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Decision-making algorithm based on the results of systematic monitoring of forested landscapes in the subsoil use territories of the Urals

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Abstract

Relevance of the study. Currently, information obtained during monitoring, including monitoring of forest lands, is of particular importance for making informed decisions on the development of natural potential. A feature of these works today is the lack of combination of data collection procedures, their processing with models of structural elements of forest lands, which requires a solution to the problem under consideration.

The aim is to form, according to the results of system monitoring, a system of interconnected decision-making algorithms in the field of forest land use in industrial regions. The methodology for the formation of a system of interrelated decision-making algorithms in the field of forest land use in industrial regions is based on the use of mathematical models of natural objects of forest ecosystems, natural phenomena in them and forest-forming processes, on the procedures of a comprehensive assessment and optimization of forest land use in industrial regions in accordance with current provisions of the concept of environmentally sustainable development of territories.

Results and their application. The algorithms for decision-making in the use of forest lands based on the results of system monitoring are considered: substantiation of strategic indicators of sustainable development of forest lands in industrial regions in the face of modern challenges and risks; comprehensive ecological and economic assessment of the natural resource potential of forest lands; determination of leeways of permissible use of forest lands in industrial regions in specific climatic and socio-economic conditions; coordination of individual interests of land users on forest lands with public preferences for the development of industrial regions; multi-criteria optimization of the use of forest lands in industrial regions. The main principles of forecasting the parameters of a comprehensive assessment of forest lands, the use of the indicator of consumption of net primary products of forest ecosystems, the sequence of greening the economy of the use of forest lands in industrial regions, justification of concessions to the extreme values of particular criteria in multi-criteria optimization are given. The proposed additional indicators of sustainable development of forest areas in the Middle Urals, the results of calculations on the change in the natural resource potential of forest lands in the subsoil use area are presented; the substantiation of the multicriteria optimization of the use of raw material resources of forest lands is given.

Conclusions. The proposed decision-making algorithms in the field of systemic monitoring of forest lands are intellectual support for users in the analysis of information in the field of land relations. They provide a substantive dialogue that allows you to form the necessary information in a user-friendly form, adjust the data processing process and make decisions.

Keywords: system monitoring, forested landscapes, decision-making algorithms, strategic indicators, integrated assessment, leeways of land use, conflicts of interest, multi-criteria optimization.

Introduction

System monitoring of forest lands is a multipurpose information system of observation, assessment (in physical terms) and forecasting consisting of monitoring the state of forest lands and monitoring the use of forest lands. Reliable information is based on mandatory knowledge about the past state of forest lands (about parameters, characteristics and indicators of indigenous forest types in specific territories). This systematic monitoring of forest lands is expressed in observations, initial assessment and forecasting of the state and use of the entire natural resource potential: forest resources (wood, non-wood, wild plants); environment-forming functions (maintaining the composition of atmospheric air, water-protecting, water-forming, climate-forming, soil-forming, environmental protection).

Nowadays, satellite-based monitoring systems are being widely developed which allow obtaining operational information about the state of forest lands; it is accumulated in the relevant databases and used most often in operational planning. A geographic database with high spatial detail for regional systems is being developed. A feature of these works is the lack of a combination of data collection procedures and their primary processing with models of structural elements of forest lands – forest ecosystems. It is necessary to combine operational, algorithmic, model and software tools for collecting and processing data on forest lands with forecasting and decision-making functions.

Methods

Decision-making algorithms based on the results of

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Table 1. Proposed additional indicators of sustainable development of forest territories in the Sverdlovsk region.
Таблица 1. Предложенные дополнительные индикаторы устойчивого развития лесных территорий в Свердловской области.

Indicators	Main parameters of indicators	
	Static	Dynamic
1. Level of conservation of primary ecosystems in forest lands	Extant montane forest Extant lowland forests Extant wetland forests	Reduction with increase in primary ecosystems
2. Frequency rate of the main forest use in forest lands (forest felling)	Percentage of territories with: – one-time logging; – two-time logging; – three-time logging	Reduction of forest land with clear-cutting Increase in the area of forest land with gradual felling and selective logging activities
3. The level of pollution of ecosystem components in forest lands	Percentage of territories with: – radioactive contamination of wood; – chemical contamination of soils; – chemical contamination of water	Expansion of forest land territories with: – isolated radioactively contaminated stands of trees; – rehabilitated forest soil and forested water catchments
4. Social value of forest lands	Percentage of forest land that performs the following functions: – recreational; – healing; – instructional and educational; – aesthetic	Increase in the area of forest land with: – rehabilitated recreational and healing areas; – developed recreational and healing areas; – natural information content of instructional and educational and aesthetic areas of forest lands
5. Social consumption of net primary products of forest land ecosystems	Percentage of undisturbed land (land with primary forest types) Shares of semi-disturbed land (land with secondary forest types, some farmland) Disturbed land (land of localities, industrial, transport and energy enterprises)	Indicator parameters change trends

systemic monitoring of forested landscapes in industrial regions of the Urals are based on:

