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CONSIDERING THE CURRENT CHALLENGES AND RISKS IN THE SUSTAINABLE LAND USE FOR MINING TERRITORIES

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The relevance of this work is conditioned by the growing challenges and risks arising in the mining areas, and the need to counteract them.
The purpose of the work is to develop methodology of a sustainable land use under the conditions of modern changes in the environment under the influence of anthropogenic stress. The authors propose to interpret the concept of "sustainable land use" as a long-term, multi-purpose and cost-effective relationship between society and land resources.
Results. The issues of methodology of sustainable land use in industrial regions are considered. The levels of sustainable land use management within the framework of the concept of biotic regulation of the environment are substantiated. The features of management on each of them are revealed, and the scientific and technical principles of sustainable land use are formulated. The strategic priorities and indicators of sustainable land use are defined. Methodological approaches to ecological and economic assessment of land resources are formulated both by components and by integrated assessment. The widespread, long-term changes of land resources and transformation of ecosystems are taken into account. The parameters according to which the "corridors" of acceptable land use are determined, including environmental parameters. The level of natural ecosystems conservation, the balance of natural and anthropogenic energy flows, the degree of extraction of natural resources, as well as social parameters are among them. The procedure of coordinating individual interests and social preferences on the basis of search of optimum effective options of sustainable land use. It is recommended to perform a multi-criteria optimization of sustainable land use by means of the lexicographical method in relatively simple situations. In more complex cases this can be attained by the method of successive concession. The options of the discount rate and the discount factor depending on the value of the discount period (according to the model of complex processes) are proposed.
Applying the results. The implementation of the developed methodological provisions allows to provide conditions for sustainable land use, counteracting risks associated with environmental challenges arising in the mining areas.

Keywords: sustainable land use; methodology of sustainable land use; levels of management; individual and public interests; multi-criteria optimization.

Introduction

The world community has come (Rio 92; Johannesburg, 2002; Rio+20) to understand the importance of correcting the development of society in relations with the natural environment. the need to develop the principles of economic activity taking into account the emerging and emerging challenges and risks has also been realized [1–3]. Nowadays, the most obvious challenges and risks are environmental threats (without reducing the importance of social ones) [4]. They are implemented in the form of various negative consequences. First, they are applicable to the natural environment, and then they are also topical for various sectors of the economy. Such sectors include land use, subsoil use, and forest management. Environmental threats are negative consequences caused by natural factors and those determined mainly by the characteristics of global climate change and anthropogenic (including technogenic) factors. They manifest themselves in the form of pollution of environmental components (air, vegetation, soil, water), in the form of accumulated industrial waste, and in the form of destruction of natural ecosystems. The main environmental risks in land use are the age-related frequency and intensity of extreme weather and climate events.

Further development of land use should be carried out in accordance with the Concept of sustainable development of territories, principles of environmental safety of the society [5] and green economy [6, 7]. This development should be based on methodologies that consider land resources are the basis of biological life [8]. The sequential relevant principles, taking into account the long-term and multi-value land resources, are also an important thing the land use should be based on. Sustainable land use is a long-term (maintenance of biotic regulation of the environment), multi-purpose (meeting the diverse needs of people) and cost-effective (optimal according to relevant indicators and criteria) relationship of society and land resources.

The purpose of the study is to develop a methodology of sustainable land use in the conditions of modern environmental changes under the influence of anthropogenic stress.

Results

Methodological provisions of sustainable land use in industrial regions, according to the authors' opinion, include the following steps:

– maintaining the necessary level of biotic regulation of the environment;
– hierarchy of sustainable land use management levels: conceptual, ideological, political and economic;
– substantiation of scientific and technical principles of sustainable land use in industrial areas [9].

