Геоинформационное моделирование и сценарный подход в системе поддержки принятия решений управления лесными ресурсами региона

Geoinformation modeling and scenario approach in the decision making support system of the forest management of a region.

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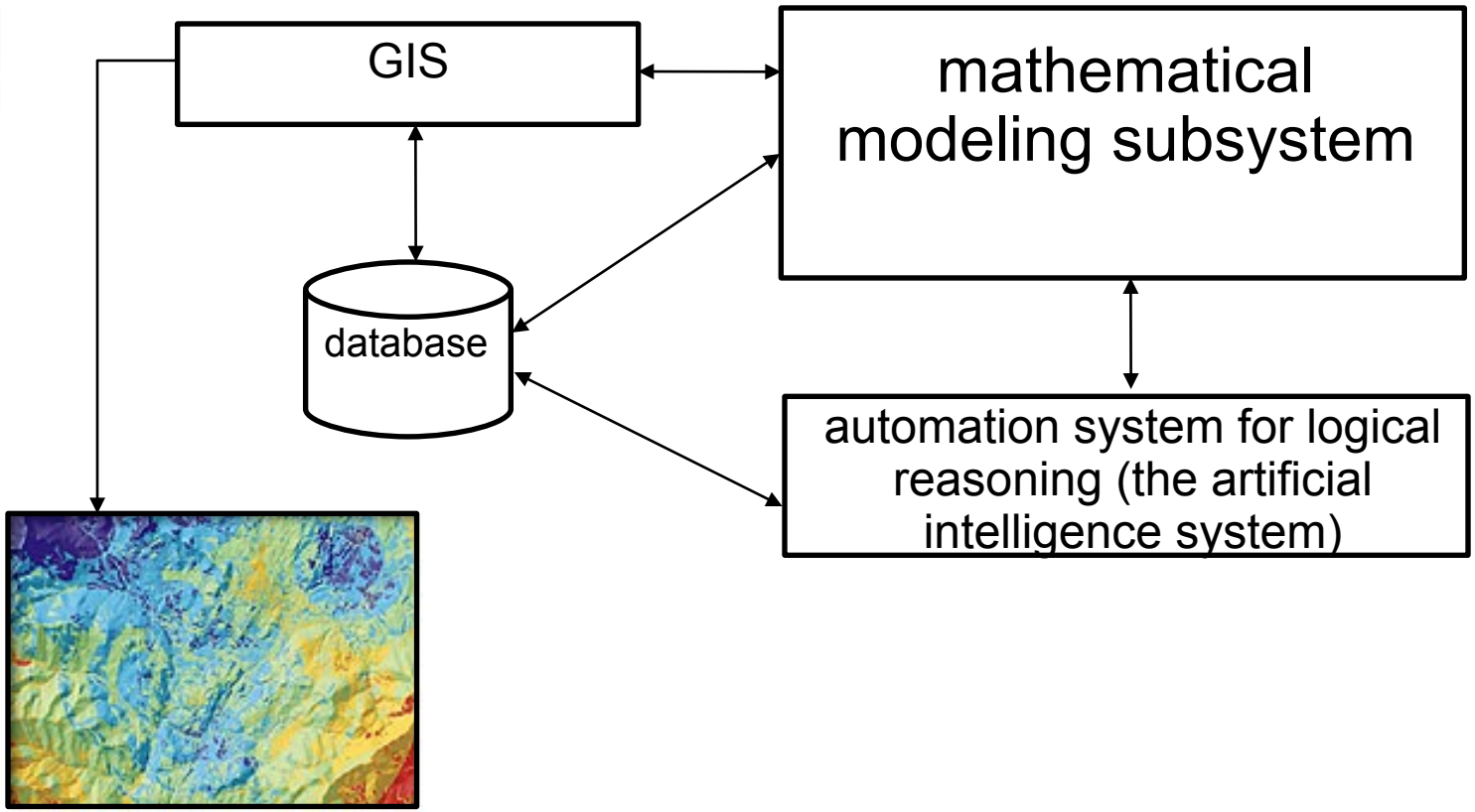
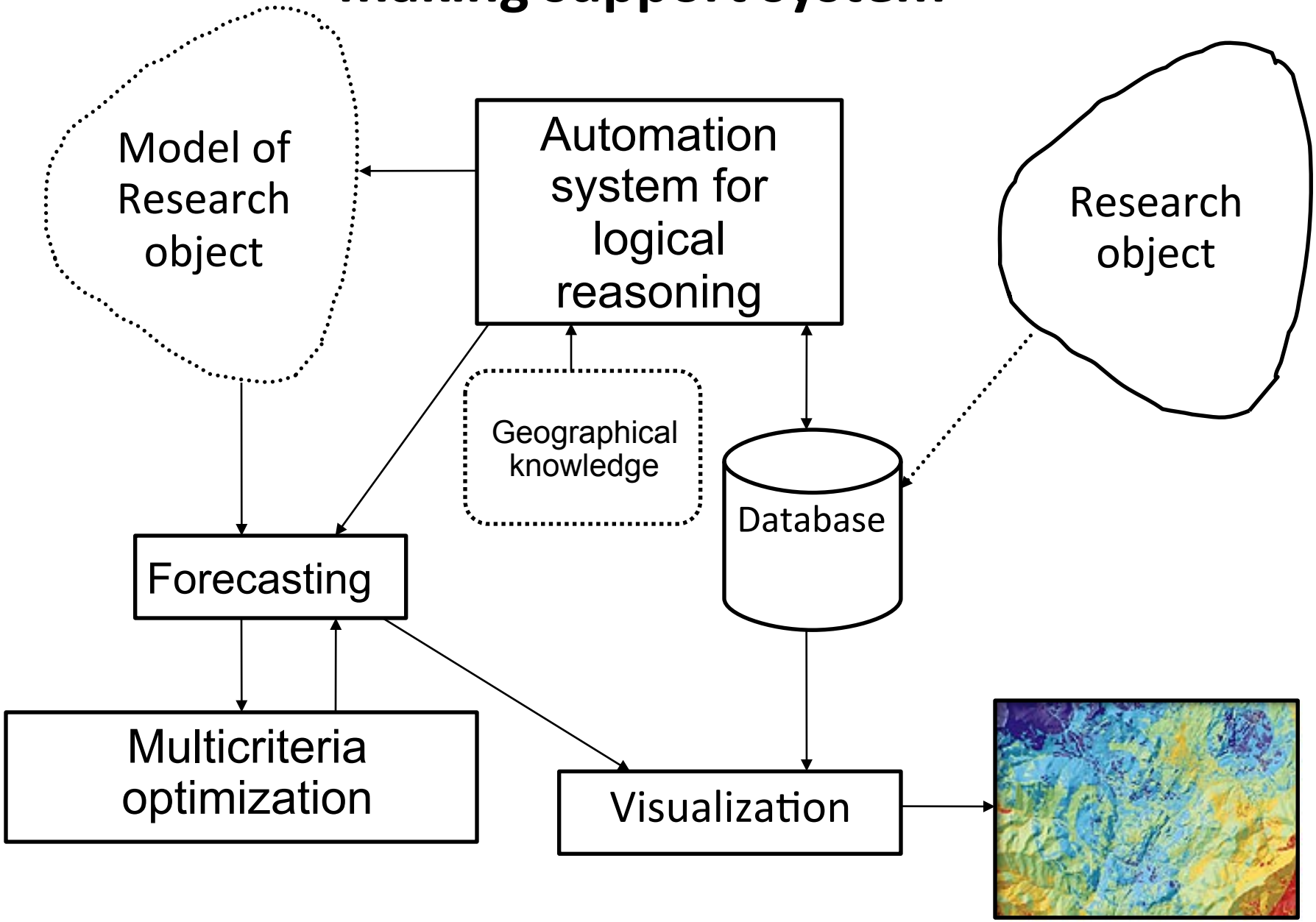
Intelligent information system