– results of collection and processing of biometric and bioproduction parameters of forest lands;

– widespread and long-term implications of the use of forest lands in industrial regions;

– mathematical models of natural objects, phenomena and processes in space (dynamics of the ratio of forest stands by species composition and types of reforestation in secondary forests) and trends over time (changes in biometric and bioproductive parameters of forest lands);

– multi-criteria optimization of the use of forest lands in industrial regions.

Results

The main decision-making algorithms based on the results of system monitoring in the use of forest lands include:

– substantiation of strategic indicators for sustainable development of forest lands in industrial regions in the face of modern challenges and risks;

– comprehensive ecological and economic assessment of the natural resource potential of forest lands;

– determination of leeways of permissible use of forest lands in industrial regions in specific climatic and socio-economic conditions;

– coordination of individual interests of land users on forest lands with public preferences for the development of industrial regions;

– multi-criteria optimization of the use of forest lands in industrial regions based on environmental, economic and social indicators.

Justification of strategic indicators of sustainable development of forest lands

Sustainable management of forests (forest lands) [1] includes issues of forest policy, forestry organization, forest inventory and forest management (harvesting of forest resources, reforestation, protection and protection of forests). At the first stage of the development of the Concept of sustainable development of forest lands (forests), there is a judgment that forest lands are very valuable property of a particular kind because the benefits brought by forests are often environment-forming functions that are not subject to material assessment. In this regard, the turnover of forest lands should be regulated on the basis of the presumption of environmental priorities in the use of forests, that is, the material assessment of the entire range of benefits of forest lands was considered almost unfeasible. Now, the developed methodology [2, 3], scientific principles [4] and informational methodological support of land assessment work on forest lands [5] make it possible to move to sustainable forest management.

The indicators of the Montreal Process [6] have been adjusted to the ecological, economic and social conditions of the Middle Urals since there are no important criteria in their totality:

– characterizing the transformation of forest landscapes over a 300-year period of industrial exploration and development of the territory;

– characterizing the change in society's consumption of net primary production (NPP) of forest land ecosystems.

A quantitative measure of net primary production in natural systems is [7] the proportion of undisturbed (primary

Table 2. Principles of discounting the effects of forest lands in industrial regions.
Таблица 2. Принципы дисконтирования эффектов лесных земель в промышленных регионах.

Evaluation conditions and type of calculation formula	Literary references (main)
One-time implementation of the effects of forest lands	
Assessment of future wood *D* at the time of forest planting $Э = \frac{Д}{(1+P)^{T}}$	A. M. Shuster (1969) [12] K. G. Goffman (1974) [13] I. V. Turkevich (1977) [9]
Estimation of future wood *D* at time *t* of the period (0, *T*): $Э = \frac{Д}{(1+P)^{T-t}}$	V. V. Varankin (1974) [14]
Estimation at the moment of the sum of annual effects *R* for the interval τ: $Э = \frac{Д = R\tau}{(1+P)^{(T-t/2-t)}}$	N. I. Kozhukhov (1988) [15]
Constant implementation of the effects of forest lands	
Estimation of the sum of the *R* annual effects for an infinite period of time (0, *T*): $Э = \frac{R}{P}$	Rosleskhoz, 2000 [16] Roszemkadastr [17]
Estimation of the sum of interval (per τ) effects *R* over an infinite period of time (0, *T*): $Э = \frac{R}{(1+P)^{\tau}-1}$	K. G. Goffman (1977) [13]
Estimation of the sum of annual effects *R* for a limited period of time (0, *T*): $Э = R\frac{\left[(1+P)^{T}-1\right]}{P(1+P)^{T}}$	K. G. Goffman (1977) [13] P. Piers (1992) [18]

Table 3. Assessment based on the results of systematic monitoring of the natural resource potential of forest lands in the Nizhny-Tagil forest cadastral region (mining sites of the Gusevogorsky, Sobstvenno-Kachkanarsky, and Vysokogorsky mineral deposits).
Таблица 3. Оценка по результатам системного мониторинга природно-ресурсного потенциала лесных земель в Нижне-Тагильском лесокадастровом районе (районы разработки Гусевогорского, Собственно-Качканарского, Высокогорского месторождений полезных ископаемых).