Biotic regulation of the environment in mining areas under the conditions of modern challenges and risks, expressed in the emergence of environmental threats, reflects the transformation of the biological energy-biomass. This happens in natural and anthropogenic channels and it reflects changes in the cycle of biogenic elements (C, O, H, K, etc.). In the natural ecosystems, before the start of a wide industrial production, people consumed from the environment 1–2 % of biological energy [8] and no changes were observed. In the early twentieth century, anthropogenic influence led to the removal of biological energy from the nature up to 5 %. As a result, there were significant negative changes in the environment. Nowadays, the increasing anthropogenic impact has formed a set of environmental threats, which are caused by the removal of more than 10% of bioenergy from nature.

In some industrial regions (for example, in Ekaterinburg or in Nizhny Tagil) this figure raised up to 30 %. Visually, this is reflected in the increase in the area of disturbed areas (built-up, contaminated), in the increase in the proportion of areas of semi-destroyed territories (agricultural land, derived forests). The deterioration of environmental conditions takes place. Modern challenges and risks determine the corresponding features of the levels of sustainable land use management, among which there are conceptual, ideological, political, and economic.

The conceptual level of management defines the main target settings for a long period of land use. From the ecosystem position, the concept of sustainable land use supposes the management of owners within the limits of the permissible change of biotic regulation of the environment. This means transformation of bioenergy in natural and anthropogenic channels and change of turnover of biogenic elements. Reasonable satisfaction of the needs of society in the results of land use is also supposed by this position. This refers to all types of land use: as a means of production (agricultural land and forest land), as a spatial basis (land settlements, industrial land and transport), and as a storeroom of minerals (subsoil use areas).

The ideological level of sustainable land use management determines the main direction and ways of implementation of conceptual guidelines. The greening of public consciousness and the economy of land use is expressed in a deeper processing of grown and extracted natural resources. The conscious formation and regulation of consumer demand for products from them is also very important.

The political level of sustainable land use management determines the formation of an appropriate conceptual legal framework to the ideological level. Its essence is to improve the legal documents; as well as the issue of differentiation of the concepts of "land" and "soil". Land is a broader concept than soil; it is a socio-economic phenomenon. The soil is a basic component of the natural environment. In the legislation of the Russian Federation there is no distinction of these concepts. In some countries (USA, China, Germany, France, Canada) they have already concluded that soil protection can be carried out only at the state level in the legislation of the legal term "soil".

The economic level of sustainable land use management determines the mechanism of practical action of the company in the field of land relations through the assessment, cost, expenses, and profit. This can also be fulfilled through the implementation of the interaction of individual land users and society with land resources (soil, territory, vegetation, and underground resources). The solution of problems of the economic level of sustainable land use management is based on modern principles of inclusion legislative and executive bodies. Business communities also participate in the search for effective options based on the use of local and global information resources in the field of land use. This is done through the analysis of associative and causal relationships between different forms and types of land use, implementation of conceptual attitudes and ideological positions.

The scientific and technical principles of sustainable land use in mining areas are proposed to include:

– justification of strategic priorities and indicators of sustainable land use [10];

– comprehensive (ecological and economic) assessment of land resources with consideration of the peculiarities of the territories [11];

– definition of "corridors" of acceptable land use in specific climatic and socio-economic conditions [12];

– aligning the individual interests of land users with public preferences [13];

– multi-criteria optimization of land use on the basis of ecological, economic and social indicators [14].

We believe that the strategic priorities and indicators of sustainable land use have a clear priority: environmental, social and, finally, economic. In the old industrial regions of Middle and Southern Urals, they reflect the negative consequences of accumulated industrial waste [15], the nature of morbidity [7] and the need to maintain increasingly complex use of the subsoil [16]. In the Northern and polar Urals, the strategic priorities have a direct interest in maintaining the traditional summary advantage from small nations of the North [17], [18] and sustainable subsoil use [19, 20]. In the regions of Western Siberia, this is a multi-purpose land use: subsoil use, development of industrial facilities and residential areas, forestry.

