Long Rotation Forestry in Boreal Ecosystems of Russia: Special Conditions for Forest Management Planning and Design

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Boreal forest belt and extent.

- The boreal forest is the largest continuous land ecosystem in the world, covering about 14 per cent of the earth´s vegetated surface.
- It forms a "green belt" of various width on the northern hemisphere stretching through Russia, Alaska, Canada and Scandinavia, roughly between latitude 45 and 70° N.
- The total area of the boreal forest is about 1.6 billion hectares or about 38 per cent of global forest area.
- The largest part by far of the boreal forest is in Russia.
- Main part of Russian forests are boreal (88%)

Boreal forest belt and extent - 1.

- Boreal forest mainly located in Russia, Canada, Finland, Sweden and USA.
- Share of boreal forest varies from 100% in Iceland, 98% in Finland to 13% in the UK and 8% in China.
- Countries having boreal forest account for 30% of world population, possess about 42% of world standing timber volume and produce and consume about 60% of world industrial round wood.
- Short rotation forestry systems usually are used to grew a specific crops, long rotation forestry systems provide a multitude of timber and non-timber products.

Example of Boreal forest – Scots pine parcel within swamp

Example of Boreal forest – Conifer forest on rocky soils

Example of Boreal forest – Mixed forest on rich soils

Peculiarities of boreal forest resources use and regeneration

Forest resources use and regeneration in Boreal zone have two very particular features:

1. Time feature – long period of time needs for forest regeneration
2. Spatial feature – growing stock distribution over the large unpopulated areas without places of birth as, for example, oil or gas

Long period of time for regeneration and high cuttings ages

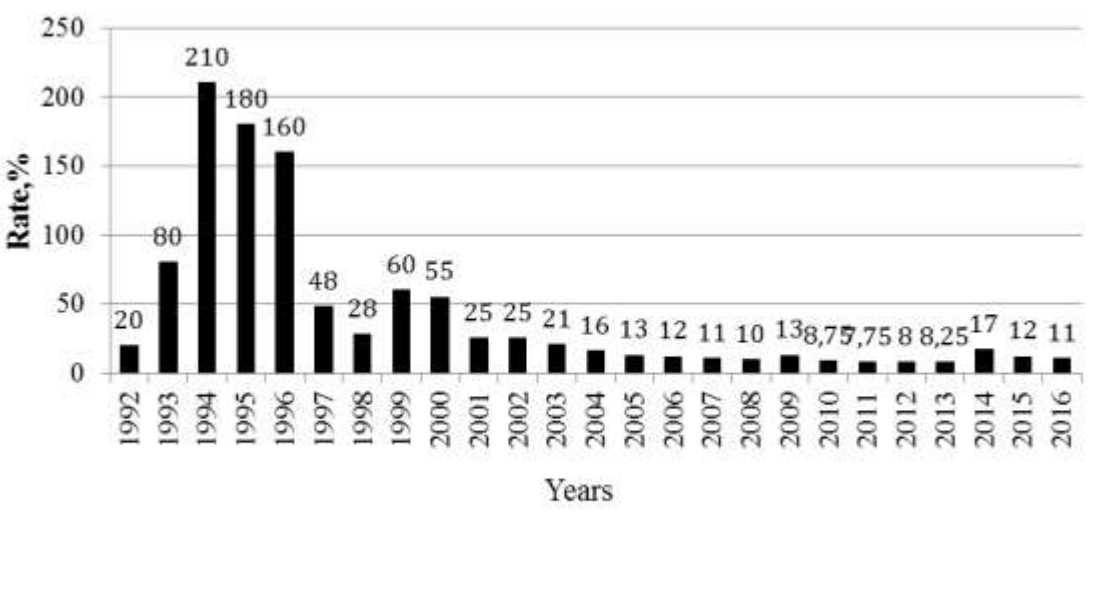
- Recommended cutting ages depends on forest region, species, growth class and forest category:

Forest region	Tree species	Growth class	Forest category	
			Protective	Exploitable
Middle taiga of European part of Russia	Scots pine, Norway spruce	IV and higher	121-140	101-120
		V and lower	141-160	121-140
	Cedar pine	All classes	241-280	201-240
	Birch	All classes	71-80	61-70
	Aspen	All classes	51-60	51-60