Rock	Capacity class	Assessment of certain types of nature's benefits of forest lands				
		Forest resources	Maintaining the composition of the air of the atmosphere	Water-protective, water-control	Climate	Deep subsoil
Pine tree	II	43.3	44.8	69.4	23.4	42.0
	III	35.2	33.9	47.6	18.9	29.7
	IV–V	18.7	16.1	20.3	8.4	12.2
Fir	II	41.9	40.2	68.2	19.6	40.6
	III	30.2	37.4	63.0	19.2	37.1
	IV–V	13.8	29.0	43.1	18.2	25.2
Birch tree	III	28.7	37.1	54.9	21.7	25.9
	IV	19.1	26.6	35.7	15.4	22.4
	V	12.3	18.5	32.5	11.2	11.7

forest types), semi-disturbed (forest lands with secondary plantations) and disturbed lands (agricultural lands, settlements, industrial facilities). The proposed additional indicators of sustainable development of forest lands characterizing the transformation of forest landscapes in the Sverdlovsk region are presented in Table 1. They enable to:

– quantify the compliance of the existing state of forest land use with the conditions of sustainable management;

– justify the leeways of the permissible removal of NPP from natural ecosystems on forest lands.

Comprehensive environmental and economic assessment of natural resource potential of forest lands in industrial regions according to system monitoring data

A comprehensive assessment of forested landscapes is carried out according to monitoring data of biometric [8] and bioproduction [9] parameters taking into account their

Table 4. Indicators of consumption of net primary production (NPP) within the territory of the Sverdlovsk region (2016), %.
Таблица 4. Показатели потребления чистой первичной продукции (ЧПП) на территории Свердловской области (2016), %.

Forest inventory district	Undisturbed land (land with primary forest types)	Semi-disturbed lands (lands with secondary forests)	Disturbed lands
1. Ivdel-Oussky	27.6	67.7	4.7
2. Serovsky	24.2	67.3	8.5
3. Tavdinsky	19.3	68.8	11.9
4. Novo-Lyalinsky	14.8	71.5	13.7
5. Nizhny Tagil	12.7	68.9	18.4
6. Alapaevsky	15.8	66.6	17.6
7. Turinsky	14.3	71.2	14.5
8. Krasnoufimsko-Shalinsky	8.1	60.0	31.9
9. Ekaterinburgsky	17.2	55.2	24.0
10. Pripyshminsky	7.4	62.8	28.0
Total	16.8	60.9	22.3

transformation [10, 11] from anthropogenic and technogenic impacts in industrial regions. The complex criterion is the assessment of forest resources and the main environment-forming functions. The basic principles of discounting the future effects of forested landscapes in the subsoil use areas of the Urals are shown in Table 2. Table 3 shows the results of calculations based on the data of systemic monitoring of the state of forest ecosystems in the region of operation of mining complexes (Nizhne-Tagil forest cadastral region).

Determination of leeways of acceptable use of forest land in industrial regions

It is carried out according to environmental parameters (the level of conservation of natural ecosystems, the balance of natural and anthropogenic energy flows – biomass in the environment, according to the degree of withdrawal of natural resources and objects – plant cover, soil, land plots), according to social parameters (employment of the population in the regional economy, health status of the population, preservation of social functions of natural landscapes) and economic parameters (technological, technical, costs, income).

The ecological parameters of the “corridors” of the permissible subsoil use of forest lands are united by a common indicator – the permissible consumption of the net primary production of the biosphere (NPPB) by society. In natural (undisturbed) ecosystems, vertebrates including humans consumed no more than 1% of NPPB [7]; by the early 20th century – more than 2% [19]. The balance of consumption of net primary production was carried out in 1991 for Austria [19]. The analysis of the consumption of net primary products for Russia was carried out in 1993 [20]. It was shown that this indicator approached the world average only for the developed territory of the European part of Russia. Nowadays, the area of territories developed by economic activity (disturbed ecosystems) in the world reaches 60%, which corresponds to human consumption of more than 10% of the net primary production of the biosphere, that is, the closure of the cycle of biogens (CO_2, nitrogen, phosphorus, potassium compounds) has already been seriously disturbed; biodiversity is significantly decreasing).

