4S1P5B	170	18.8	15.6	5	4	130	0.5	G12	12.7	458
2	1	6B4S	80	18	15	4	5	90	0.5	B14	11.6	456
2	7	10P	150	22	14	5	3	70	0.3	T12	9	237
2	9	6S4B+P	170	19.2	16	5	29	160	0.6	G12	15.4	532
2	10	5S5B	170	18	15	5	4	140	0.6	G12	15	590
2	11	5S5B	170	18	15	5	6	140	0.6	G12	15	590
2	13	4P3S3B	170	19.2	14	5	17	120	0.5	T12	12.9	446
3	1	6B2A12S	70	15.6	13.6	4	4	90	0.6	B16	13.2	691
3	4	5S2P3B	170	17.6	14.2	5	4	110	0.5	G12	12.5	514
3	5	5S5B+P	170	18	15	5	2	140	0.6	G12	15	590
4	9	6S4B	170	16.8	14.8	5	34	140	0.6	G12	15.4	695
4	15	6S4B	170	18.8	15.8	5	14	160	0.6	G12	15.4	555

## 2. 4 Growth simulation and calculation

After transformed data was received, ProdMod was used for growth simulations. During this simulation I was looking at volume increment. ProdMod simulates stand growth in 5-year periods. In this case simulation was made for two 5-year periods. After that increment per each year was calculated with the formula given below:

$$V_1 = V_0 + \frac{V_5 - V_0}{5}$$

$V_1$  = volume the first year of simulation

$V_0$  = volume from the database

$V_5$  = volume the fifth year of simulation.

In table 5 some examples on data from the simulations is presented.

Table 5 – Example showing the results of simulation for two stands

District №	Stratum №	Species composition	Age	Diameter, cm	Height, m	Area, ha	Volume, m <sup>3</sup> /ha	Site index	Basal area, m <sup>2</sup> /ha	Number of trees per ha	Year of simulation
1	4	5P2S3B	150	18.4	13.9	4	90	T12	11	399	0
1	4	5P2S3B	151	18.6	14	4	91.3	T12	11.1	397	1
1	4	5P2S3B	152	18.8	14.1	4	92.6	T12	11.2	395	2
1	4	5P2S3B	153	19	14.2	4	93.9	T12	11.3	393	3
1	4	5P2S3B	154	19.2	14.3	4	95.2	T12	11.4	392	4
1	4	5P2S3B	155	19.4	14.4	4	96.5	T12	11.5	391	5
1	4	5P2S3B	156	19.6	14.5	4	97.8	T12	11.6	389	6
1	4	5P2S3B	157	19.8	14.6	4	99.1	T12	11.7	388	7
1	4	5P2S3B	158	20	14.7	4	100.4	T12	11.8	386	8
1	4	5P2S3B	159	20.2	14.7	4	101.7	T12	11.9	385	9
1	4	5P2S3B	160	20.3	14.8	4	103	T12	12	383	10
1	6	5S5B+P	170	17	14.5	32	140	G12	15	639	0
1	6	5S5B+P	171	17.2	14.6	32	141.9	G12	15.2	636	1
1	6	5S5B+P	172	17.4	14.7	32	143.8	G12	15.4	634	2
1	6	5S5B+P	173	17.6	14.8	32	145.7	G12	15.6	631	3
1	6	5S5B+P	174	17.7	14.9	32	147.6	G12	15.8	628	4
1	6	5S5B+P	175	17.8	15	32	149.5	G12	16	625	5
1	6	5S5B+P	176	18	15.1	32	151.4	G12	16.2	623	6
1	6	5S5B+P	177	18.2	15.2	32	153.3	G12	16.4	621	7
1	6	5S5B+P	178	18.4	15.3	32	155.2	G12	16.6	618	8
1	6	5S5B+P	179	18.5	15.4	32	157.1	G12	16.8	615	9
1	6	5S5B+P	180	18.6	15.5	32	159	G12	17	612	10

## 2. 5 Economic calculations

### 2. 5. 1 Timber prices

When doing this study I was thinking a lot about what timber prices it is possible to use. First of all I found out how timber prices were changing during the last 10 years (table 6). Prices were in USD. But it was not possible to find the prices for the year 1998, because of the economic crisis (default) in Russia.

Table 6 – Real prices for timber from 1999 to 2007

Year	Price in USD	Exchange rate RUR/USD	Price in RUR
1999	30.9	25.59	790.73
2000	28.8	27.79	800.35
2001	29.8	29.4	876.12
2002	31.6	31.63	999.51
2003	38.8	30.5	1183.4
2004	41.4	29.21	1209.29
2005	41.4	28.43	1177.00
2006	42.4	26.67	1130.81
2007	55.3	25.01	1383.05

Table 6 shows that prices were changing quite much, but the reasons for the changes are not clear, and also it is necessary to say that prices in RUR hardly depend on the exchange rate. After it, I decided that the constant price for timber for all 10 years should be used in this work. Prices were taken from the year 2008, because all data for calculating the costs was from the year 2008. Of course when talking about timber prices, it should be taken into account what kind of species it is, what kind of assortments, and also timber quality. But in this study, for making calculations easier, the average price for 1 m<sup>3</sup> of timber was taken. In the year 2008, the average price for timber was 1750.73 RUR

### 2. 5. 2 Calculation of commercial timber volume

After receiving data from the simulations and finding how volume increases, the next step was to find how the share of merchantable wood changes. For finding this share, the formula was used which was introduced by Ollas (1980).

$$Prop\% = \left(1 - \frac{0.86}{d - mind}\right) \times 100$$

Prop% = proportion (share) of merchantable wood

d = average diameter at the breast height in centimeters

mind – is the minimum diameter of merchantable (5 cm was used in calculations) wood.

For example diameter at the breast height is 18 cm.

$$Prop\% = \left(1 - \frac{0.86}{18 - 5}\right) \cdot 100 = 93.4\%$$

This proportion will help to find how much of the growing stock volume is sold and also to calculate harvesting costs.



### 2. 5. 3 Calculation of costs

Costs for timber logging include several types of costs.

First of all logging companies in Russia are renting forests from the state. One type of costs is lease payment. Logging company is renting forest land, for which annual allowable cut is calculated, and every year they should pay per each cubic meter of this annual allowable cut. For this area the annual payment in the year 2008 was 90,9 RUR/m<sup>3</sup>. This payment was used for calculations. Another part of costs is costs for using machines. This part was quite complicated to calculate. First of all I found how much harvester and forwarder per 1 working hour cost. This data was received from “Karellesprom”. In this area they are using harvester Volvo EC210BLC and forwarder John Deere 1110D. Costs for using machines include: salaries for operators, gasoline and oil for machines, spare parts for machines, amortization, payments for lease, payments for maintenance etc. Costs for harvester and forwarder per hour are shown below:

$$\begin{aligned}\text{Harvester} &= 2697.3 \text{ RUR/hour} \\ \text{Forwarder} &= 2839.46 \text{ RUR/hour}\end{aligned}$$

The next step was to find how many hours they will work in different conditions in different stands.