Long rotation period and problems of management planning

- For forest management planning the consequences are in limited possibility to use regular economics methods and categories of business planning.
- Now really absent even theory of economic planning for periods of time of 80-100 years and more.
- During such a long periods of time may be sharp social, economic and technological changes

Fluctuation of the rate of refinancing of the Russian central bank during 25 years period 1992-2016



- Mean rate of refinancing for this period is 42.4%, max – 210, min – 7.75 standard deviation – 56.7 and coefficient of variation – 74.8

Time value of money, discount losses and "damnation" of discounting

- Formula of complex percent describes the elevation of money value in time:

a_0 – initial value

r – rate of discount

a_1 - value after 1 period of time (year)

$a_1 = a_0(1+ r)$

a_t – value after t periods

$a_t = a_0(1+ r)^t$ or $a_0 = a_t/(1+r)^t$

Time value of money, discount losses and "damnation" of discounting - 1

- Calculation according complex percent formula: let a_t=1, r=0.12 (12%), t=100 years, then $a_0 = 1.2*10^{-5}$
- For example 1 000 000 RUR after 100 years is equivalent 12 RUR now
- In other words in order to receive income of 1000 000 RUR after 100 years it is reasonable now invest no more than 12 RUR.

Time value of money, discount losses and “damnation” of discounting - 2

- “Damnation” of discounting provides fast cheapening future values and make it unreasonable to invest for long periods of time and therefore facilitate exhaustible use of any natural resources including forest.
- Especially fast cheapening take place under high rates of discount (r) which is characteristic for countries with economies in transition and high level of inflation.
- Demonstrated dramatic fluctuations in r make it virtually impossible to obtain some reasonable decision based on the NPV approach.
- Forest management plans can’t be changed each year according discounting rate variability.
- The above facts prevent investments in forestry operations and calls for "extra-long money".

LRF problems

- First problem needed to be resolve for LRF is how to combine annual variability of economic environment with long term sustainable use of forest resources for provision of economic, ecological and social values and services.
- Second problem is to find the source for extra-long money for investments in forestry operations on 100 years and more.
- We suggest two stage planning approach based on sustainability principles and forest rent:

1. Long-term planning on rotation period
2. Annual planning of wood harvest on allowable level and accumulation of forest rent.

Sustainability principles for LRF

- There is two main principles of sustainable forest management:

1. Principle of inexhaustibility
2. Principle of permanent (continuous) use

Principles background

- Principle of inexhaustibility make it possible to use forest resources in the future. We don't know how forest resources will be used after 100 years in the future but we have to offer a possibility of use them for future generations.
- According to this principle each planning period may be harvested only mature and over mature tree stands.
- Maturity age should guarantee provision of ecological and social values and services some of which haven't market price.
- Principle of permanent use suppose keeping at least the same in time the quantity of forest resources use.

Optional optimization model of forest resources use on rotation period based on principles of inexhaustibility and continuity - notations

x_1, x_2…x_n – harvested areas for each planning period – have to be determined

S_0 – area of mature and over mature tree stands at the beginning of planning period

S_1 – area of tree stands of age 1 age class before mature

……

S_n – area of tree stands of age n age class before mature

r – transition coefficient between nearest age classes

Optimization model of forest resources use on rotation period based on principles of inexhaustibility and continuity

$$\sum_{j=1}^{n} x_j \Rightarrow \max$$

$$\begin{cases} x_1 \le S_0 + r \cdot S_1 \\ x_1 + x_2 \le S_0 + S_1 + r \cdot S_2 \\ x_1 + x_2 + x_3 \le S_0 + S_1 + S_2 + r \cdot S_3 \\ \vdots \\ x_1 + x_2 + \ldots + x_n \le S_0 + S_1 + \ldots + S_n \end{cases}$$

$$\begin{cases} x_1 \le x_2 \\ x_2 \le x_3 \\ \ldots\ldots\ldots . \\ x_{n-1} \le x_n \end{cases} \qquad x_1 \ge 0, x_2 \ge 0 \ldots x_n \ge 0$$