Table 4 shows the indicators of consumption of net primary products within the territory of the Sverdlovsk region (2016). In terms of the level of NPP consumption of forest lands, the territories of three forest cadastral districts of the Sverdlovsk region (Ivdel-Oussky, Serovsky and Tavdinsky) correspond to environmentally sustainable development; disturbed lands occupy 4.7–11.9%. Two forest cadastral districts of the region have approached an environmentally intense sustainable development; disturbed lands reach 15%. Three forest cadastral districts of the Sverdlovsk region (Krasnoufimsko-Shalinsky, Ekaterinburg, Prypyshminsky) have a catastrophic level of ecological status; disturbed lands that do not produce NPP of natural ecosystems already occupy 24–32% of the territory here.

Coordination of individual interests of land users of forest lands with public preferences for the development of industrial regions

The main features of the relationship between individual and public interests in the use of forest lands in industrial regions are mainly as follows:

– individual interests consist in maximum profit in a relatively short period of time, and public preferences in the long-term, constant use of forest lands;

– individual interests do not reflect the complexity of the use of forest land resources, and social preferences are in the optimal use of the entire set of forest (natural) benefits;

– individual interests ignore the systemic nature of forest lands (interconnections in forest ecosystems), and social preferences perceive forest land plots as an interconnected element of the global vegetation cover system.

The algorithm for reconciling individual interests and social preferences consists in:

– consistent greening of the economy of forest land use from its existing form in the form of income maximization (by reducing its own costs), first to accounting and discounting external costs, and then to the sustainable development economy – a “green” economy [21] with maximum consideration of the consequences and minimizing negative impacts;

– substantiation the ratio of market discount rates for forest land users [18] and discount rates for public preferences [22];

– substantiation (determination) of concessions to the inter-

The sequence of assessing the greening of the economy of the use of forest lands in industrial regions while coordinating

Table 5. Sequence of greening the economy of the use of forest lands (including for purposes of "... the development of mineral deposits" – Articles 21 and 25 of the "Forest Code of the Russian Federation" in the form of their lease for a period of up to 49 years).
Таблица 5. Последовательность экологизации экономики использования лесных земель (в том числе для целей «… разработки месторождений полезных ископаемых». Статьи 21 и 25 «Лесного кодекса РФ» в форме их аренды на срок до 49 лет).

Type of net present value	Determination of net present value
Net present value of the subsurface user (land user) *E* for the period of *T* years – the term of development of the field	$Э = \sum_{t=1}^{T} \frac{R_t - (З_t + З_{et})}{(1+P_t)^t} \to \max$ (1)
Total cost of the subsoil user (land user) for the period of *T* years – the term of development of the field	$Э = \sum_{t=1}^{T} \frac{R_t - (З_t + З_{et} + C_t)}{(1+P_t)^t} \to \max$ (2)
Long-term environmental and economic impact of subsoil use (land use) for the period of more than *T* years – after shutting down production	$Э = \sum_{t=1}^{T} \frac{R_t - (З_t + З_{et} + C_t)}{(1+P_t)^t} \pm \sum_{t=T+1}^{>T} \frac{Y_t}{(1+P_t)^t}$ (3)

Note: *R* – land use product value; $З_t$ – amount of costs; $З_{et}$ – environmental production costs including the cost of preventing environmental damage (for example, for wastewater treatment plants) and economic damage from environmental pollution (for example, payments for emissions of pollutants); *P* is the discount indicator (for individual users of natural resources in the range of 0.08–0.12, mainly depends on the interest rate prevailing in the market); C_t – external costs; Y_t is the sum of long-term environmental and economic impact for a period significantly longer than *T*.

the individual interests of land users with public preferences for the development of the territory is shown in Table 5.

Optimization of forest land use

For evaluation of indeterminate forms of optimal solutions, a matrix of *n* land use options is compiled [23]. Further, additional special criteria for the evaluation of indeterminate forms of optimal decisions in the use of forest lands are calculated.

The criterion of "average costs" in land use is determined by the maximum of the average values of the *P* index for each set of state parameters:

$$\max_j = \left(\frac{P_{1j} + \ldots + P_{ij} + \ldots + P_{6j}}{6} \right) = \max P_j, \quad (4)$$

where P_{ij} is the indicator of the efficiency of the *i*-th option with the *j*-th set of parameters.

