Ecological and Economic Evaluation of the Disturbed Lands Recultivation Projects in the Republic of Crimea

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Abstract. The development of the extractive industry leads to the increase in the number of quarries on the territory of the Crimean peninsula and, as a consequence, to the increase of the area occupied by the disturbed lands requiring recultivation. The reclamation of such land plots on the basis of creating the necessary conditions for the development of regenerative successions of zonal vegetation on them and ultimately the formation of soils is much cheaper for land users. Therefore, studies of the rates of soil formation, including using the methods of mathematical modeling of the processes of formation of the humus horizon of the soil over time, have become relevant.

Calculation of the economic efficiency of reclamation of the disturbed lands has been carried out for the Alexandrovskoye saw-limestone field in the Chernomorsky region of the Republic of Crimea. The assessment has been carried out within the framework of two models: mining engineering with further self-overgrowing of the reclaimed land plots under pastures and integrational, including both mining engineering and biological stages with possible carrying out a number of agrotechnical works on further improvement of pastures, based on the calculation of the cost-effectiveness indicator. This indicator is based on the selection of the best options for remediation work at the minimum value of the integral operational and investment costs and takes into account the effect of the time factor. The calculation results have shown that, in terms of cost-effectiveness, it is more rational to use the mining engineering model with further self-overgrowing of the sites to be reclaimed when it comes to the reclaiming of the disturbed lands of the Alexandrovskoye quarry.

1. Introduction
The development of the extractive industry in the Crimea in recent years has led to the growth of quarries and an increase in the area of the disturbed land. According to statistics from the Ministry of Ecology and Natural Resources, about 80% of the total area of anthropogenically transformed land have been occupied by open-pit mining at quarries. Almost 4881 hectares of land are in the disturbed state, of which 1,516...
hectares require recultivation [1, 2]. These are territories where large areas are occupied by dumps, excavations of rocks having been formed during the extraction of minerals (iron ore, agrochemical raw materials, building materials: limestone, rubble and crushed stone, sand and gravel, brick-tiled and ceramic raw materials, etc.), under the intensive reclamation, industrial and residential construction, etc. The reclamation of such sites and creation of necessary conditions for the formation of soils on the disturbed or artificially created surfaces, together with the restoration successions of zonal vegetation, is the basis of the restoration dynamics of ecosystems, which is much cheaper for land users.

2. Relevance and problem statement
At the current rate of reclamation, it will take decades to return the lands to economic use. When developing measures for the reclamation of dumps of deposits, an urgent task is to study the processes of soil formation on the surfaces disturbed or artificially created by man. At the same time, it is necessary to take into account such important methodological aspect that ecosystem, using internal mechanisms, is capable of a self-healing process. Zonal conditions for the occurrence of these processes have repeatedly become the object of soil genetic and economic research [3, 4, 5, 6, 9].

Usage of the variety of techniques to intensify the process of soil formation: the application of soil-replanting, biological reclamation and other progressive measures, sometimes leads to higher costs of reclamation of the disturbed lands [6, 7, 8, 9]. We believe that the most cost-effective measures will be aimed at stimulating the process of soil self-healing. The development of the system of measures aimed at stimulating the soil formation processes will make it possible to actively include the reclaimed land in agricultural use. When developing remediation strategies, it is necessary to take into account the fact that the reclamation of one hectare of land at current prices ranges from 800 000 rub./ha to 2 000 000 rub./ha - taking into account the totality of costs. Therefore, an economic analysis of the effectiveness of measures for the remediation of dumps on the basis of taking into account the rates of natural soil formation will be timely and relevant.

3. Research results and their practical significance
As a result of the field studies of the disturbed lands in the dumps of mineral deposits of the peninsula, we have analyzed the peculiarities of soil formation at the “initial” stages of soil formation. The properties of soils being formed on different parent rocks are largely determined by the relationships in the biota – substrate system, and therefore in young soils, whose age varies from several years to several decades, the processes of tillage take place much more intensively than in full-profile counterparts [9]. To assess the intensity of the formation of humus soil horizon in areas of the disturbed land, it is advisable to use previously obtained models of the formation of humus soil horizon in the early stages of soil formation (less than 200 years). For the territory of the disturbed lands, where the major parent rocks are primarily loess clay, loam, red-brown and yellow-brown clay model of soil humus horizon is given by [10]:

\[ H = 162 \cdot \exp[-\exp(1.0 - 0.02 \cdot T)], \]

(1)

where \( H \) - the humus horizon mm; \( T \) is the time of soil formation, years.