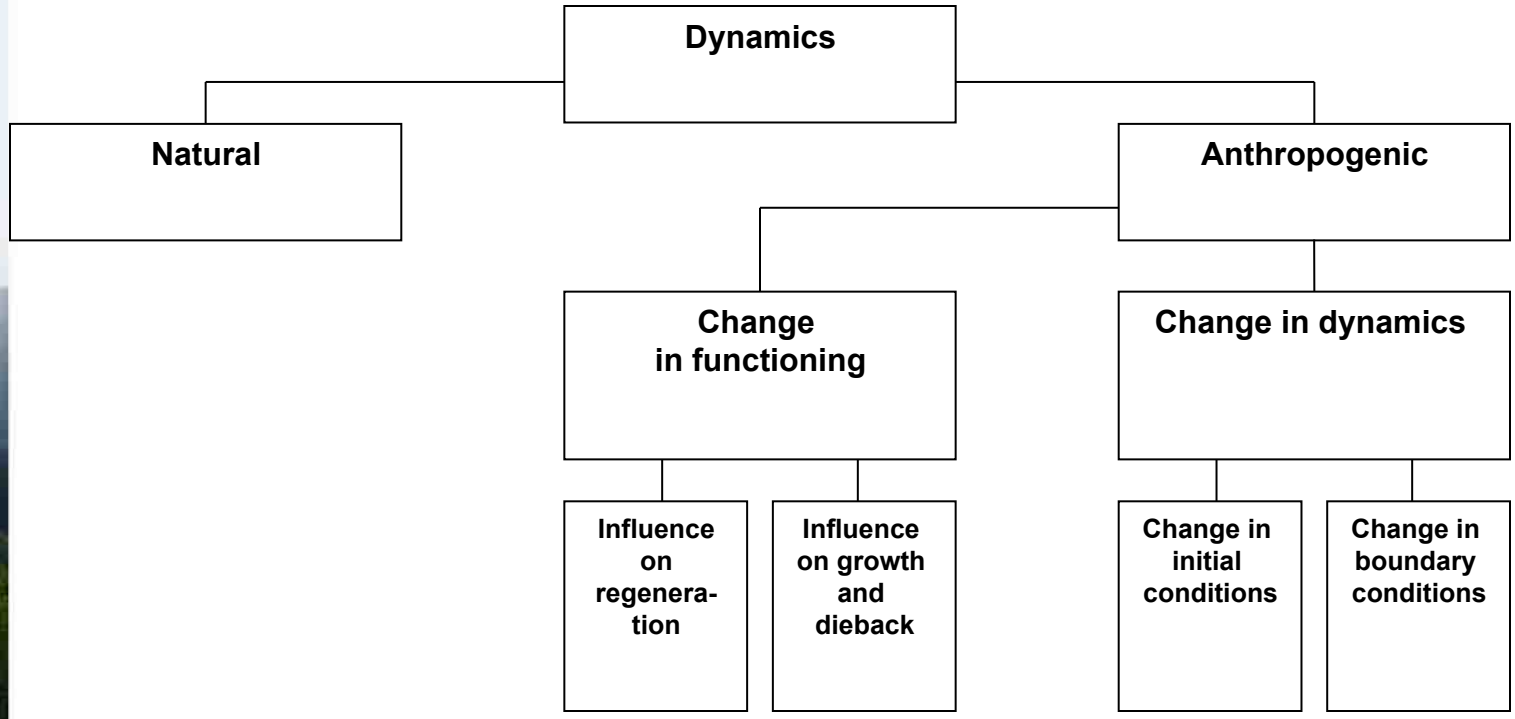
Decision making support system is a complex of three basic subsystems, namely, GIS, the mathematical modeling subsystem, and the logical reasoning automation system (artificial intelligence system).