The "minimax cost" criterion. When using the criterion of "minimax costs", the land use option is selected for which the worst result is better than the worst for any other option:

$$\max_j P_j^{\min} = \min_j \max_i P_{ij}. \quad (5)$$

The "minimax risk" criterion. For particularly difficult cases of land-use organization, a rational option is chosen according to the criterion of "minimax risk". In this case, the difference P_{ij} is converted into the risk matrix R_{ij} according to the ratio:

$$P_{ij} = P_{ij} - P_i^{\max} = P_{ij} - \max \overline{P}_{ij}. \quad (6)$$

ests of individual users and public preferences based on the analysis of the dependence of the criteria on land use options [23].

The meaning of this criterion is to eliminate the risk of too large losses in the event of extreme conditions for the functioning of land use objects (climate change, risks of floods, wildfires, risks of diseases and the spread of pests of flora and fauna in forest lands). This concludes the algorithm for one-criterion optimization of the use of forest lands based on data from system monitoring and information support for a comprehensive assessment of forest lands; Following is the multicriteria optimization itself.

Multi-criteria optimization of forest land use based on environmental, economic and social indicators (criteria) consists in a strictly formalized presentation of this problem [24–26]: selection and justification of particular optimization criteria separately for environmental, social, economic and technological factors; determination of extreme values of particular criteria for the efficiency of forest land use, revealing, if necessary, the uncertainty of single-criterion optimal solutions (in the presence of several different land-use options near the extreme value of the criterion); justification of a complex optimization criterion on the basis of particular criteria (environmental, social, economic, technological) in the form of an integral criterion based on the reduction of all criterion measures to the monetary form or to other measures, for example, on the basis of energy distribution [27, 28] or in vector form (solved by the lexicographic method or the method of concessions [29–31].

The main provisions of multicriteria optimization of land use in industrial areas of subsoil use by economic measures are set out in publication [32].

Conclusion

Strategic priorities and indicators of the multipurpose use of forest lands have a clear sequence: environmental, social and, finally, economic ones. In the old industrial regions of the Middle and Southern Urals, they reflect the negative consequences of accumulated industrial waste and the need to maintain the increasingly complex land use. In the Northern and Subpolar Urals, the strategic priorities for the use of forest lands reflect the maintenance of traditional land use among the indigenous peoples of the North.

The proposed decision-making algorithms in the field of systemic monitoring of forest lands are intellectual support for users in the analysis of information in the field of land relations. They provide a substantive dialogue that allows you to form the necessary information in a user-friendly form, adjust the data processing process and make decisions.