For calculating this, formulas from Carlsson (2008) were used.

For harvester the time consumption is calculated:

$$th = A0 + \frac{A1}{NharvSt} + A2 \cdot MeanStV$$

th = time consumption per harvested tree (min/stem)

NHarvSt = number of harvested stems per hectare (No/ha)

MeanStV = mean merchantable volume of harvested trees (m<sup>3</sup>)

A0 = coefficient – 0.56

A1 = coefficient – 79

A2 = coefficient – 1.31

Mean merchantable volume of the tree was calculated using this formula:

$$MeanStV = \frac{GSV \cdot Prop\%}{Nt}$$

MeanStV = mean merchantable volume of the tree (m<sup>3</sup>/st)

GSV = growing stock volume per ha (m<sup>3</sup>/ha)

Prop% = proportion of merchantable timber

Nt = number of trees per ha

For example: growing stock volume is 140 m<sup>3</sup>/ha, Proportion of merchantable wood is 93%, and number of harvested trees is 639 tree/ha.

$$MeanStV = \frac{140 \cdot 0.93}{639} = 0.204 \text{ m}^3/\text{st}$$

$$th = 0.56 + \frac{79}{639} + 1.31 \cdot 0.204 = 0.95 \text{ min/tree}$$

Cost per hectare was calculated with the formula below:

$$Ch = HC \cdot NHarvSt \cdot th$$

C – costs for harvesting (rub/ha)

HC – Machine cost per minute

$$Ch = \frac{2697.3}{60} \cdot 639 \cdot 0.95 = 27290 \text{ RUR/ha}$$

For forwarder a formula from Carlsson (2008) was also used:

$$tf = B0 + \left( B1 + \frac{2 \cdot TrD}{TrS \cdot LC} \right) \cdot VH$$

tf = Time consumption per hectare for forwarder (min/ha)

TrD = Single terrain transport distance (m)

TrS = travel speed for forwarder (60 m/min was used in calculations)

LC = load capacity, for John Deere 1110D – 13 m<sup>3</sup>

VH = harvested volume per hectare (m<sup>3</sup>/ha)

B0 = coefficient = 74

B1 = coefficient = 2.16

For defining transportation distance, it is necessary to think about the shape of the clear cut and its size. It can be the distance from the center of the clear cut to the road. In Russia, clear cuts usually have a rectangular shape with sides of 500 meters and 1000 meters, roads can be from the short side or from the long side, in this case the transport distance was found:

$$\frac{250 + 500}{2} = 375 \text{ m}$$

But a clear cut can be not only of the rectangle shape but also of another shape, so for these calculations transportation distance of 400 m was used.

For example VH = 140m<sup>3</sup>/ha

$$tf = 74 + \left( 2.16 + \frac{2 \cdot 400}{60 \cdot 13} \right) \cdot 140 = 520 \text{ min/ha}$$

To calculate forwarder cost per hour it should be multiplied with machine cost (RUR/min)

$$Cf = \frac{2839.46}{60} \cdot 520 = 24609 \text{ RUR/ha}$$

But the problem is that harvester and forwarder work as a system of machines; thus, it means that costs should be calculated not separately for each machine but for the system. For this purpose, productivity of each machine should be calculated and then productivity of the system of machines.

Productivity of harvester is calculated using the formula (Shegelman *et al.*, 2007):

$$Ph = \frac{k1 \cdot k2 \cdot 60 \cdot 8 \cdot MeanStV}{th}$$

Ph = productivity of harvester per shift

k1 = coefficient for using working time (0.9)

k2 = coefficient for using machine (0.9)

MeanStV = mean merchantable volume of harvested trees

th = time consumption for harvesting one tree.

For example: MeanStV = 0.204 m<sup>3</sup>/tr, th = 0.95 min/tree

$$Ph = \frac{0.9 \cdot 0.9 \cdot 60 \cdot 8 \cdot 0.204}{0.95} = 83.5 \text{ m}^3/\text{shift}$$

Forwarder productivity is calculated with the formula (Shegelman *et al.*, 2007):

$$Pf = \frac{k1 \cdot k2 \cdot 60 \cdot 8 \cdot GSV}{tf}$$

Pf = productivity of forwarder per shift

k1 = coefficient for using working time (0.9)

k2 = coefficient for using machine (0.9)

GSV = growing stock volume m<sup>3</sup>/ha

tf = time consumption per ha

For example: GSV = 140 m<sup>3</sup>/ha, tf = 520 min/ha.

$$Pf = \frac{0.9 \cdot 0.9 \cdot 60 \cdot 8 \cdot 140}{520} = 104.7 \text{ m}^3/\text{shift}$$

Productivity of the system of machines is calculated with the formula from the book “Technique and technology of logging operations” by Shegelman *et al.* (2004).

$$Ps = \frac{Ph \cdot Pf}{Ph + Pf}$$

Ps = productivity of the system of machines

For example: Ph = 83.5 m<sup>3</sup>/shift, Pf=104.7 m<sup>3</sup>/shift.

$$Ps = \frac{83.5 \cdot 104.7}{83.5 + 104.7} = 46.5 \text{ m}^3/\text{shift}$$

A cost for system of machines is calculated with the formula below:

$$Cs = \frac{GSV \cdot 8 \cdot (Ch + Cf)}{Ps}$$

Cs = costs of system of machine

Ch = harvester cost per hour

Cf = forwarder cost per hour

Ps = productivity of the system of machines

For example: GSV = 140 m<sup>3</sup>/ha, Ch = 2697.3 RUR/hour, Cf = 2839.46 RUR/hour, Ps = 46.5m<sup>3</sup>/shift.

$$Cs = \frac{140 \cdot 8 \cdot (2697.3 + 2839.46)}{46.5} = 133358.5 \text{ RUR/ha}$$

#### 2. 5. 4 Calculation of the Net Value

The next step of this study was to calculate Net value for one hectare in different stands. It was calculated using the formula:

$$NV = P \cdot MV - C$$

NV = net value

P = price per cubic meter

MV = merchantable volume (m<sup>3</sup>/ha)

C = costs

Costs consist of costs for logging operations and costs for rental payments (Cs and Rp)

For example: P=1750.73 RUR/m<sup>3</sup>, GSV=140 m<sup>3</sup>/ha, Prop%=93%, Cs=133358.5, Rp=90.9 RUR/m<sup>3</sup>

$$NV = 1750.73 \cdot 140 \cdot 0.93 - 133358.5 - 90.9 \cdot 140 = 81860.5 \text{ RUR/ha}$$

#### 2. 5. 5 Calculation of value growth

Every year a stand increases its volume; therefore, in this part calculation of net value increment is shown.

$$\Delta V = NV2 - NV1$$

For example: NV1 = 81068.41 RUR and NV2 = 83576.13 RUR

$$\Delta V = 83576.13 - 81068.41 = 2507.72 \text{ RUR/ha}$$

#### 2. 5. 6 Calculation of indicator percent

After all those calculations, indicator percent was calculated. For this the following formula was used:

$$ip = \frac{\Delta V}{V + B} \cdot 100\%$$

But in Russia there are no private forests, and it is impossible to calculate land value, because the owner of all forestland is the state. Renting payments were included in costs, so this formula will look a little different from the traditional one.

$$ip = \frac{\Delta V}{V} \times 100\%$$

For example:  $\Delta V=2507.72$  RUR,  $V=83576.13$  RUR

$$ip = \frac{2507.72}{83576.13} \cdot 100 = 3\%$$

In table 7 below a part of the final table for calculating indicator percent is given.