Methodological tools for ecological-economic evaluation of land resources both component and integrated, is based on the natural characteristics (biometric and bioproduction). It is also based on technological and technical parameters, economic equivalents of these indicators, and defining comprehensive criteria taking widespread parameters into account. Transformation of lands under anthropogenic and natural impacts and long-term changes (natural resource use processes, the effect of accumulated damage), as well as the risks of various situations due to climate change, are presented in this work [11].

Assessment of the impact of global climate change on various forms and types of land use in the Urals and Western Siberia [21] based on the obvious results in the sectors of land use. For these sectors, first, the impact of climate changes the most critical (the amount of precipitation and river flow distribution to surface and groundwater component in the catchment). Second, the conclusions about the impact of climate change have acceptable validity. The examples of such changes can be changing the carbon-reducing role of land [22], a shift in the boundaries of plant formations to the North on the plains and up in the mountainous areas [23]. Other examples include thawing areas of permafrost [24] and the transformation of the Northern forest-swamp systems [25].

As experience shows, the definition of "corridors" of acceptable land use is most often made by environmental parameters which include the level of conservation of natural ecosystems, the balance of natural and anthropogenic energy flows-biomass in the environment, the degree of withdrawal of natural resources and objects-vegetation, soil, land) [9, 12]. Social parameters include employment in the economy of the region, health status of the population is mentioned less often. Preservation of social functions of natural landscapes and economic parameters (technological, technical, cost, income) are also important. A number of specific goals of territorial planning in the industrial regions of the Urals (the goals of the branch of planning) have historically been solved within the framework of land and forest management, implementation of transport projects, solving problems of mining or hydraulic engineering construction. Environmental planning principles in these works were ignored or decided narrowly in the interests of industry planning. As a result, many of the industry projects have received a high-profile anti-ecological glory (Plant called "Uralasbest", Kachkanarsky ore mining and processing enterprise, etc.).

The principle of consistency in the development of ore deposits is expressed in the developed technological platform (the author would like to emphasize the word *technological*). It includes many technological operations on the territory of administrative establishment. This is the system in the field of the subsoil use. It is considered here as "the organization of enterprises ... consuming resources from the outside...". We describe the system of subsoil use enterprises at the present stage not only by the "external consumption of resources", but also by the technological, economic consequences of such consumption for the enterprise itself. This is also the case for the surrounding natural environment (violation of biotic regulation in the regions), for the society (the need to harmonize the interests of individual subsoil users with public preferences), and in the conditions of modern challenges and risks. A valid value of anthropogenic pressures in such areas greatly exceeds the theoretically allowed limits. The definition of acceptable "corridors" is determined through the value of the indicator called "environmental footprint". This indicator shows the number of conventional hectares of land needed to support a person's life with the current level of consumption and waste management, including the area needed to deposit CO_2 emissions. This indicator provides a simultaneous assessment of the environmentally sustainable development of the region (country); compares the development of production with the assimilation potential of the biosphere; it allows to determine the deviation from the "norm" in the socio-ecological and economic development of the region (country).

The practical meaning of the indicator shows what it is necessary to strive for in order to implement sustainable land use on this territory. In practice, this means that it is necessary to close down existing enterprises, which cannot be done at the same time. Under these conditions, the authors propose fixing the state at the time of assessment, which is already determined by the mountain allotment or other types of land use, and the implementation of landscape planning of the entire administrative territory. Landscape planning (in all the variety of definitions) in this case is understood by us as a set of methodological tools and procedures used to build this spatial organization of activity in particular landscapes that would ensure sustainable nature management and preservation of the basic functions of the landscape as the life support systems [26]. The estimated stage of landscape planning allows to obtain an objective assessment of the state of the existing natural conditions of the planning territory. The criteria recommended for such an assessment should meet the following requirements:

– to be focused on the main objectives of the use of the territory in the conditions of equal priorities of preservation of ecological balance and sustainable socio-economic development;

– to reflect the current state of the natural environment in both natural and modified ecosystems under the impact of economic activity;

– to give an idea of possible changes in the state of individual natural components in the implementation of the main directions of use of the territory and the permissible level of such use [27].

