Information Support of System Monitoring and Complex Assessment of Forestlands in Industrial Regions

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Abstract. The need for systematic monitoring and complex evaluation of forest lands in industrial regions (on the example of the Urals and Western Siberia) is considered. The methodology of system monitoring and complex evaluation of forest lands on the basis of the concept of sustainable development of territories and biotic regulation of the environment, taking into account the widespread and long-term consequences of nature-land-forest management, modeling of natural objects, phenomena and processes, combining data collection and processing procedures with models of structural elements of forest lands with algorithms of forecasting and decision-making is presented. The scientific and technological principles of system monitoring and information support of complex evaluation of forest lands in industrial regions are considered. The results of using a sound methodology and the proposed principles of system monitoring and complex evaluation of forest land in industrial regions in solving practical problems are presented: substantiation of the concept of environmental safety of the development of the Middle Urals, the role of the natural potential of forest lands in the national accounts structure, the formation of sustainable subsoil use.

1. Introduction
The need for system monitoring and complex evaluation of forest lands in industrial regions is caused by the following reasons:
– the ecological value of the forest lands as the basis of biotic regulation on the given territory (forest lands transformation leads to the disruption of the given territories hydrological regime, soil disturbance and degradation of indigenous fauna and flora);
– forest lands (forests) indispensability as the main sink and neutralizer of industrial air, soil, and water pollution taking place on the industrially developed territory (1.6-1.9 million tons of pollution get released into the atmosphere and 800–1 000 million m3 of polluted waters discharge into the water bodies in the Middle Urals annually; 1,300–1,500 of oil spills occur and 320–360 hectares of soil are disturbed in Western Siberia);
– the increasing interest of economic entities in transferring forest lands of the forest funds to other land categories (in the Urals, mainly to the industrial and transport land) and finding other ways to use subsoil (there are 455 oil deposits discovered on the forest fund territory in Western Siberia);
– insufficiency of currently existing scientific and methodological support of forest lands evaluation system monitoring, that does not reflect the full extent of the public (and not just from the individual land users point of view) importance of natural resources land potential;
– forest lands monitoring and evaluation procedures currently do not comply with the modern principles of the concept of sustainable development of territories.
2. Methods

Forest lands as a subject of system monitoring and complex evaluation in industrial regions:
– are a product of biological and geochemical processes occurring on the surface of our planet [1] that result in the formation of soil cover [2–4] with the corresponding level of chemical elements (including heavy metals) and natural level of radiation [5];
– forest lands are the basis for the formation of the previously primary forest types, that contain the genetic “memory” about maintaining the conditions for sustainable development of the forest cover territory [6];
– in the present moment, as a result of an anthropogenic and man-made impact, forest lands can be described as ecological systems of nominally primary and various secondary forest plantations [7, 8];
– forest lands are a source of nature's benefits: resources that are manifested in the form of different physical objects, environment-forming functions, that provide favourable conditions for biota and material production, and social role contributing to the satisfaction of spiritual and aesthetical needs of the society [9];
– in industrial regions forest lands are the main accumulators and converters of man-made environmental pollutions (industrial gases, anthropogenic aerosols, dust, and radiation) [10];
– forest lands are currently [11] the most important element of the global climate change process (temperature rise occurring on the planet) regulating on-land flows of atmospheric air, the hydrological territory regime, forming the characteristics (parameters) of the heat balance of the territory [12–14].

The methodology of system monitoring and information support of the industrial regions forest lands complex evaluation is based on:
– fundamental scientific principles of the concept of territories sustainable development, based on biotic regulation of the environment [15];
– taking into account the widespread and long-term consequences of nature-land-forest management of forest land in industrial regions [16, 17];
– mathematical modeling of natural features, phenomena, and processes occurring on forest lands in space (tree stands relationship dynamics based on its species composition and types of reforestation in a secondary forest) and time (changes in biometric and bioproduction parameters of forest lands) [18, 19];
– combining data collection and processing procedures with the models of forest lands structural elements [18, 20] and forecasting and decision-making algorithms [21] in order to use forest lands in industrial regions (the Urals and Western Siberia).