Table 7 – Example of results from calculations: costs, net value, indicator percent

District №	Stratum №	Species composition	Age	Diameter, cm	Height, m	No of stems per ha	Area, ha	Volume, m <sup>3</sup> /ha	Price, rub/m <sup>3</sup>	Year of simulation	Rent per ha	Mean tree volume, m <sup>3</sup>	Productivity of system of machines, m <sup>3</sup> /shift	Costs of the machine system thousands rub/ha	Net value, thousands rub/ha	Value growth, rub/ha	ip%
1	4	5P2S3B	150	18.4	13.9	399	4	90	1750.7	0	8181	0.21	43.6	91.3	47.9	0	
1	4	5P2S3B	151	18.6	14	397	4	91.3	1750.7	1	8299	0.22	44.0	91.8	49.6	1670	3.37
1	4	5P2S3B	152	18.8	14.1	395	4	92.6	1750.7	2	8417	0.22	44.4	92.3	51.3	1668	3.25
1	4	5P2S3B	153	19	14.2	393	4	93.9	1750.7	3	8536	0.22	44.8	92.8	52.9	1667	3.15
1	4	5P2S3B	154	19.2	14.3	392	4	95.2	1750.7	4	8654	0.23	45.1	93.4	54.5	1598	2.93
1	4	5P2S3B	155	19.4	14.4	391	4	96.5	1750.7	5	8772	0.23	45.5	94	56.1	1597	2.84
1	4	5P2S3B	156	19.6	14.5	389	4	97.8	1750.7	6	8890	0.24	45.9	94.5	57.8	1663	2.88
1	4	5P2S3B	157	19.8	14.6	388	4	99.1	1750.7	7	9008.	0.24	46.2	95	59.4	1594	2.68
1	4	5P2S3B	158	20	14.7	386	4	100.4	1750.7	8	9126	0.25	46.6	95.5	61.0	1661	2.72
1	4	5P2S3B	159	20.2	14.7	385	4	101.7	1750.7	9	9245	0.25	46.9	96.1	62.6	1592	2.54
1	4	5P2S3B	160	20.3	14.8	383	4	103	1750.7	10	9363	0.25	47.2	96.6	64.2	1579	2.46
1	6	5S5B+P	170	17	14.5	639	32	140	1750.7	0	12726	0.20	46.4	133.7	81.1	0	
1	6	5S5B+P	171	17.2	14.6	636	32	141.9	1750.7	1	12899	0.20	46.8	134.4	83.6	2508	3.00
1	6	5S5B+P	172	17.4	14.7	634	32	143.8	1750.7	2	13071	0.21	47.1	135.2	86.0	2435	2.83
1	6	5S5B+P	173	17.6	14.8	631	32	145.7	1750.7	3	13244	0.22	47.5	135.9	88.5	2499	2.82
1	6	5S5B+P	174	17.7	14.9	628	32	147.6	1750.7	4	13416	0.22	47.8	136.7	90.9	2328	2.56
1	6	5S5B+P	175	17.8	15	625	32	149.5	1750.7	5	13590	0.22	48.2	137.3	93.2	2329	2.5
1	6	5S5B+P	176	18	15.1	623	32	151.4	1750.7	6	13762	0.23	48.5	138.2	95.6	2426	2.54
1	6	5S5B+P	177	18.2	15.2	621	32	153.3	1750.7	7	13935	0.23	48.9	139	98.0	2422	2.47
1	6	5S5B+P	178	18.4	15.3	618	32	155.2	1750.7	8	14107	0.24	49.2	139.7	100.5	2487	2.47
1	6	5S5B+P	179	18.5	15.4	615	32	157.1	1750.7	9	14280	0.24	49.5	140.4	102.8	2328	2.26
1	6	5S5B+P	180	18.6	15.5	612	32	159	1750.7	10	14453	0.24	49.9	141.1	105.2	2329	2.21

## 2. 6 Calculation of annual allowable cut

For establishing the annual allowable cut for the study area, the annual allowable cut of all Rimskoe forest enterprise, 71680 m<sup>3</sup> from 24975 ha, was used. I then assumed that annual allowable cut per hectare in the study area (10740 ha) was the same, resulting in annual harvesting volume of 30824 m<sup>3</sup>. This harvesting volume of 30824 m<sup>3</sup> was taken as a target volume, which should be achieved during every year of the planning period.

## 2. 7 Selecting stands for clear cuts

In the process of selecting clear-cut stands to achieve the annual allowable cut, not only indicator percent was taken into account, but also the spatial concentration of clear cuts and road accessibility. To handle the concentration of clear cuts, the study area was divided into 5 blocks of approximately the same size (figure 4). The clear-cut stands in each of these blocks were then assigned to two specific years during the ten-year period.

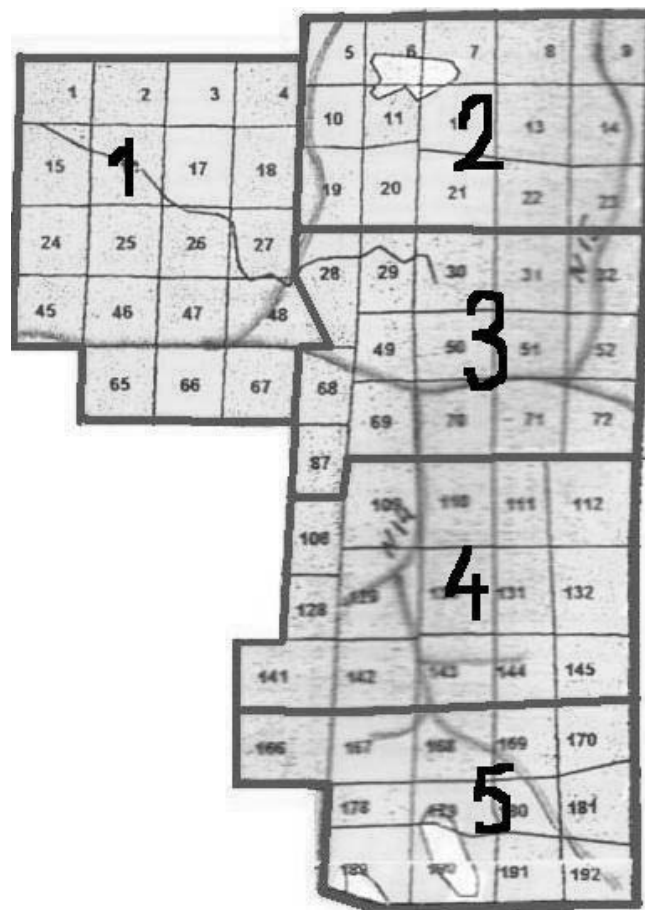


Figure 4 – Map showing the division of the study area into blocks

After it, the average indicator percent was calculated for every block to decide from which one to start planning areas for clear cuts.