The requirements are embodied in the categories of "values" and "sensitivity" of individual components of the natural environment. As a result of processing of all information at the output, a set of maps of industrial use of the territory is created, in which zoning of the territory by types of use is carried out. There are three types of goals:

– conservation;
– development;
– improvement.

After that, a map-concept of the use of the territory is created on the basis of the analysis of socio-economic problems (including maps of the real use of the territory). It identifies areas recommended for the preservation of the natural environment and socio-economic development. It also defines territories with the most acute environmental problems, for which specific measures are planned for the restoration of the landscape. Moreover, it specifies the directions of development of the territory. All the systems broken during the use are combined into one zone for the purpose of their improvement and restoration. The duration and technology of landscape restoration may vary depending on the nature and degree of degradation [27].

Coordinating interests in land usage in industrial Western Siberia and the Urals is an issue which holds a special position in methodology. In this region, the interests of public and private landowners often overlap. This overlap is apparent in the subsoil use areas.

Here, the individual interests of subsoil users are manifested in relatively short periods of time (the duration of deposits development), and public preferences require the preservation of permanent, long-term subsoil use. The main features of the ratios of individual and public interests in subsoil use are shown in the Table 1.

The procedure of individual interests' coordination and public preferences consists of:

– consistent greening of the subsoil use economy: from its existing form in the form of income maximization (by reducing own expenses), first to accounting and discounting of external costs, and then to the economy of sustainable development ("green" economy) [6, 7] with maximum consideration of environmental consequences and minimization of negative impacts (Table 2);

– justification of the ratios of market discount rates for subsoil users and discount rates of social preferences [28];

– the study (definition) of concessions to the interests of individual subsoil users and the public preferences on the basis of the dependence criteria analysis from the options of deposits development [13].

In the current economic system, the market discount rates for subsoil use systematically exceed the public discount rate, which is due to the following reasons. First, individual subsoil users discount their economic income taking into account risks (economic, socio-political, and environmental). At the same time, the unreliability of ownership of the subsoil object (license areas) increases risks. Some risks of subsoil users are not risks for the company. They are associated with transfers within the company (transfer of rights, transfer of payments, etc. [29]). Subsoil users (private capital) are very reluctant to take risks in the implementation of scientific and technical projects characterized by unpredictability and uneven results [30]. Secondly, subsoil users are guided by considerations of a limited (often relatively short) period of operation of the deposit [31] and they use high discount rates. General preferences deny differences in attitude to different periods (generations), so the discount period is long [32]. The society should act as if the discount rate (reflecting the norm of temporary preferences) is at a minimum. Table 3 shows the values of rates and the discount rate (by the formula of compound interest) depending on the duration of the period of use of the subsoil plot [11]. The search for optimal (effective) options for sustainable land use begins with the determination of optimal options for all particular criteria with the disclosure of the uncertainty of single-criterion solutions. For this purpose, a matrix of land use options in the zone of uncertainty of optimal solutions is compiled (Table 4).

Disclosure of uncertainties is performed using specific criteria. The criterion of "average costs" in land use is determined by the maximum of the average values of the indicator P for each set of state parameters (vertical matrix):

$$\max_j \left(\frac{P_{1j} + \dots P_{ij} + \dots + P_{6j}}{6} \right) + \max_j \bar{P}_j . \quad (1)$$

Table 1. The ratio of individual and public interests in subsoil use.
Таблица 1. Соотношение индивидуальных и общественных интересов при недропользовании.