Fig. 1 shows the types of coniferous and deciduous forest plantations restorative dynamics in the Middle Urals, illustrating the concepts of environmentally sustainable development and taking into account widespread and long-term consequences that allow to perform modeling of forest objects phenomena and processes in order to make appropriate decisions in the field of forest management.

![Forest land dynamics diagram](image)
3. Results
The scientific and technological principles of forest lands system monitoring in industrial regions were substantiated, taking into account the degree of natural (forest) features transformation, changes in natural phenomena occurring in forest ecosystems and changes in the nature of forest-forming processes, including the following ones [22]:
– capturing and collecting the indicators of forest lands; the list of the main natural indicators of the forest lands ecological potential (environment-forming functions) is given in Table 1;
– accumulation and systematization of forest lands indicators; Figures 2 and 3 show the obtained histograms of changes in the tree stands (relative) height and current timber increment in the Middle Urals;
– providing information on forest lands in accordance with the characteristics of the territories; the system of forest lands classifiers used in the process of monitoring is given in the Table. 2;
– forecasting of the changes in the parameters of forest lands located in industrial regions; the possible types of reforestation shifts categorized by groups of forest types (pine forests) are given in Table. 3

The substantiated scientific and technological principles of information support meant for complex evaluation of forest land in industrial regions include the following ones:
– substantiation and accumulation of generalizing equivalents of the forest lands parameters based on the secondary forests resource potential, characteristics of the environment-forming and social functions of forest lands that are located on the territories that were subjected to a long-term human impact (pollution, transformation, disturbance), allowing to reliably assess the social (environmental, social) and economic significance of forest lands areas in terms of widespread and long-term aspects of nature-land-forest use management;
– substantiation and construction of a criterion for the complex evaluation of forest land in industrial regions, that reflects the levels of transformation (replacement of primary natural systems on forest lands territory with secondary ones), disturbance (change in the forest plantations composition) and degradation of forest lands (decrease in biometric parameters, reduction of production processes);
Table 1. Recorded indicators of forest lands environment-forming functions.

| Forest lands environment-forming functions | Natural functions indicators (qualitative and quantitative) |
|-------------------------------------------|----------------------------------------------------------|
| Maintaining the atmosphere composition    | Average periodic timber increment. The coefficients of the phytomass increment of forest plantations individual components. The ability to absorb CO2 and release O2. Coefficients adjusting this ability. Timber bulk density. |
| Water protection and water regulation      | Precipitation indicators. Average long-term indicators of river flow. The tree stands height. The coefficients adjusting the catchment relief and waterlogging, the tree species, the age of a forest plantation, its density and bonitet. |
| Climate-forming                            | Wind speed, temperature and humidity of air and soil, moisture evaporation from the soil surface as well as the number of frosts and snow accumulation. |
| Soil-forming                               | The average stock and commercial value of timber obtained from soils of different bioproductivity. The coefficients of the reduction of timber average stock and commercial value due to soil erosion. |
| Environment protection functions (air purification, soil protection, water purification) | The minimum width of the protective zones (windbreaks). The ability of forest vegetation to absorb gaseous, aerosol pollution and dust from the air atmosphere. The ability of soil cover and water to detain pollution. The ability of forest vegetation to resist water erosion of the soil. |
| Resource-preserving                        | Indicators of designated forest areas forest vegetation, water, and forest fauna reproduction as well as the water sources conservation. |
| Informational                              | Indicators of certain categories of forests protective functions, all forests located in specially protected natural areas (for the purpose of information conservation on the genetic, species and ecosystem levels). |
**Figure 2.** Histograms of changes occurring in the relative height of coniferous forest plantations in the Middle Urals categorized by age classes.