Average indicator percent was calculated using the following formula:

$$Aip = \frac{\sum_{i=1}^n ip_i \times S_i}{\sum_{i=1}^n S_i}$$

Aip = average indicator percent in block,  
 S = area of a forest stand, ha.

For the first year the block with the lowest average indicator percent was chosen, then the next block etc. In the year 6, the average indicator percent was calculated again for these 5 blocks, but stands that were clear cut before were removed from the calculation.

Table 8 below shows which block was cut the first year, the second etc.

Table 8 – Average indicator percent in blocks for different years

Year	Block 1	Block 2	Block 3	Block 4	Block 5	No of block for cutting
1	1.81	1.85	1.78	1.51	1.27	5
2	1.77	1.69	1.73	1.47	1.25	4
3	1.73	1.59	1.67	1.44	1.23	2
4	1.69	1.53	1.62	1.41	1.21	3
5	1.66	1.48	1.56	1.38	1.19	1
6	1.7	1.5	1.64	1.39	1.22	5
7	1.67	1.46	1.6	1.36	1.21	4
8	1.63	1.43	1.57	1.34	1.19	2
9	1.6	1.39	1.54	1.31	1.17	3
10	1.57	1.36	1.51	1.29	1.16	1

In each block and year stands for clear cuts were selected by giving the highest priority to the stands with low indicator percent and easy road access. See data on all selected stand in the appendix.

## 2. 8 Evaluation of the plan

The idea of this study was to try to apply indicator percent in Russian forestry. Thus, after clear cuts were chosen it was necessary to evaluate the plan. For this purpose I decided to compare the suggested plan with clear cuts that were made by the logging company on this territory. For that all data about the harvesting that the company did on this territory was taken and the comparison was made of the average indicator percent for each year, cut volume for each year, net value and net value from one cubic meter.

Several problems were found with this comparison. First of all there was no data for the first 3 years of logging operations on this territory; therefore, the comparison was made only for the last seven years. The second problem was that company had not made any logging in the first block (5<sup>th</sup> and 10<sup>th</sup> years in the plan); thus, for fair comparison this block and those years were excluded. Then in some years the logging company cut more, because they were using the annual allowable cut of the whole enterprise. It means that those years were also excluded from the comparison of the average indicator percent, net value and cut volume, because if they cut more it is not fair to compare the net value and indicator percent.

Finally I came up to the point when it was possible to compare only three years of the activities of the company, after all the issues that were excluded. It is 4<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> years of the plan. For calculating the average indicator percent for each year, I used the formula which was used for calculating the average percent for blocks, but instead of stand areas, were used areas of clear cuts.



### 3. RESULTS

The calculated indicator percents for potential clear cut stands are generally low. Around 79% percent of the area has an indicator percent less than 2% (figure 5).

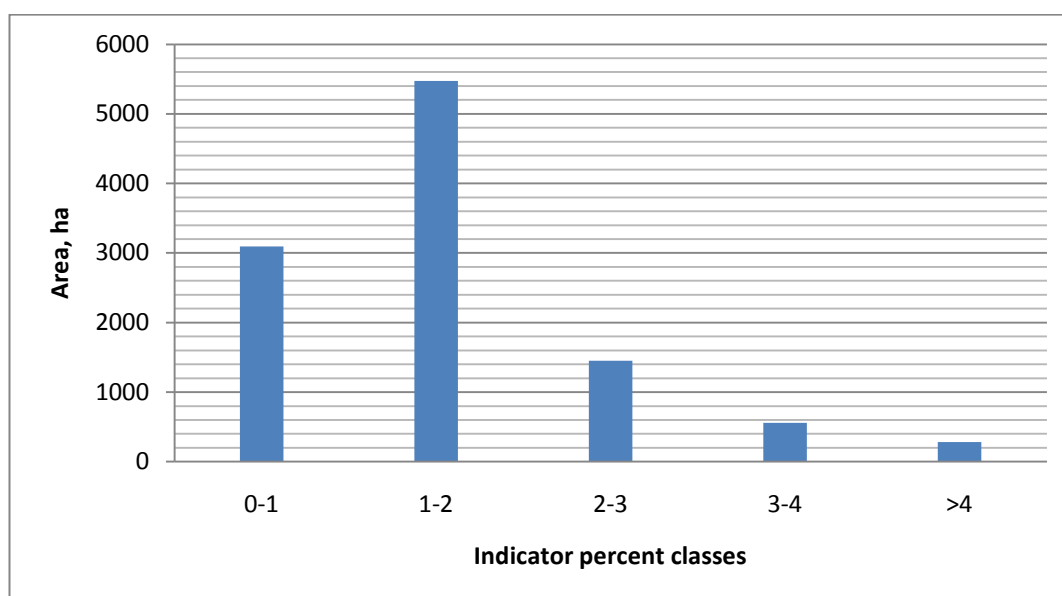


Figure 5 – Area distribution of classes of indicator percent in year 1 of the planning period for all potential clear cut stands

In the suggested plan the annual harvested volumes are close to the calculated annual allowable cut of 30824 (table 9). The years selected for comparison have on average the same harvest level. Harvested area in suggested plan is smaller than in actual company's clear cuts and mean volume in average is 6.9 cubic meters higher.