The general scenario of the use of Decision making support system



Schematic of control actions on forest



The regional-level models

- The regional-level model uses the following variables: the total forestless area ($S_н$) of the territory; the total area uncovered in forest (S_{i0}); the area covered in forest, with the *i*-th species predominating, including in young forest of the first (S_{i1}) and the second (S_{i2}) age classes; and in average-aged forests (S_{i3}); maturing (S_{i4}), mature (S_{i5}) and overmature (S_{i6}) forest stands. These dependencies are all time-dependent.

$$dS_{Ki}/dt = -\lambda_{K1i}S_{Ki}(t) + u_{Ki}(t) + u_{KHi}(t) - u_{\Gamma Ki}(t)$$

$$dS_{i1}/dt = \lambda_{K1i}S_{Ki}(t) + \lambda_{01}p_{0i}S_0(t) - \lambda_{12i}S_{i1} - u_{Pi1}(t) - u_{Hi1}(t) - u_{\Gamma i2}(t)$$

$$dS_{i2}/dt = \lambda_{12i}S_{i1}(t) - \lambda_{23i}S_{i2}(t) - u_{Pi2}(t) - u_{Hi2}(t) - u_{\Gamma i2}(t)$$

$$dS_{i3}/dt = \lambda_{23i}S_{i2}(t) - \lambda_{34i}S_{i3}(t) - u_{Pi3}(t) - u_{Hi3}(t) - u_{\Gamma i3}(t) + I_i$$

$$dS_{i4}/dt = \lambda_{34i}S_{i3}(t) - \lambda_{45i}S_{i4}(t) - u_{Pi4}(t) - u_{Hi4}(t) - u_{\Gamma i4}(t)$$

$$dS_{i5}/dt = \lambda_{45i}S_{i4}(t) - \lambda_{56i}S_{i5}(t) - u_{Pi5}(t) - u_{Hi5}(t) - u_{\Gamma i5}(t)$$

$$dS_{i6}/dt = \lambda_{56i}S_{i5}(t) - u_{Pi6}(t) - u_{Hi6}(t) - u_{\Gamma i6}(t) - I_i$$

(11)

- where λ_{jKi} is the intensity coefficient of transition of the area from one (*j*) category of lands or a group of ages to the other (*K*) for forests, with the *i*-species predominating, or for a definite category of lands (without the index *i*); p_{0i} is the share of the areas uncovered in forest; $u_{pij}(t)$ is the annual logging area in forest stands of the *i*-th species of the *j*-th age group at time *t*; $u_H(t)$ is an increase in the forestless area in the course of capital construction through the other categories of lands (

The subregional-level models

- The subregional-level model reflects the dynamics of forest reserves of the forest raw-materials base according to land categories and age groups: the forestless area (S_H), the area uncovered in forest (S_0), the area covered in forest, including in young growth and average-aged forest (S_1), and in maturing (S_2), mature and overmature forests (S_3). The characteristics of the area are spatially distributed and vary over time. The dynamics of these indices is described by the formulas

$$dS_H/dt = -\lambda_{H0}S_H(t,\xi_1) + \lambda_{0H}S_0(t,\xi_1) + u_H(t,\xi_1)$$

$$dS_0/dt = -\lambda_{01}S_0(t,\xi_1) + \lambda_{H0}S_H(t,\xi_1) - \lambda_{0H}S_0(t,\xi_1) + \sum_j u_j(t,\xi_1) - u_{H0}(t,\xi_1)$$

$$dS_1/dt = \lambda_{01}S_0(t,\xi_1) - \lambda_{12}S_1(t,\xi_1) - u_1(t,\xi_1) - u_{H1}(t,\xi_1)$$

$$dS_2/dt = \lambda_{12}S_1(t,\xi_1) - \lambda_{23}S_2(t,\xi_1) - u_2(t,\xi_1) - u_{H2}(t,\xi_1)$$

$$dS_3/dt = \lambda_{23}S_2(t,\xi_1) - u_3(t,\xi_1) - u_{H3}(t,\xi_1)$$

- where λ is the intensity coefficient of transition of the area from one category of lands or age group to the other; is the annual are of fellings in forest stands of the *j*-th age group at time *t* in the unit vicinity of the point ξ_1; is an increase in the forestless area in the course of capital construction through the other categories of lands (u_{Hi}).

The modeling scenarios and multicriteria optimization

- When performing calculations in terms of the models, the user can access (to make relevant changes) the parameters of the main felling volume, tending fellings, fires and treeplanting. Each of these parameters can assume three values: 0% (none), 50% (a half of the volume), and 100% (total volume).

- The results of calculations are evaluated using the set of criteria:

$\max_j \min_i W^j(t_j)$, where $W^j(t_i)$ is the standing crop (for all species and ages) calculated from the *j*-th scenario in the year t_i;

$\min_j \max_i S_0^j(t_j)$, where $S^j_0(t_i)$ is the area "uncovered in forest" calculated from the *j*-th scenario in the year t_i, in which the forest can grow;

$\max_j \left(S_4^j + S_5^j\right)$, where $S^j_4(t_i)$, and $S^j_5(t_i)$, respectively, correspond to the area of mature and overmature forests calculated from the *j*-th scenario for the forecasted period.

$\min_j \max_i S_5^j(t_j)$, where $S^j_5(t_i)$ is the area of overmature forests calculated from the *j*-th scenario in the year t_i.