Interests (preferences) of the individual subsoil users and their consequences	Interests (preferences) of the society in the field of natural resources
Interest – a maximum profit for a relatively short period of subsoil use	Considering the long-term nature of subsoil use in the interests of existence in the society
Interest – maximum use of the most accessible types of useful resources; minimization of internal expenses	Optimal use of all natural and resource potential of the territory (resources, environmental functions, and social role)
Consequences – low efficiency of certain types of mineral resources in the market conditions	Improving the efficiency of certain types of subsoil use that are little relevant to the market through the use of a set of natural resources
Consequences – side and indirect effects of subsoil use are ignored	Secondary and indirect effects are considered or are required to be considered
Interest – lack of interest in using the profits of subsoil use for environmental protection and technical improvement of production	Society's interest in the preservation of the natural environment, in the use of subsoil use profits in the creation and development of infrastructure for deep processing of extracted resources
Consequences – high risks of adverse environmental and economic situations	Reducing the impact of negative risks in the subsoil due to the change of species of wildlife, due to the summation of protective measures
Interests (preferences) of individual subsoil users and their consequences	Interests (preferences) of the society in the field of nature management
Consequences – high risks for the development of breakthrough technologies, inability to overcome the threshold of synchronous costs for breakthrough technologies	Taking risks and costs through guarantees, through budget financing, through targeted programs. The state is a major subject in the market of new technologies –
Consequences – "conservation of natural benefits" – are not taken into account or taken into account to a small extent	Interests assume: – employment in the region's economy; – long-term stabilization of the natural resource potential of the territory; – preservation of certain types of natural benefits (natural ecosystems)

Table 2. The sequence of greening the economy for the conditions of subsoil use (the use of parts of subsoil).
Таблица 2. Последовательность экологизации экономики для условий недропользования (с использованием участков недр).

Type of discounted income	Determination of the discounted income
Present value of Э with internal cost for the period T, years	$Э = \sum_{t=1}^{T} \frac{R_t - (З_t + З_{et})}{(1+P_t)^t} \to \max$
Present value based on the total amount of the costs	$Э = \sum_{t=1}^{T} \frac{R_t - (З_t + З_{et} + C_t)}{(1+P_t)^t}$
Discounted income, taking into account long-term environmental and economic consequences	$Э = \sum_{t=1}^{T} \frac{R_t - (З_t + З_{et} + C_t)}{(1+P_t)^t} \pm \sum_{t=T+1}^{>T} \frac{Y_t}{(1+P_t)^t}$

Note: R_t value of subsoil use products; $З_t$ – expenses; T – time; t – discounting period; $З_{et}$ – environmental costs of production, including costs of prevention of harm to the environment (for treatment facilities) and economic damage from environmental pollution (payment for emissions of polluting substances); P – a discount indicator; C_t – external expenses; Y_t – amount of long-term ecological and economic impacts over the period, much larger than T.

When using the "minimax cost" criterion, choose a land-use option for which the worst result is better than the worst for any other option:

$$\max_j P_j^{\min} = \min_j \max_i P_{ij}. \tag{2}$$

Criterion (2), compared to criterion (1), insures against negative consequences in the most unfavorable implementation of the land-use management system.

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

$$R_{ij} = P_{ij} - P_i^{\max} = P_{ij} - \max \overline{P}_{ij}.$$

The purpose of this criterion is to eliminate the risk of too much loss when extreme conditions of land use objects (climate change, flood risks, natural fires) appear.