Table 9 – Annual harvested area, annual harvested volumes and mean volume of harvested area in the suggested plan and what the forest company has actually harvested, yellow color shows years that were compared, red color shows years that were excluded from comparison

Year	Plan			Company		
	Harvested area, ha	Harvested volume, m <sup>3</sup>	Mean volume of harvested area, m <sup>3</sup> /ha	Harvested area, ha	Harvested volume, m <sup>3</sup>	Mean volume of harvested area, m <sup>3</sup> /ha
1	140.5	30743.65	218.8			
2	139	30945.4	222.6			
3	134	30846.2	230.2			
4	152	30790.8	202.6	121	28906.4	238.9
5	180	30760.5	170.9	59	12976.5	219.9
6	117	30752	262.8	166.7	33140.1	198.8
7	136	30796.7	226.4	138	29845.6	216.3
8	134	30768.4	229.6	81	18670.4	230.5
9	153	30668	200.4	207	46572.3	225
10	187	30747	164.4	291	63882	219.5
Average	138.2	30788.9	222.8	141.9	30630.7	215.9

Figure 6 shows species distribution on harvested area. In the suggested plan, mainly mix stands dominated by spruce would be harvested. Pure spruce stands would be cut in year 7 of the suggested plan.

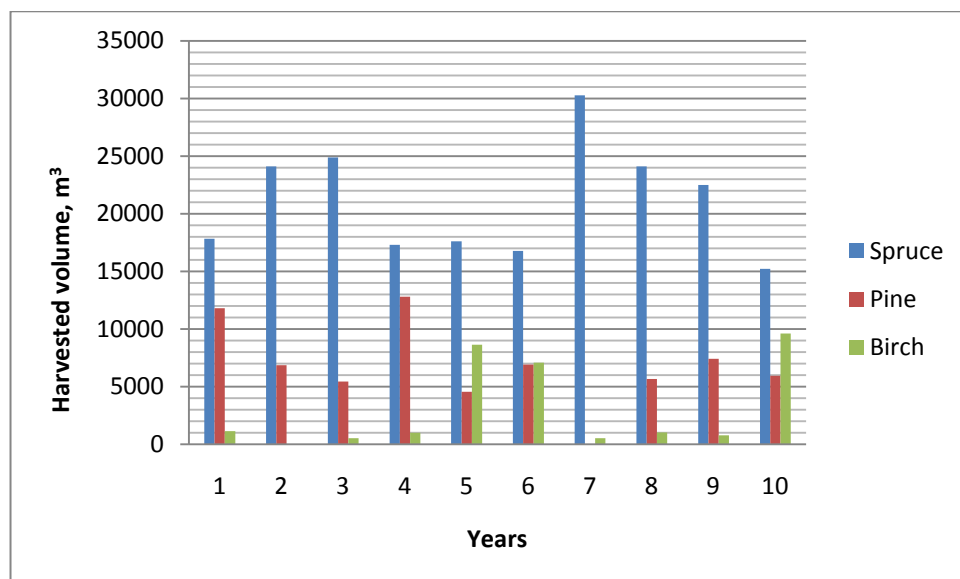


Figure 6 – Species distribution over the area which was going to be harvested according to the suggested plan

For comparison of average indicator percent was taken 8 years of suggested plan and 3 years of clear cuts made by company (table 10). Average indicator percent in suggested plan is 0.83% and for territory which was actually harvested by company it is 0.92%. Difference between them is small, it means that company was choosing right stands for making clear cuts, but still they can improve methods of choosing it.

Table 10 – Average indicator percent in the suggested plan and for the stands that the forest company has actually harvested, yellow color indicates years that were compared, red color shows years that were excluded from comparison

Year	Plan	Company
1	0.82	
2	0.79	
3	0.73	
4	0.85	0.81
5	1.08	0.77
6	0.93	1.07
7	0.83	0.89
8	0.76	0.77
9	0.92	1.03
10	1.3	0.79
Average	0.83	0.92

Figure 7 shows indicator percent distribution per area percentage. The main difference is that in indicator percent class 0.75-1, bigger area would be cut in the suggested plan than in actual clear cuts made by the company, and the company has more area in indicator percent class 1-1.25.

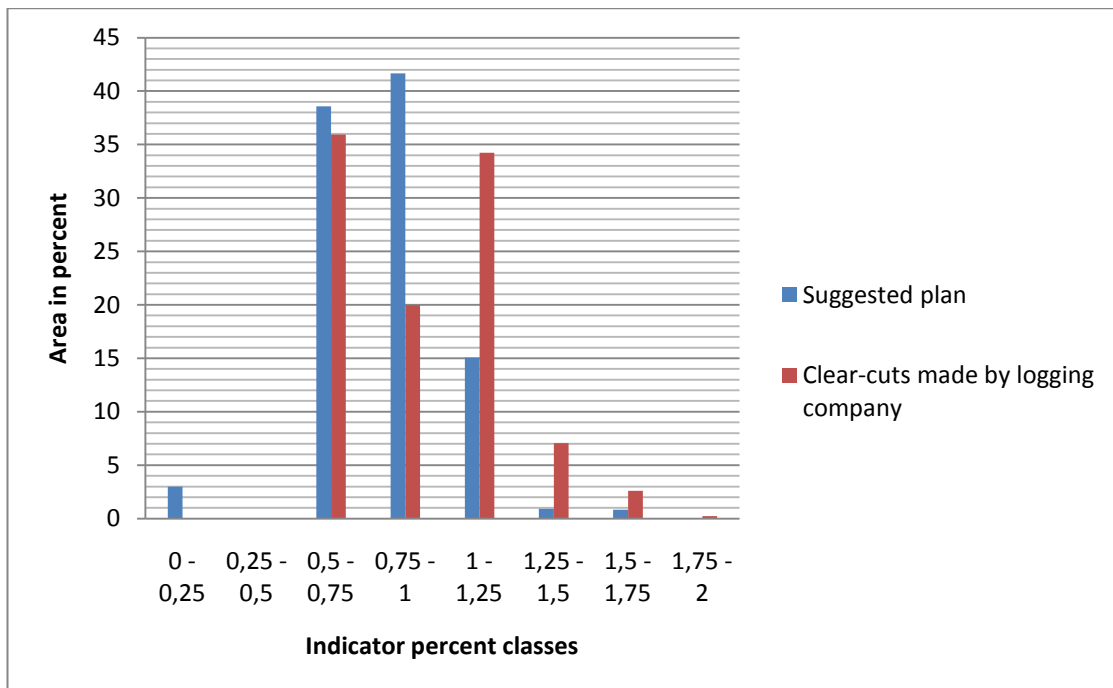


Figure 7 – Indicator percent classes per area in percent from all clear cut area (data for the suggested plan is taken from 8 years of comparison, and for actual clear cuts made by the company - for 3 years of comparison)

The next step was to compare the net value of the suggested plan and the net value of the company (table 11). Average net value in the suggested plan is higher by 600 thousand RUR. Average net value for the suggested plan is 26.3 m. RUR and the average net value from clear cuts made by the logging company is 25.6 m. RUR.