- Each calculated scenario is evaluated using this set of criteria. Multicriteriality is an integral feature of most real choice problems and requires special methods of analysis. In decision making theory where the feasible solutions are evaluated simultaneously from several indices (criteria), the Edgeworth-Pareto principle is widely used; according to this principle, the best solutions should be chosen among the Pareto-optimal solutions .

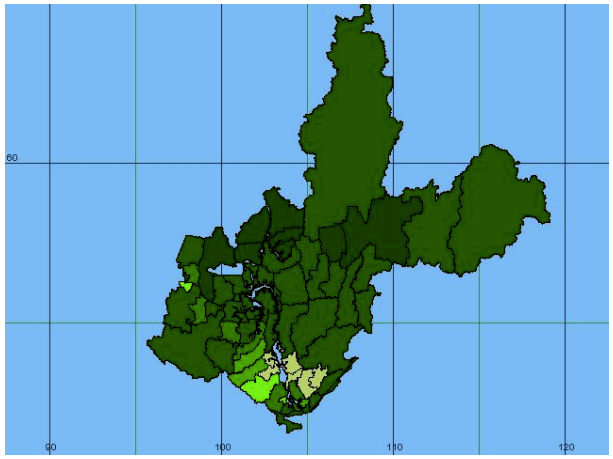
No.	Pareto	Parameters			
		tending, %	fellings, %	fires, %	planting, %
1	1	100	100	100	100
2	0	0	100	50	0
3	1	0	100	50	50
4	0	0	50	100	0
5	1	50	50	100	0
6	1	0	50	50	100
7	0	50	0	100	0
8	0	0	50	100	0
9	1	50	0	0	100
10	0	0	50	50	0

- Thus, of the 10 scenarios, 5 scenarios were discarded.
- The optimal scenarios for forest resource management are:

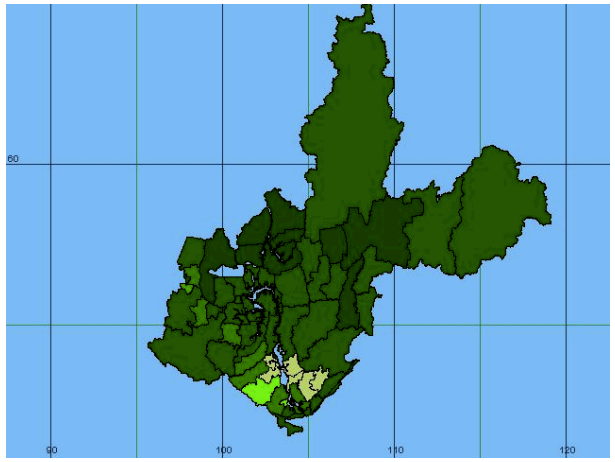
1. the carrying out, in full volume, of main fellings and treeplanting having regard to the current number of fires in the region's forests;
2. no main fellings, the carrying out of tending fellings in full volume, and treeplanting in a half of the volume, and a decrease of the number of fires by a factor of 2;
3. the carrying out of main fellings and tending fellings in a half of the volume, and no fires, with the current number of fires;
4. no main fellings, the carrying out of tending fellings in a half of the volume, treeplanting in full volume, a decrease of the number of fires by a factor of 2;
5. an increase in forested areas and timber reserves for all age groups – no main fellings, the carrying out of tending fellings in a half of the volume, treeplanting in full volume, and no fires.

The regional-level models

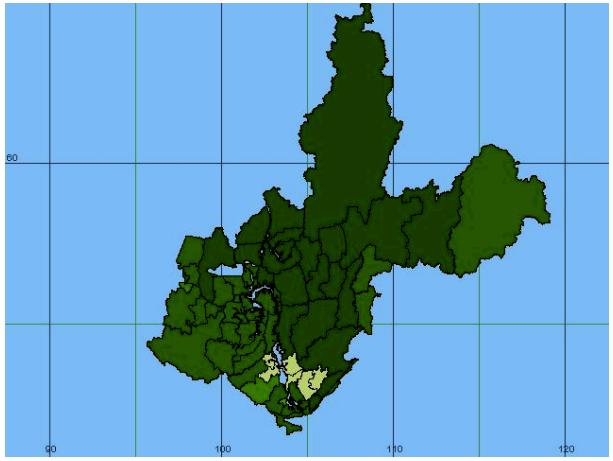
The dynamics of natural changes in the distribution of forest resources of coniferous species of a mature and overmature age class