Second characteristic feature of forest resources use – spatial distribution

- Spatial distribution and cutting plots conditions variation in the forest over the area is a cause of forest rent
- Forest rent is the extra income which appears due to natural specific of forest resources
- There is two main kinds of differential rent

1. Rent due to good position regarding transportation network
2. Rent due to extra productivity of tree stands

Model for forest rent estimation-notations

x_i - harvested area on the plot of type i, ha;

N - number of plots, prescribed for harvesting for this year

a_i - growing stock on plot i, м3/ha;

S_i - plot i area, ha;

c_i - harvest and transportation cost for plot i, RUR/ha

p_i - price of wood on cutting plot i, RUR/м3;

$g_i = p_i \cdot a_i - c_i$ - income after forest use on 1 ha of plot i, RUR/ha,

b - allowable cutting volume, м3.

Model:
problem of linear programming

Direct

$$\sum_{i=1}^{N} g_i * x_i \to \max$$

$$\sum_{i=1}^{N} a_i * x_i \le b$$

$$0 \le x_i \le S_i, i = 1,...,N$$

Dual

$$w * b + \sum_{i=1}^{N} u_i * S_i \to \min$$

$$w * a_i + u_i \ge g_i, i = 1,...,N$$

$$w \ge 0$$

$$u_i \ge 0, i = 1,...,N.$$

Model: estimation of rent

Dual variables (shadow price of plot areas limitations) is estimation of forest plot rent:

$$u_i^* = g_i - \frac{g_n}{a_n} * a_i = \left(\frac{g_i}{a_i} - \frac{g_n}{a_n} \right) * a_i$$

g_n - min income after use 1 ha of worthiest plot *n*, RUR/ha,

a_n - growing stock on worthiest plot *n*, м3/ha

Model:estimation of the forest rent due to cutting plot location relatively transportation network

In this case in order to eliminate the influence on the rent plot productivity suppose equality of growing stocks on estimated and worthiest plots:

$$a_i = a_n = a$$

then

$$u_i^* = g_i - g_n = p_i \cdot a_i - c_i - p_n \cdot a_n + c_n = a \cdot (p_i - p_n) + (c_n - c_i).$$

Rent is equal to sum 2 components, first, wood quality difference estimate and, second, difference in harvesting and transportation cost between plots.

Model:estimation of the forest rent due to high cutting plot productivity

In this case in order to eliminate the influence on the rent plot location suppose the equality of harvesting and transportation costs on estimated and worthiest plots:

$$c_i = c_n = c$$

then

$$u_i^* = a_i \cdot (p_i - p_n) + c \cdot \left(\frac{a_i}{a_n} - 1 \right).$$

rent volume is equal sum of two components, first, difference in wood quality as earlier and, second, ratio of growing stocks on estimated and worthiest plots.