Table 11 – Net values in the suggested plan and for the stands that the forest company has actually harvested, yellow color indicates years that were compared, red color shows years that were excluded from comparison

Year	Plan, mln RUR	Company, mln. RUR
1	26.7	
2	26.0	
3	26.9	
4	26.5	25.1
5	23.6	11,5
6	27.4	26.7
7	24.8	24.9
8	26.6	16.1
9	24.9	39.1
10	22.5	52.8
Average	26.2	25.6

To make comparison of the net value of one cubic meter, only the years 5 and 10 there were excluded because the company was not doing any clear cuts on this territory (block 1). Therefore, 8 years of the suggested plan and 5 years of the activities of the company were compared (table 12). The average net value of one cubic meter in the suggested plan is higher by 9 RUR, and in the suggested plan the average net value of one cubic meter is 851,2 RUR, and the average net value of one cubic meter in the company is 842,2 RUR.

Table 12 – Net values from cubic meter of merchantable timber in the suggested plan and for the stands that the forest company has actually harvested, yellow color indicates years that were compared, red color shows years that were excluded from comparison

Year	Plan	Company
1	866.9	
2	840.2	
3	873.1	
4	859.5	868.5
5	765.9	885.8
6	889.6	807.1
7	804.4	834.2
8	865.1	861.7
9	811.0	839.6
10	732.2	826.2
Average	851.2	842.2

Figure 8 shows how the stands selected for clear-cutting were allocated in the 5 different blocks and in which year each block was harvested. Each color shows different year of making clear-cut. All stands were selected by giving the highest priority to the stands with low indicator percent and easy road access.

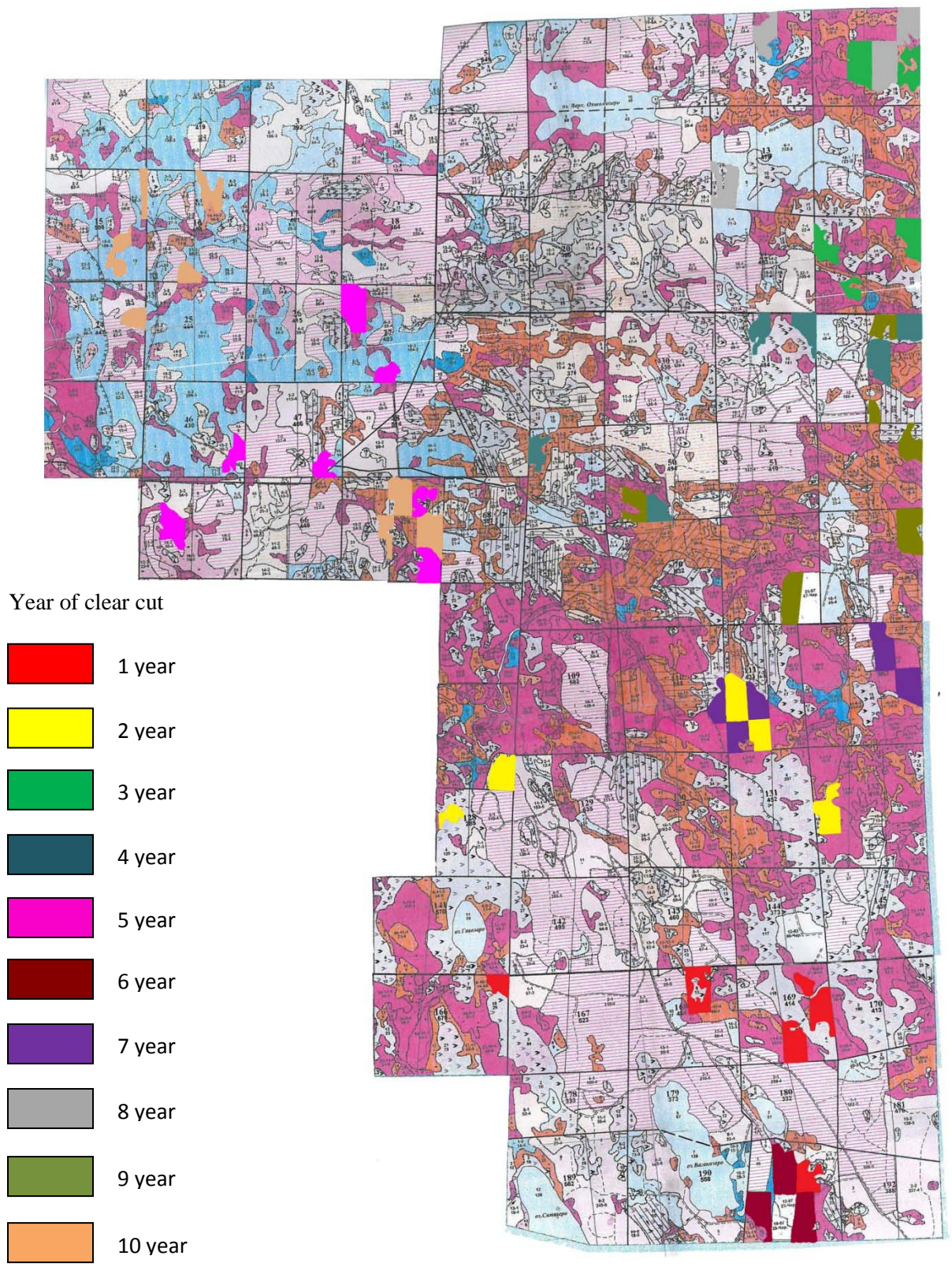


Figure 8 – Map with allocation of clear cuts in the suggested plan

## 4. DISCUSSION

The idea of this study was to try to use indicator percent in Russian conditions. The results of this study show that it is possible. Comparison of indicator percent showed that the difference between the suggested plan and the clear cuts made by the company is quite small. There are several reasons for that. The first and the main one is that if we look at figure 5, it is easy to see that the major part of the stands has quite low indicator percent, 8500 ha out of 10747ha have indicator percent less than 2%, it means that the logging company was cutting stands with low indicator percent because there were no other stands to cut, only the stands with low indicator percent. The second reason is that when the logging company is given some recommendations, from the state planning company, they look at the growing stock volume, and choose the stands with a high stock volume for clear cuts. It means that if the growing stock volume is high, the net value is likely to be high and indicator percent probably will be low. The third reason for a small difference could be that lots of stands are very old, and it is easy to see that from figure 3. From figure 3 it is visible that in the suggested plan, the major part of the stands have indicator percent between 0.5 and 1%, but at the clear cuts made by the company it is from 0.5 to 1.25, that is why there is a difference in the results.

Species that would be cut according to the suggested plan are mainly spruce and pine. Those species are the most important for Karelian pulp-and-paper mills and for sawmills as well. If we compare it with the species that the company cut, the result will be absolutely the same, because the company cuts spruce and pine.

If we look at the results from the point of the stands that were not clear cut, it is possible to say that the value growth there is a bit higher in the suggested plan, because the stands with higher indicator percent were left. But it is also necessary to say that some of the stands have quite high indicator percent, but the value growth is low. It is because of a very low growing stock volume (less than 100 m<sup>3</sup>/ha). Those stands were not cut because costs are higher than the income. If we look at them from the angle of a private forest owner and use Faustmann formula, it could be that it is necessary to cut them, because in the future they can give income, but in Russia there is no private forestry, so the logging company is not using this land and not cutting it, because it will not give any benefit.