REFERENCES

1. Lebedev Yu. V. 2011, *Otsenka lesnykh ekosistem v ekonomike prirodopol'zovaniya* [Assessment of forest ecosystems in environmental economics]. Ekaterinburg, 583 p.
2. Sellers P. J., Dickinson R. E., Randall D. A., Betts A. K, Hall F. G.. Berry J. A.,Collati G. J., Denning A. S., Mooney H. A., Nobre C. A., Sato N., Field C. B., Henderson-Sellers A. 1997, Modeling the exchanges of energy, water, and carbon between continents and the atmosphere. *Science*, vol. 275, pp. 502–509. https://doi.org/10.1126/science.275.5299.502
3. Lebedev Yu. V. 2015, Methodology, principles and practice of forest ecosystem assessment. *Izvestiya vysshikh uchebnykh zavedeniy. Lesnoy Zhurnal* [Bulletin of Higher Educational Institutions. Russian Forestry Journal], no. 2, pp. 9–20. (*In Russ.*)
4. Krupinin N. Ya., Lebedeva T. A. 2015, *Informatsionnoye obespecheniye otsenochnykh rabot po lesnym zemlyam Srednego Urala (territorii nedropol'zovaniya)* [Information support for appraisal works on forest lands of the Middle Urals (subsoil use territories)]. Ekaterinburg, 159 p.
5. 2008, Montreal Process: Criteria and indicators for the conservation and sustainable management of temperate and boreal forests. *Lesokhozyaystvennaya informatsiya* [Forestry Information], no. 10, pp. 89–96. (*In Russ.*)
6. Gorshkov V. G. 1995, *Fizicheskiye i biologicheskiye osnovy ustoychivosti zhizni* [Physical and biological foundations of life sustainability]. Moscow, 472 p.
7. Kondratyev K. Ya., Krapivin V. F., Varotsos C. A. 2003, Global Carbon Cycle and Climate Change. Chichester, U. K.: Springer Praxis Books, 343 p.
8. Krapivin V. F., Shutko A. M. 2012, Information technologies for remote monitoring of the environment. Chichester, U. K.: Springer Praxis Books, 498 p.
9. Walter L. L., Brecle S. W. 1985, Ecological systems of the geosphere. Berlin: Spfinger Verlag, 242 p.
10. Watson R. T., Noble I. R., Bolin B., Ravindranath N. H., Verardo D. J., Dokken D. J. 2000, Land use, Land-use change, and forestry. Cambridge: Cambridge University Press, 875 p.
11. Shuster A. M. 1969, *Faktor vremeni v otsenke ekonomicheskoy effektivnosti kapital'nykh vlozheniy* [The time factor in assessing the economic efficiency of capital investments]. Moscow, 243 p.
12. Goffman K. G. 1974, *Uchot faktora vremeni pri ekonomicheskoy otsenke lesnykh zemel'* [Actual time factor in the economic assessment of forest lands]. Moscow, pp. 72–76.
13. Varankin V. V. 1974, *Metodologicheskiye voprosy regional'noy otsenki prirodnykh resursov* [Methodological issues of regional assessment of natural resources]. Moscow, 239 p.
14. Kozhukhov N. I. 1988, *Ekonomika vosproizvodstva lesnykh resursov* [Economy -of forest resources reproduction]. Moscow, 262 p.
15. 2000, Methodology for the economic assessment of forests: Resolution no. 43 of 10.03.2000. Moscow, 31 p.
16. Methodology for the state cadastral valuation of forest lands in the Russian Federation. Approved by the Federal Land Registry on 15.04.2002, no. P. 263, 49 p.
17. Peter H. Pearse. 1992, Introduction to Forestry Economics. Moscow, 224 p.
18. Danilov-Danilyan V. I., Losev K. S. 2000, *Ekologicheskiy vyzov i ustoychivoye razvitiye* [Environmental challenge and sustainable development]. Moscow, 416 p.
19. Losev K. S., Potapov I. I., Chesnokova I. V., Dokukina T. P. 2008, Externalities from the standpoint of modern ecology. *Ekonomika prirodopol'zovaniya* [Environmental economics], no. 5, pp. 3–8. (*In Russ.*)
20. Gusev A. A. 2014, Ways to form a green economy in Russia. *Ekonomika prirodopol'zovaniya* [Environmental economics], no 1, pp. 28–36. (*In Russ.*)
21. Robert M. Solow. 1974, The economics of resources or the resources of economics. American Economic Review: Papers and Proceedings of the Eighty-sixth Annual Meeting of the American Economic Association, vol. 64, no. 2, pp. 1–14. https://www.jstor.org/stable/1816009
22. Lebedeva T. A., Kokovin P. A., Arefiev S. A. 2017, Scientific basis for sustainable land use in industrial regions. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal* [News of the Higher Institutions. Mining Journal], no. 4, pp. 19–27. (*In Russ.*)
23. Marchuk G. I. 1984, Environment and optimization problems. *Trudy Matematicheskogo Instituta imeni V. A. Steklova* [Proceedings of the Steklov Institute of Mathematics], vol. 166, pp. 123–129. (*In Russ.*)
24. Melentiev L. A. 1976, *Optimizatsiya razvitiya i upravleniya bol'shikh sistem energetiki* [Optimizing the development and management of large energy systems]. Moscow, 320 p.
25. Popyrin L. S. 1978, *Matematicheskoye modelirovaniye i optimizatsiya teploenergeticheskikh ustanovo*k [Mathematical modeling and optimization of heat and power plants]. Moscow, 416 p.
26. Podolinsky S. A. 2005*, Trud cheloveka i yego otnosheniye k raspredeleniyu energii* [Human labor and its relationship to the distribution of energy], edition 2. Moscow, 160 p.
27. Bolshakov V. N., Korytin N. S., Kryazhemsky F. V., Shishmarev V. M. 1998, A new approach to assessing the cost of biotic components of ecosystems. *Ekologiya* [Ecology], no. 5, pp. 339-448.
28. Fishburn P. C. 1974, Exceptional Paper – Lexicographic orders, utilities and decision rules: a survey. *Management science*, vol. 20, no. 11, pp. 1413–1496. https://doi.org/10.1287/mnsc.20.11.1442
29. Grabovsky W. 1972, Lexicographic and time minimization in the transportation problem. Warszawa, 142 p.
30. Podinovsky V. V., Gavrilov V. M. 2016, *Optimizatsiya po posledovatel'no primenyayemym kriteriyam* [Optimization according to consistently applied criteria]. Moscow, 192 p.
31. Lebedev Yu. V., Kokarev K. V. 2016, *Resheniye mnogokriterial'nykh zadach v nedrpol'zovanii metodom posledovatel'nykh ustupok* [The solution of multicriteria problems in subsoil use by the method of successive concessions]. Innovative geotechnologies in the development of ore and non-ore deposits: book of reports of the conference. Ekaterinburg, pp. 133–136.