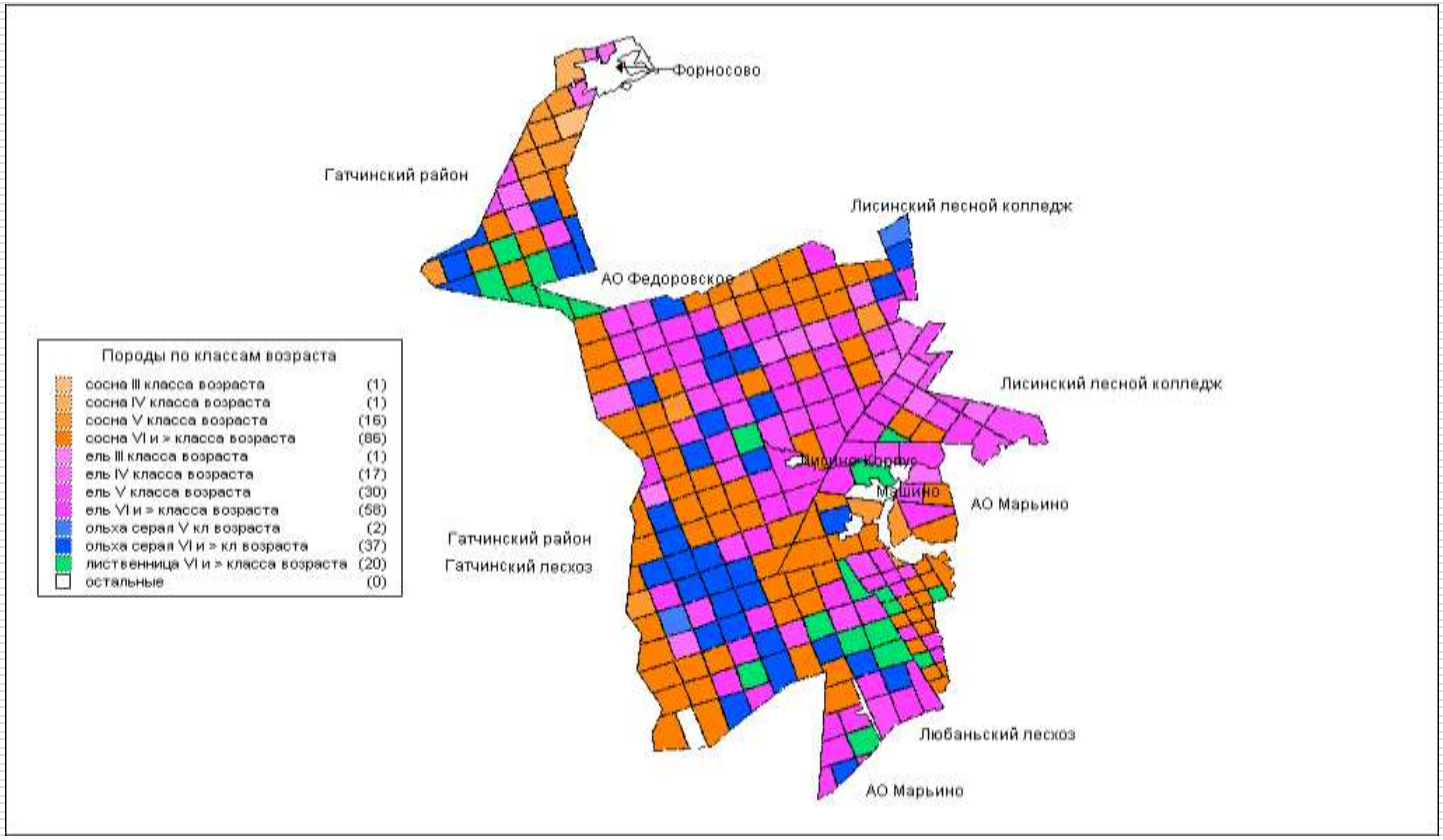
Main information layers of GIS needed for forest rent calculations

- Block and compartment borders
- Forest features
    1. Species composition
    2. Age structure
    3. Growing stock
    4. Wood quality class
- Settlements
- Road network
- Hydrographic network including rivers, streams, lakes, bogs etc.
- Relief