The net value per cubic meter is higher in the suggested plan. It is possible to explain why it is higher, i.e. because harvesting costs in the suggested plan are lower. The stands that were chosen have very low indicator percent, but it is necessary to say that indicator percent depends on costs too, if costs are less the net value per cubic meter is higher and indicator percent is lower. Costs can be lower because of tree sizes. Average annual area of clear cuts in the suggested plan is lower by 3.7 hectares, but the average growing stock volume is higher by 6.9 m<sup>3</sup>/ha (table 9). It means that trees in the suggested plan probably have bigger diameters and because of that the time consumption for machines is less, and costs are less too. And it is the reason why the net value per cubic meter is higher in the suggested plan.

The results that were received can be affected by several factors: price, simplification in the calculation of indicator percent, data transformation, simulation software, Swedish functions for calculating productivity etc. Timber price significantly depends on the type of assortment produced, price for pulpwood could be half of the price for sawn timber; in this case it was necessary to find the best solution which price to use. Finally in this work the average price from all kinds of assortments was used. The use of the average price did not affect calculations

seriously, because for fair comparison the average price was taken for calculating net values from both the suggested plan and clear cuts made by the company. Therefore, if we use another price, there will still be the same difference in results. But it will be true only if the same type of stands was harvested. If stands will be different (species, age, site index etc.) the price can affect the level of indicator percent (because bigger logs from old stands will have higher price and higher net value, and younger stands will have smaller logs and smaller price, but higher value growth). But as it is shown in figure 3, majority of the stands are very old; thus, the constant average price would not seriously affect the results.

The calculation of indicator percent was simplified, because in Russia there is no private forestry and logging companies are paying forest rent. The rent period is quite short, only 49 years, it means that recently clear-cut forest stand will be immature and not ready for clear-cut again during rent period according to Russian logging rules. For state as forest owner it can be possible to calculate land value, but in this work I was looking how private logging companies can introduce indicator percent in planning. For them there is no point to look on land value, because they can't use it for their own needs. This simplification haven't seriously affect the results, because in the study area site index is quite low. It means, that if land value is calculated it will be quite low. So it wouldn't seriously affect my results.

Three variables were transformed during this study. First of all, the relative basal area was transformed into basal area. There was no problem with this transformation, and according to the forest companies that sometimes do the same transformation for their own needs, there should not be any mistake, and transformation was done well. Then the number of trees per hectare was calculated, and there should not be any problems either, because variables for this calculation were diameter and basal area, so the mistake in these calculations should be small. The biggest question is how well the transformation from site productivity classes to site index was done. In the data received the average height was given, and the dominant height is used for site index. Thus, a mistake was possible in defining the site index, and it can affect calculations for the indicator percent. If the site index is overestimated, the indicator percent will probably be higher than in reality, because it will show that stands can grow better and the value growth will be higher. If the site index is underestimated, the indicator percent will be lower than in reality, because the site index will show worse conditions for stand development and probably the value growth will be lower. In the study area, the majority of the stands are old, and almost all trees in one stratum have the same height, so the average height does not significantly differ from the dominant height. It means that even if there is a mistake, it will not affect the results significantly, because it will be small.

The next thing, which can affect the results is computer software. Akaykin (2009) was making a study about using ProdMod in northwest Russia, and his study showed that it was possible to use it, and simulation does not make big mistake. In this case this program was possible to use for this study too. The average volume increment in Karelia is 1.3-1.5 cubic meters per hectare, and the simulation gives the same result, around 1.4 cubic meters per hectare in most stands. It differs for some stands in both ways (can be more than the average or less), depending on the site index, age, tree species composition and number of trees per hectare.

For calculating productivity Swedish formulas (Carlsson, 2008) were used based on regression analysis. It was possible that this also affects the results in terms of making mistakes for cost calculation. In this case the results of calculation of productivity were compared with the results that were received by Gerasimov et al. (2008). It was shown that in average productivities that were calculated and average productivity for northwest Russia were similar, and the difference was very small. For the system of machines (harvester + forwarder) productivity in Gerasimov's study is  $46 \pm 15$  m<sup>3</sup>/shift, and calculated productivities are in the range between 25 and 70

m<sup>3</sup>/shift. It means that there was no significant mistake, and application of Swedish formulas for calculating the productivity did not affect the results seriously.

Nowadays, when market economy is developing very fast in the Russian Federation, people and companies are more interested in using their resources in a rational way. Thus, according to the new relationship between logging companies and the state, the use of indicator percent can be very interesting for both sides (to manage forests more efficiency). The results of this study showed that this way of setting priorities for clear cuts can be used in Russia. Traditionally planning based on indicator percent and financial maturity has been associated with private forestry (Moiseev, 2006). Therefore, its implementation in Russia could be quite difficult. But after the new forest code was adopted in Russia, the relationships between the state and private companies have changed. The new Russian Forest code is making the first step for private forestry in Russia, and now logging companies are responsible for all treatments in forests, not only for logging. If a logging company is interested in renting forest for a long time it should manage it properly and effectively. And in this case this study can be useful to make the right planning of areas for clear cuts. In Russia, indicator percent cannot be used for defining maturity of the stand because of the legislation, which envisages other methods for defining maturity (quality maturity based on stand age). But instead of the classical use of indicator percent for defining financial maturity it can be used for prioritization among stands.

Introduction of indicator percent in Russia will be very difficult. There are several challenges for it: tradition, legislation, data availability, and suitable growth simulation programs. The first and the main one is the issue of tradition. For a long time, Russia had planned economy, but planning based on indicator percent does not fit that. Forestry has traditionally been conservative; therefore, introduction of indicator percent can be very problematic because of mentality of people.

The second challenge is legislation. The longest planning horizon in Russian forestry is 10 years, and this plan is not a plan of the company, but it is a plan from the state for developing the whole forest sector, and in this case it is very hard for companies to develop their own plans, because they should follow the plan, which was suggested from the state.

After the Soviet Union collapsed, forestry has not received enough money and because of that forest inventory has not been systematic. For doing the right planning it is necessary to have a good database, but it is not so good, because in many places there has been no forest inventory for more than 10 years. But for making right forecast about stand development it is necessary to have systematical forest inventory. Especially for using indicator percent it is necessary to know volume increment and this data can be received and calculated if there is good forest inventory. There should also be special market research for forecasting timber prices, but nobody is doing it now. Thus, the lack of this data will create serious problems for introducing indicator percent in Russia.