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Алгоритм принятия решений по результатам системного мониторинга лесопокрытых ландшафтов на территориях недропользования Урала

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Аннотация

Актуальность исследования. В настоящее время особую значимость для принятия обоснованных решений по освоению природного потенциала имеет информация, получаемая в процессе мониторинга, в том числе мониторинга лесных земель. Особенностью этих работ на сегодня является отсутствие совмещения процедур сбора данных и их обработки с моделями структурных элементов лесных земель, что требует решения рассматриваемой проблемы.

Целью исследования является формирование по результатам системного мониторинга системы взаимосвязанных алгоритмов принятия решений в сфере использования лесных земель в промышленных регионах. Методология формирования системы взаимосвязанных алгоритмов принятия решений в сфере использования лесных земель в промышленных регионах базируется на использовании математических моделей природных объектов лесных экосистем, природных явлений в них и лесообразующих процессах, на процедурах комплексной оценки и оптимизации использования лесных земель в промышленных регионах в соответствии с современными положениями концепции экологически устойчивого развития территорий.

Результаты и их применение. Рассмотрены разработанные по результатам системного мониторинга алгоритмы принятия решений в сфере использования лесных земель: обоснование стратегических индикаторов устойчивого развития лесных земель в промышленных регионах в условиях современных вызовов и рисков; комплексная эколого-экономическая оценка природно-ресурсного потенциала лесных земель; определение «коридоров» допустимого использования лесных земель в промышленных регионах в конкретных природно-климатических и социально-экономических условиях; согласование индивидуальных интересов землепользователей на лесных землях с общественными предпочтениями развития промышленных регионов; многокритериальная оптимизация использования лесных земель в промышленных регионах. Изложены основные принципы прогнозирования параметров комплексной оценки лесных земель, использования показателя потребления чистой первичной продукции лесных экосистем, последовательности экологизации экономики использования лесных земель в промышленных регионах, обоснования уступок экстремальных значений частных критериев при многокритериальной оптимизации.

Выводы. Приведены предложенные дополнительные индикаторы устойчивого развития лесных территорий на Среднем Урале, результаты расчетов по изменению природно-ресурсного потенциала лесных земель в районе недропользования; дано обоснование многокритериальной оптимизации использования сырьевых ресурсов лесных земель. Предложенные алгоритмы принятия решения в сфере системного мониторинга лесных земель являются интеллектуальной поддержкой пользователей при анализе информации в сфере земельных отношений. Они обеспечивают предметный диалог, позволяющий формировать необходимую информацию в удобном для пользователя виде, вносить коррективы в процесс обработки данных и принимать решения.

Ключевые слова: системный мониторинг, лесопокрытые ландшафты, алгоритмы принятия решений, стратегические индикаторы, комплексная оценка, «коридоры» землепользования, конфликты интересов, многокритериальная оптимизация.

ЛИТЕРАТУРА

1. Лебедев Ю. В. Оценка лесных экосистем в экономике природопользования. Екатеринбург: УрО РАН, 2011. 583 с.
2. Sellers P. J., Dickinson R. E., Randall D. A., Betts A. K, Hall F. G.. Berry J. A., Collati G.J., Denning A. S., Mooney H. A., Nobre C. A., Sato N., Field C. B., Henderson-Sellers A. Modeling the exchanges of energy, water, and carbon between continents and the atmosphere // Science. 1997. Vol. 275. P. 502–509. https://doi.org/10.1126/science.275.5299.502
3. Лебедев Ю. В. Методология, принципы и практика оценки лесных экосистем // Изв. вузов. Лесной журнал. 2015. № 2. С. 9–20.
4. Крупинин Н. Я., Лебедева Т. А. Информационное обеспечение оценочных работ по лесным землям Среднего Урала (территории недропользования). Екатеринбург: УГГУ, 2015. 159 с.
5. Монреальский процесс: критерии и индикаторы сохранения и устойчивого управления лесами умеренной и бореальной зон // Лесохозяйственная информация. 2008. № 10. С. 89–96.
6. Горшков В. Г. Физические и биологические основы устойчивости жизни. М.: ВИНИТИ, 1995. 470 с.