Based on the model (1) for uneven soil, speed formation of soils having been formed on loose parent material is defined by the following formula [10]:

\[ V = (-\lambda) \cdot H \cdot \exp(a + \lambda T) \cdot \exp[-\exp(a + \lambda T)], \]

(2)

where \( V \) - velocity of soil in mm/year; \( \lambda, \alpha \) - coefficients characterizing the initial conditions of soil formation.
According to models (1) (2), in the conditions of the Crimean peninsula at the initial stages of soil formation (from 10 to 50 years), the rates of soil formation reach maximum values of 0.8-1.2 mm/year. Subsequently, the formation of the humus horizon significantly decreases from 0.8 mm/year after 100 years from the beginning of soil formation to 0.2 mm/year after 200 years, which ensures the formation of soil almost 20 mm on the rock surface after 10 years; in 20 years, the capacity increases to 26 mm, in 25 years - 30 mm [10]. This allows us to recommend the reclamation of the disturbed lands, taking into account the natural rates of soil formation, that is, the conduct of the mining and technical stage with further self-overgrowing of plots. An analysis of the economic efficiency of such reclamation models will make it possible to make adjustments to the projects being developed.

In evaluating rehabilitation projects, not only their social and environmental consequences, but also technical and financial and economic results should be considered [11]. At the same time, the financial and economic results of the selection of projects for introducing them into the plan for remediation activities should be based both on assessing their compliance with the strategic goals of the land user and on comparing possible alternative approaches to solving the set tasks using certain performance criteria [12]. Information characterizing a rational project, the conditions for its implementation should be contained in the relevant justification, which is prepared, and implemented in the business plan.

From the recognized methods of assessing the financial and economic efficiency of various investment projects [13] to assess the remediation activities of the disturbed land plots, in our opinion, it is possible to use the following:

– not taking into account the effect of the time factor and being used, as a rule, at the stage of preliminary selection of projects [14];

– based on the action of the time factor and serving the purpose of the final selection of the best project options for the maximum income from the available alternatives [15];

– based on the action of the time factor and serving the purpose of the final selection of the best project options for the minimum amount of operational and investment costs of the available alternatives [15].

The main financial and economic performance assessment of remediation projects and similar one-time events in the first method [16] are: payback period (T<sub>o</sub>) and the coefficient of efficiency of investments (І<sub>k</sub>) in the project. However, they do not allow to adequately evaluate projects, because they do not take into account the effect of the time factor.

The second method is based on the selection of the best options for the remediation work on the maximum value of the integral income, taking into account the time factor and is calculated using the indicators: net present value of the project (NPV); its internal rate of return (IRR); profitability index (PI) project [17]. The practice of calculating of these indicators shows that their use in evaluating and analyzing projects of this type is very limited, since the calculation of the value of the net cash flow is very difficult.

The third method, based on the selection of the best options for reclamation work on the minimum value of integral costs and taking into account the time factor, is represented by the indicator of cost effectiveness (EAC), the decision criterion which evaluates projects only by costs [18, 19]. It can be used when there are two or more alternatives with the same result. For the selection of the project is not necessary to make complex calculations of positive cash flow. The decision rule is to choose the option that has the lowest cost. Bearing in mind that all costs, both investment and operating costs, are multi-temporal in the project of restoration works, the costs should be aligned with the equivalent annual costs. The calculation of the cost-effectiveness indicator for alternative projects is carried out according to the formula [20-21]

\[ EAC = \left[ \sum_{t=0}^{n} K_t(1 + p)^{-t} + \sum_{t=0}^{n} AC_t(1 + p)^{-t} \right] \cdot \left[ \sum_{t=0}^{n} (1 + p)^{t} \right]^{-1}, \]  

(3)
where \( t \) is the serial number of the year; \( K_t \) - investments in the project in the year, rub.; \( AC \) - average annual operating costs for the care of the land plot after the completion of restoration works, rub.; \( p \) is the discount rate; \( m \) - the duration of the period during which investment have been made, years; \( n \) is the duration of the period during which the performance evaluation has been carried out, including agrotechnical work to further improve the land, years.