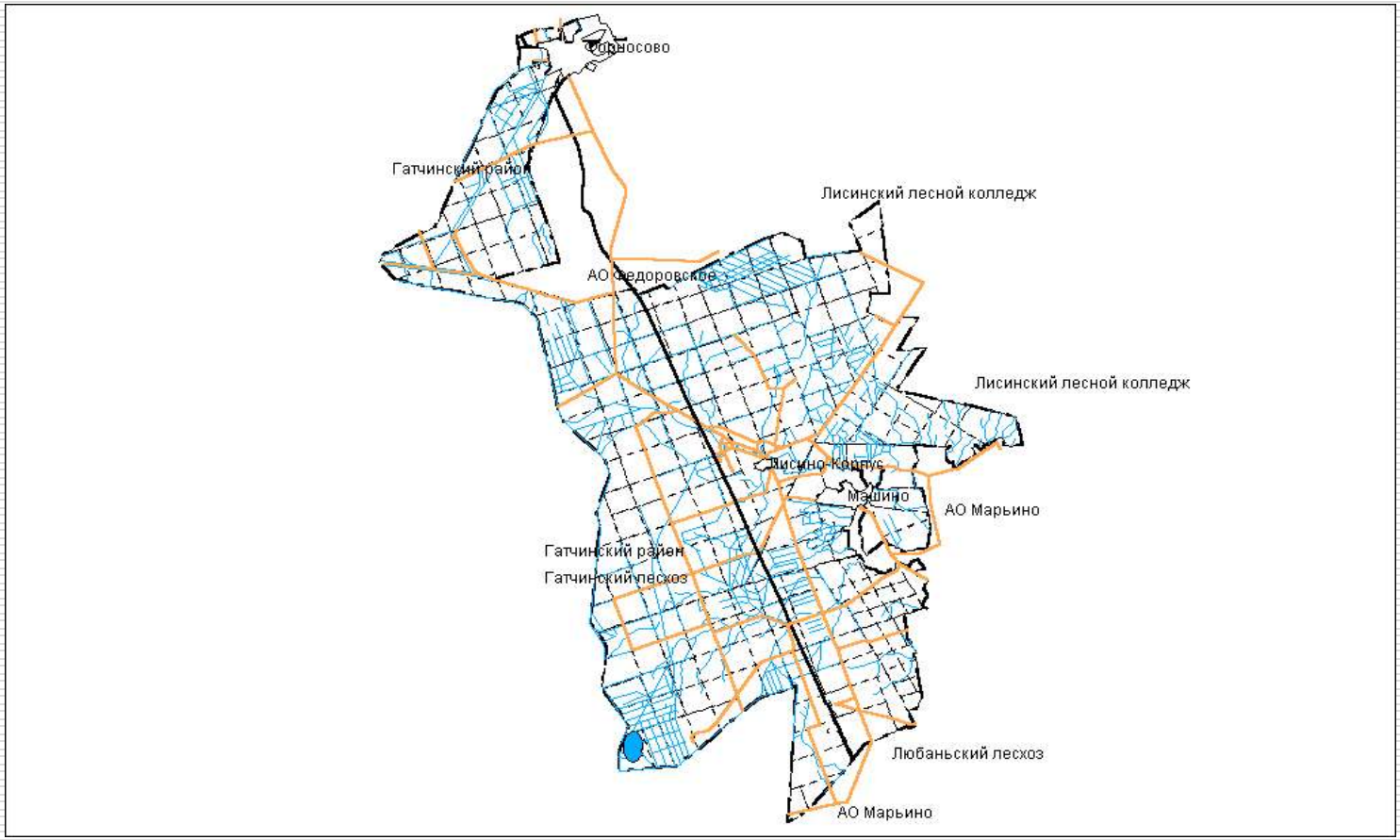
Main GIS facilities needed for rent estimations

- Distance calculations
- Area calculations

Sample map of blocks of Lisino training and experimental forest of FTU colored according to species and age



Map of hydro- and road network of Lisino training and experimental forest of FTA



Estimation of forest rent for Lisino training and experimental forest of FTU

№	**№** Of block	**№** Of plot	Distance, meters	GST (a_i), м^3/ha	Rent, RUR/ha
1	3	12	4330	360	1331.3
2	3	1	4698	340	1224.0
3	7	3	4523	310	1130.4
4	6	27	5098	300	1048.0
5	11	29	4743	290	1040.4
6	4	17	2393	240	1011.5
7	10	14	5148	290	1009.2
…	…	…	…	…	…
325	23	33	10285	190	405.8
326	38	28	12674	270	404.7
326	39	8	12683	270	404.0
327	28	2	11421	220	403.3
329	38	14	12490	260	402.4
330	37	29	12491	260	402.4
…	…	…	…	…	…
650	88	44	18120	340	15.9
651	85	36	17966	160	14.0
652	88	50	18171	250	8.3

Forest rent – main source of extra-long money needed for LRF

- Forest resources use cause the forest rent as a result of natural differences in position and productivity of harvested plots.
- Forest rent should be considered as a main source of income for covering of all kind of long term expenses related to forestry operations, forest regeneration and protection as well as cost for sustaining of ecological and social functions of forests which haven’t market price but needed in proper management.

Practical importance of the forest rent

Introduction of forest rent into forestry management practice allows:

- equalizing of economics environment for harvesting companies by extracting extra income
- uniform distribution of cutting plots over forest area
- prevent exhaustible use of good located and high productive forests

Thank you very much for your kind attention!