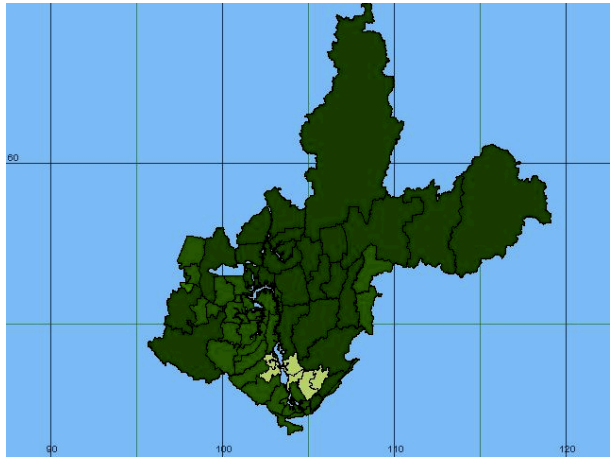
initial instant of time



5 years later



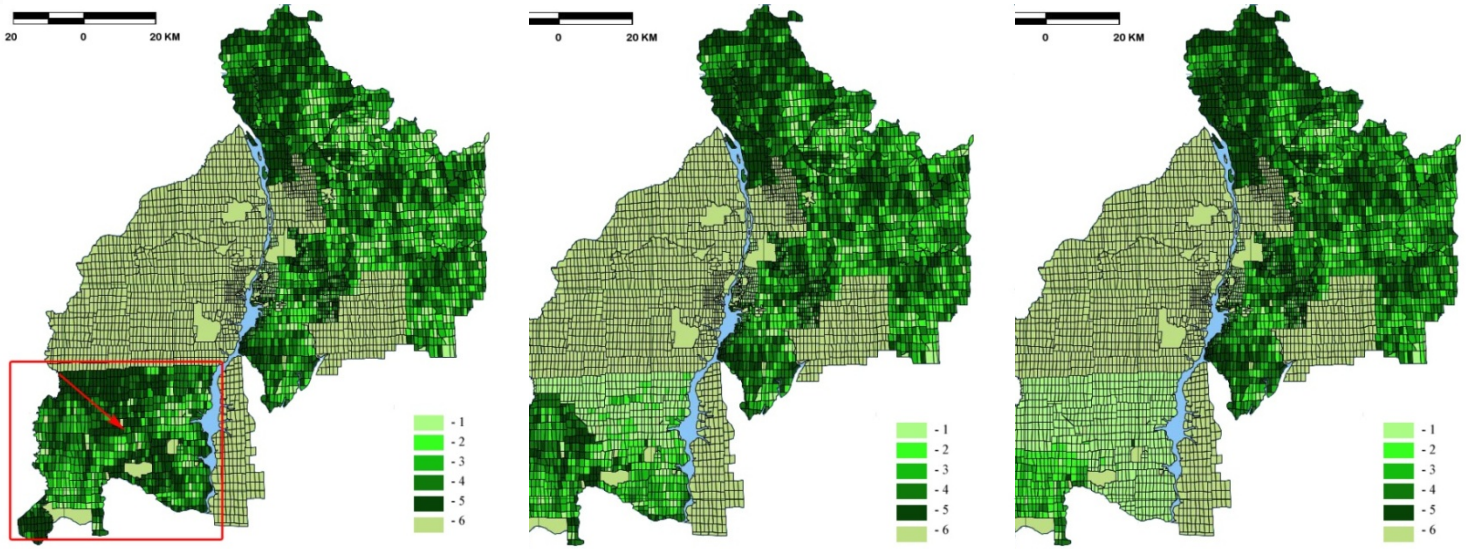
22 years later



30 years later

The subregional-level models

Relative area of mature and overmature forests vs. total area of the compartment.



at the beginning of the modeling period

50 years later

100 years later

The direction of the vector of felling in this example is shown in figure by the red arrow; accordingly, the tree fellings were calculated only for the territory roughly outlined by a triangle. The calculations were carried out for the territory of the Educhansky district forestry of the Ust-Ilimsk district, the maximum felling volume was estimated at 500 thou m^3/year, and the maps of the conditions of mature and overmature forests (the relative area of mature and overmature forests vs. total area of the compartment) at the initial time of modeling, and 50 and 100 years later are provided in figure.


Thank for your attention!