Growth simulation software is not used on a wide scale, and lots of companies make plans not based on the future development of stands, but only on the grounds of the data that they have at the moment. These programs should be developed, but it is very hard to do it, because lots of data is needed for making a good simulator, and as I said above, there is lack of data from forest inventory.

The way of planning based on indicator percent suits market economy well. As far as it develops in Russia fast, logging companies will be interested in using it in the future. The issue of people's mentality will be solved with time, and other problems can also be solved. The new



forest legislation is slowly moving towards private forestry in Russia, and indicator percent can be used on a wide scale, because problems with data and software can be solved.

This study showed that this type of planning gives good economic results and it can be used with all Russian rules and restrictions for clear cuts, but more research is required on this topic, i.e. in other areas with the stands that are not so old. It will help to understand how well forest companies are planning, and if they can improve their plans with it.

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## APPENDIX

Table - Clearcuts of the suggested plan for 10 years in 5 blocks

№ District	№ Stratum	Area	Growing stock volume	Net value per ha, mln. rub.	Net value per clearcut, mln. rub.	ip%	Area of clearcut	Cut volume per clearcut	Year of cut	Block №
166	9	12	201.4	0.16	1.89	0.94	12	2416.8	1	5
168	5	48.7	241.1	0.22	7.60	0.54	34.5	8317.95	1	5
168	7	27	221.5	0.19	0.28	0.85	1.5	332.25	1	5
168	11	12	201.7	0.17	0.26	1.06	1.5	302.55	1	5
169	6	5	191	0.17	0.84	0.64	5	955	1	5
169	7	7	201.5	0.16	0.98	0.98	6	1209	1	5
169	8	3	221.6	0.17	0.52	0.97	3	664.8	1	5
169	11	101	191.5	0.16	6.33	0.99	39	7468.5	1	5
169	12	12	151.4	0.12	1.16	1.28	10	1514	1	5
191	8	9	291.6	0.28	2.22	0.63	8	2332.8	1	5
191	13	90	261.5	0.23	4.57	0.70	20	5230	1	5
108	33	33	220.6	0.20	6.76	0.16	33	7279.8	2	4
111	13	156	212.8	0.17	11.01	0.89	66	14044.8	2	4
128	2	5	222.4	0.20	0.98	0.66	5	1112	2	4
128	3	9	192.4	0.16	0.98	0.79	6	1154.4	2	4
132	15	93	253.6	0.22	6.27	0.90	29	7354.4	2	4
9	7	131	233.9	0.20	15.32	0.68	75	17542.5	3	2
23	3	29	233.9	0.21	5.43	0.67	26	6081.4	3	2
23	4	23	225.1	0.20	4.52	0.93	23	5177.3	3	2
23	17	10	204.5	0.17	1.65	0.97	10	2045	3	2
31	6	43	225.6	0.19	7.38	0.77	38	8572.8	4	3
31	7	8	184.8	0.16	0.94	0.82	6	1108.8	4	3
32	6	43	254.8	0.23	5.38	0.56	23	5860.4	4	3
32	7	3	184.8	0.14	0.43	0.88	3	554.4	4	3
32	10	17	235.6	0.21	1.91	0.71	9	2120.4	4	3
32	13	35	244.4	0.23	4.23	0.53	19	4643.6	4	3
32	17	6	143.6	0.12	0.71	0.82	6	861.6	4	3
32	18	15.5	114.4	0.07	0.66	1.57	9	1029.6	4	3
49	3	17	154.4	0.13	2.16	0.93	17	2624.8	4	3
50	17	50	155.2	0.12	2.60	1.17	22	3414.4	4	3
27	1	69	166	0.13	6.03	0.97	46	7636	5	1
27	11	17	166.5	0.11	1.67	1.21	15	2497.5	5	1
46	16	19	168	0.12	2.34	1.36	19	3192	5	1
47	14	17	134.5	0.10	1.72	0.94	17	2286.5	5	1
65	11	58	167	0.12	4.48	1.18	36	6012	5	1
67	9	19	177	0.14	2.23	1.07	16	2832	5	1
67	28	24	227	0.20	1.76	0.78	9	2043	5	1

Continuation of table – Clearcuts of suggested plan for 10 years in 5 blocks

№ District	№ Stratum	Area	Growing stock volume	Net value per ha, mln. rub.	Net value per clearcut, mln. rub.	ip%	Area of clearcut	Cut volume per clearcut	Year of cut	Block №
67	31	16	187.5	0.14	2.1	1.13	15	2812.5	5	1
67	32	7	207	0.17	1.22	0.86	7	1449	5	1
191	3	10	229.6	0.20	1.21	0.85	6	1377.6	6	5
191	7	25	298	0.27	4.34	1.19	16	4768	6	5
191	8	9	299.6	0.29	0.29	0.61	1	299.6	6	5
191	11	34	240.2	0.22	7.32	0.85	34	8166.8	6	5
191	13	90	269	0.24	14.20	0.68	60	16140	6	5
110	22	31	229.1	0.19	4.35	0.73	23	5269.3	7	4
111	13	156	219.8	0.17	7.67	0.85	44	9671.2	7	4
112	7	128	229.8	0.18	12.75	0.8	69	15856.2	7	4
8	6	65	239.6	0.21	6.81	0.61	32	7667.2	8	2
9	7	198	240.4	0.21	11.41	0.66	54	12981.6	8	2
9	10	14	260.4	0.25	1.23	0.58	5	1302	8	2
9	12	9	171.2	0.13	1.02	1.15	8	1369.6	8	2
13	13	35	212.8	0.18	6.15	0.97	35	7448	8	2
32	6	43	260.8	0.24	4.81	0.54	20	5216	9	3
32	27	7	242.6	0.22	1.54	0.69	7	1698.2	9	3
50	17	50	161.7	0.13	3.00	1.1	24	3880.8	9	3
52	7	27	172.6	0.13	2.68	1.11	20	3452	9	3
71	19	51	215.3	0.17	6.40	1.04	37	7966.1	9	3
72	4	9	211.7	0.18	1.26	0.78	7	1481.9	9	3
72	10	61	183.5	0.14	5.19	1.16	38	6973	9	3
15	9	16	221	0.18	2.34	1.23	13	2873	10	1
15	17	35	176	0.13	3.20	1.26	24	4224	10	1
16	5	19	175	0.13	2.49	1.2	19	3325	10	1
16	24	16	142	0.10	1.55	1.22	15	2130	10	1
24	17	17	173	0.13	2.169	1.06	17	2941	10	1
67	5	6	118	0.09	0.51	0.99	6	708	10	1
67	8	116	155	0.11	6.86	1.45	64	9920	10	1
67	9	19	184	0.15	0.59	1.01	4	736	10	1
67	17	23	154	0.11	1.28	1.37	12	1848	10	1
67	20	5	236	0.20	0.82	0.84	4	944	10	1
67	21	9	122	0.08	0.70	1.6	9	1098	10	1