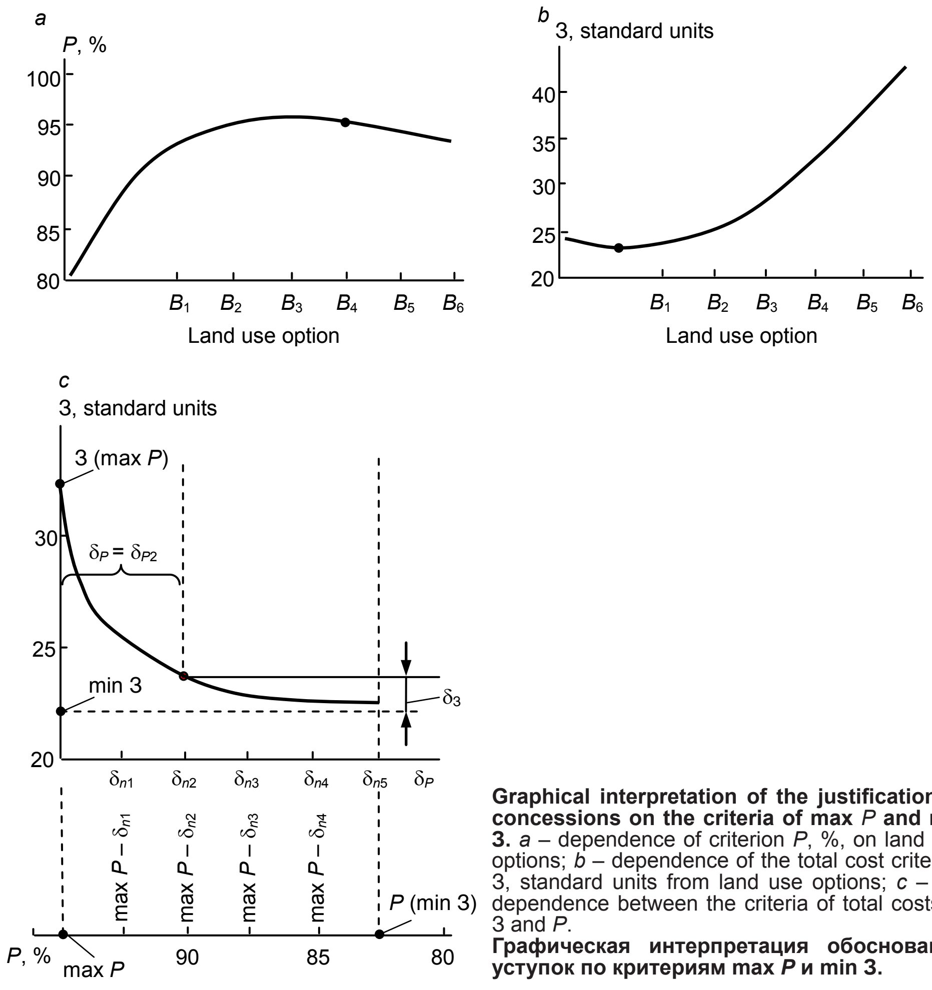
Multi-criteria optimization of sustainable land use is performed in relatively simple situations by lexicographical method, and in more complex cases – by successive concessions [14, 33]. For Figure the graphical interpretation of the justification of concessions α_P and $\alpha_З$ to the max P criteria (maximum land use efficiency – the level of resource potential) and min З (minimum total costs) is given.

Table 3. Values of discount rate and discount rate depending on the value of the period of discounting (on the model of complex processes).
Таблица 3. Значения ставки дисконта и коэффициента дисконтирования в зависимости от величины периода дисконтирования (по модели сложных процессов).

Discount period, years	Discount rate, ρ	Discount factor	Discount period	Discount rate, ρ	Discount factor
15–19	0.0820 – 0.0755	0.277–0.263	50–74	0.0346–0.0264	0.172–0.153
20–29	0.0667–0.0570	0.251–0.230	75–100	0.0249–0.0196	0.150–0.138
30–49	0.0502–0.0375	0.213–0.179	–	–	–

Table 4. The scheme of the matrix of land use options in the zone of uncertainty of optimal solutions.
Таблица 4. Схема матрицы вариантов землепользования в зоне неопределенности оптимальных решений.