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7. Kondratyev K. Ya., Krapivin V. F., Varotsos C. A. Global Carbon Cycle and Climate Change. Chichester, U. K.: Springer Praxis Books, 2003. 343 p.
8. Krapivin V. F., Shutko A. M. Information technologies for remote monitoring of the environment. Chichester, U. K.: Springer Praxis Books, 2012. 498 p.
9. Walter L. L., Brecle S. W. Ecological systems of the geosphere. Berlin: Spfinger Verlag, 1985. 242 p.
10. Watson R. T., Noble I. R., Bolin B., Ravindranath N. H., Verardo D. J., Dokken D. J. Land use, Land-use change, and forestry. Cambridge: Cambridge University Press, 2000. 875 p.
11. Шустер А. М. Фактор времени в оценке экономической эффективности капитальных вложений. М.: Наука, 1969. 243 с.
12. Гофман К. Г. Учет фактора времени при экономической оценке лесных земель // Экономическая оценка лесных земель. М., 1974. С. 72–76.
13. Варанкин В. В. Методологические вопросы региональной оценки природных ресурсов. М.: Наука, 1974. 239 с.
14. Кожухов Н. И. Экономика воспроизводства лесных ресурсов. М.: Лесная промышленногсть, 1988. 262 с.
15. Методика экономической оценки лесов. Постановление № 43 от 10.03.2000 г. М.: Рослесхоз. 31 с.
16. Методика государственной кадастровой оценки земель лесного фонда РФ: утв. Росземкадастром 15.04.2002 г., № П/263. 49 с.
17. Пирс П. Х. Введение в лесную экономику / пер. с англ. М.: Экология, 1992. 224 с.
18. Данилов-Данильян В. И., Лосев К. С. Экологический вызов и устойчивое развитие. М.: Прогресс-Традиция, 2000. 416 с.
19. Лосев К. С., Потапов И. И., Чеснокова И. В., Докукина Т. П. Экстерналии с позиций современной экологии // Экономика природопользования. 2008. № 5. С. 3–8.
20. Гусев А. А. Пути формирования «зеленой» экономики в России // Экономика природопользования. 2014. № 1. С. 28–36.
21. Robert M. Solow. The economics of resources or the resources of economics // American Economic Review: Papers and Proceedings of the Eighty-sixth Annual Meeting of the American Economic Association. 1974. Vol. 64, № 2. P. 1–14. https://www.jstor.org/stable/1816009
22. Лебедева Т. А., Коковин П. А., Арефьев С. А. Научные основы устойчивого землепользования в промышленных регионах // Изв. вузов. Горный журнал. 2017. № 4. С. 19–27.
23. Марчук Г. И. Окружающая среда и проблемы оптимизации // Труды МИАН СССР. 1984. Т. 166. С. 123–129.
24. Мелентьев Л. А. Оптимизация развития и управления больших систем энергетики. М.: Высш. школа, 1976. 320 с.
25. Попырин Л. С. Математическое моделирование и оптимизация теплоэнергетических установок. М.: Энергия, 1978. 416 с.
26. Подолинский С. А. Труд человека и его отношение к распределению энергии. Изд. 2-е. Сер. «Мыслители Отечества». М.: Белые Альвы, 2005. 160 с.
27. Большаков В. Н., Корытин Н. С., Кряжемский Ф. В., Шишмарев В. М. Новый подход к оценке стоимости биотических компонентов экосистем // Экология. 1998. № 5. С. 339-448.
28. Fishburn P. C. Exceptional Paper – Lexicographic orders, utilities and decision rules: a survey // Management science. 1974. Vol. 20, № 11. P. 1413–1496. https://doi.org/10.1287/mnsc.20.11.1442
29. Grabovsky W. Lexicographic and time minimization in the transportation problem. Warszawa, 1972. 142 p.
30. Подиновский В. В., Гаврилов В. М. Оптимизация по последовательно применяемым критериям. М.: Ленанд, 2016. 192 с.
31. Лебедев Ю. В., Кокарев К. В. Решение многокритериальных задач в недропользовании методом последовательных уступок // Инновационные геотехнологии при разработке рудных и нерудных месторождений: сб. докл. конф. Екатеринбург: УГГУ, 2016. С. 133–136.

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