**Figure 3.** Histograms of changes occurring in current periodic timber increments in the spruce forests of the Middle Urals.
Table 2. Forest lands areas classifiers used in the process of system monitoring and land evaluation.

| Land categories | Types of functional (recreational) use of forest areas | Nature’s (forest) benefits | Types of effects evaluated |
|-----------------|--------------------------------------------------------|-----------------------------|----------------------------|
| Agricultura l land | Exploitable forests | Forest resources | Timber |
| Residential area | Overgrown farmland | CO2 uptake | Lumber |
| | Recreational (green) zones | Environment-forming functions (climate, soil) | Recreation al load | Buildings, structures |
| | Forest parks | Environment protection functions (air, water, soil) | | |
| | Natural monuments | Social functions: educational function; aesthetic function | | |
| Forest lands | Forest reserves | Forest resources | Large timber: Wood chips, Firewood |
| | Exploitable forests | Environment-forming functions (climate, soil) | Recreation al load | Building, structures, houses, furniture, paper, cardboard |
| | Protective forests: Types of protective forests; Designated forest areas | Environment protection functions (air, water, soil) | Social functions | |

Table 3. Projected types of reforestation shifts categorized by groups of pine forests types.

| Forest type group | Pine forests | Spruce forest |
|-------------------|--------------|---------------|
| with pre-generation undergrowth | without pre-generation undergrowth | with pre-generation undergrowth | without pre-generation undergrowth |
| Lingo | 1 | 2; 3 | – | – |
| Berry plantation | 1 | 2; 3 | 1; 3 | 3; 4; 5 |
| Linden | 1; 3 | 4; 5 | 3 | 5 |
| Mixed grass | 1; 3 | 4; 5 | 3 | 4; 5 |
| Grass and green moss | 1; 3 | 4; 5 | 1; 3 | 3; 4; 5 |
| Tall grasses and riverine | – | – | 3 | 4; 5 |
| Moss and horsetail | 1; 3 | 4; 5 | 1; 3 | 4; 5 |
| Sphagnum and marsh grass | 1; 3 | 4; 5 | 3 | 4; 5 |

Note. Legend of reforestation shifts types: 1 – nominally primary conifer forests that were grown from the pre-generation undergrowth; 2 – nominally primary conifer forests with subsequent renewal; 3 – short-term
secondary deciduous forests; 4 – long-term secondary deciduous forests; 5 - stable-term secondary deciduous forests.

– consideration of forest lands development and use spatiotemporal dynamics occurring in intensively developed areas due to the effects of man-made impacts (the impact of accumulated environmental damage) and the emergence of modern challenges and risks (information is presented in Fig. 1, 2 and Fig. 3, 4);
– the application of decision-making algorithms in the process of forest land use; selection of strategic priorities and sustainable land use indicators, search for “corridors” of forest lands allowable use in specific natural and climatic as well as socio-economic conditions, coordination of individual interests in using forest lands in accordance with public preferences and multi-criteria optimization of forest land use based on environmental, social and economic indicators.

4. Conclusion
The substantiated methodology and developed principles of system monitoring and information support provided for the complex evaluation of forest lands that were used to solve practical problems of sustainable land use in the industrial regions of the Urals and Western Siberia.

Tab. 4 presents the calculation results based on the of the complex ecological and economic evaluation of the vegetation cover (forest ecosystems) located on the territory, where the mining of the Kachkanar-proper iron ore deposit is planned to take place, and which will be subjected to a radical transformation (tree stands deforestation, topsoil stripping).

Table 4. Complex environmental and economic evaluation of the Kachkanar-proper iron ore deposit territory vegetation cover (forests).

| Prevalent tree stand species | Area, ha | In total |
|------------------------------|---------|---------|
|                              | forest resources | forest environment-forming functions | forest social functions | |
| Mountain forests             |         |         |         |         |
| pine                         | 1,000   | 22      | 158     | –       | 180   |
| spruce                       | 300     | 5.5     | 36.5    | –       | 42    |
| birch tree                   | 200     | 3.5     | 18.5    | –       | 24    |
| Cedar forest (cedar)         | 250     | 20      | 70      | –       | 90    |
| Green Zone                   |         |         |         |         |
| pine                         | 400     | 12      | 60      | 72      | 144   |
| spruce                       | 100     | 2       | 12      | 14      | 28    |
| birch tree                   | 250     | 4       | 20      | 36      | 60    |
| TOTAL                        | 2,500   | 69      | 122     | 568     |

Note: The scale of the forest land cadastral value taken from the Sverdlovsk Oblast Government Decree No. 1276-PP [33] is used in accordance with the inflation rates for the period 1999-2018.

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