Options of land use – parameters control $Y = \{f; s; r\}$	Conditions of multipurpose use – condition parameters $X = \{a; b; c; g; p; f\}$				
	X_1	…	X_j	…	X_6
Y_1	P_{11}	…	P_{1j}	…	P_{16}
Y_i	…	…	…	…	…
…	P_{i1}	…	P_{ij}	…	P_{i6}
Y_6	…	…	…	…	…
	P_{61}	…	P_{6j}	…	P_{66}



Graphical interpretation of the justification of concessions on the criteria of max *P* and min З. *a* – dependence of criterion *P*, %, on land use options; *b* – dependence of the total cost criterion З, standard units from land use options; *c* – the dependence between the criteria of total costs of З and *P*.
Графическая интерпретация обоснования уступок по критериям max *P* и min З.

The optimal option of land use is the solution of a two-criterion problem, solved in the following sequence:
1) Find max $P(X_1; Y_2)$.
2) Find min З $(X_2; Y_2)$ at $P(X; Y) \le \max P(X_1; Y_1) - \alpha_p$.

Summary

Concern about the current challenges and risks of sustainable land use is an important social goal for land use planning with all the diversity of land use. By attention to this, the issue of land use management should become one of the priorities of environmental, social and economic policy. The practical solution of methodological support of sustainable land use should be solved on the basis of the fundamental scientific base and the latest achievements of science and practice. Thus, the account of modern challenges and risks (accumulation of environmental harm increasing frequency of intensity of extreme weather and climate events) in sustainable land use in mining areas is to implement the proposed methodological regulations. The enterprises planning and management of land resources should be carried out on the basis of the sustainable land use management levels hierarchy within the concept of bio-environmental regulation and landscape planning of the territory within the administrative boundaries.

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УЧЕТ СОВРЕМЕННЫХ ВЫЗОВОВ И РИСКОВ В УСТОЙЧИВОМ ЗЕМЛЕПОЛЬЗОВАНИИ НА ГОРНОПРОМЫШЛЕННЫХ ТЕРРИТОРИЯХ

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Актуальность данной работы обусловлена ростом вызовов и рисков, возникающих на горнопромышленных территориях, и необходимостью противодействовать им.
Целью исследования является разработка методологии устойчивого землепользования в условиях современных изменений окружающей среды под влиянием антропогенных нагрузок. Понятие устойчивого землепользования авторы предлагают трактовать как долговременное, многоцелевое и экономически выгодное взаимоотношение общества и земельных ресурсов.
Результаты и их применение. Рассмотрены вопросы методологии устойчивого землепользования в промышленных регионах. Обоснованы уровни управления устойчивым землепользованием в рамках концепции биотической регуляции окружающей среды, раскрыты особенности управления на каждом из них, сформулированы научно-технические принципы устойчивого землепользования. Определены стратегические приоритеты и индикаторы устойчивого землепользования, сформулированы методические подходы к эколого-экономической оценке земельных ресурсов как по компонентам, так и по комплексной оценке, с учетом широкопространственных, долговременных изменений земельных ресурсов и трансформации экосистем. Выявлены параметры, согласно которым определяются «коридоры» допустимого землепользования, в их числе: экологические параметры, уровень сохранения естественных экосистем, баланс природных и антропогенных потоков энергии, степень изъятия природных ресурсов, а также социальные параметры. Предложена процедура согласования индивидуальных интересов и общественных предпочтений на основе поиска оптимальных эффективных вариантов устойчивого землепользования. Рекомендуется выполнение многокритериальной оптимизации устойчивого землепользования лексикографическим методом в относительно простых ситуациях, а в более сложных случаях – методом последовательных уступок. Предложены варианты значений ставки дисконта и коэффициента дисконтирования в зависимости от величины периода дисконтирования (по модели сложных процессов). Реализация разработанных методологических положений позволяет обеспечить условия для устойчивого землепользования, противодействующего рискам, связанным с экологическими вызовами, возникающими на горнопромышленных территориях.

Ключевые слова: устойчивое землепользование; методология устойчивого землепользования; уровни управления; индивидуальные и общественные интересы; многокритериальная оптимизация.

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