Evaluation of the effectiveness of the remediation measures has been carried out for the Alexandrovskoe field of saw limestone, located in Chernomorsky region of the Republic of Crimea, on the Tarkhankut peninsula. Based on the practice of land reclamation, the assessment of the effectiveness can be carried out within the framework of two models of the remediation projects with minimal financial and economic costs: mining engineering with further self-overgrowing of the reclaimed land plots under pastures and integration, including both mining engineering and biological stages, with the possible implementation of the number of agrotechnical works to further improve pastures (turf disking, rolling by rollers, sowing grass mixtures, etc.).

In this project of reclamation of the disturbed lands (57.6 hectares) of the Alexandrovskoye field of saw limestone, it is assumed that in the next fifty years of further exploitation of the land plot under an exhausted deposit, its economic use is possible only as a pasture, which does not involve the production of real products. Consequently, in a timely manner, a positive cash flow will not be generated. In subsequent years, a low level of positive cash flow is possible with a low coefficient of probability when sowing annual and perennial grasses and unproductive grain crops, therefore the value of such cash flow can be neglected. The data for calculating of the performance indicators of rehabilitation projects with minimal financial and economic costs for the Alexandrovskoye saw-limestone deposit is presented in Table 1.

### Table 1. Baseline data for assessing the effectiveness of the reclamation of the Alexandrovskoye quarry (under pasture)\(^a\).

| Indicators for assessing the project | Model of recultivation                  |                      |
|-------------------------------------|-----------------------------------------|----------------------|
|                                     | mining and technical stage with         | integration project  |
|                                     | further self-development                |                      |
| Investment in the project of        | 10753,65                                 | 27102,09             |
| recultivation, ths. Rub. -          |                                          |                      |
| total, incl. project years          |                                          |                      |
| initial investment in project       | 10753,65                                 | 18309,3              |
| implementation                      |                                          |                      |
| investments in the 2nd year of the  | –                                        | 4370,97              |
| project                             |                                          |                      |
| investments in the 3rd year of the  | –                                        | 4421,52              |
| project                             |                                          |                      |
| Average annual net cash flow, rub.  | –                                        | –                    |
| Discount rate, %                    | 10                                      | 10                   |
| Duration of the period during which | 50                                      | 50                   |
| the project is estimated, years     |                                          |                      |
| Average annual operating production | –                                        | 173,7                |
| costs for pasture maintenance, ths. |
| Rub.                                |                                          |                      |

\(^a\) – all data are defined in 2017 prices.

The assessment of the Alexandrovskoye saw-limestone deposit in the two previously presented reclamation models is possible only on the basis of the third group of methods, namely the cost-effectiveness method, since the result in terms of net cash flow will be either negative, which indicates the inefficiency of the projects (table 2), or to obtain such a result is not possible, which is also a negative result for the calculation. Consequently, the assessment of the financial and economic efficiency of the recultivation projects for the land plot of the Aleksandrovskoye quarry as a whole in terms of the indicators of both the first and second groups is either not defined (\( T_o, IRR, PI \)), or is zero (\( I_k, NPV \)).
Evaluation of the effectiveness of reclamation of the disturbed lands of the Alexandrovskoye quarry in terms of cost-effectiveness (table 2) indicates that the land reclamation model based on the mining engineering works with further self-overgrowing of the reclaimed sites is more efficient by 2,238,481 rub. or 1.7 times.

**Table 2.** Indicators for assessing the effectiveness of the reclamation of the Alexandrovskoye quarry

| Indicators for evaluating the effectiveness of the | Model of reclamation of |
|--------------------------------------------------|-------------------------|
|                                                  | mining engineering stage with further self-expansion of the |
|                                                  | integration project     |
| The payback period of the project, years         | x                       |
| The efficiency of investment in the project, %   | --                      |
| Net present value of the project, rub.           | --                      |
| Internal rate of return, %                       | x                       |
| Yield index                                      | x                       |
| Cost effectiveness, rub.                         | one 315,454             |
|                                                  | 3,553,935               |

* all calculations were made in prices of 2017.

4. Conclusions
In the context of the current socio-economic situation, the potential for self-healing of soils must be taken into account when designing and implementing measures for the rehabilitation of the territory of mineral resource dumps. During the reclamation of dumps in the modern conditions of the Crimea, the rate of formation of the humus soil horizon varies from 2.77 mm/year to 1.31 mm/year and over 20 years, a humus horizon is being formed, having a thickness of more than 2 cm. Measures to intensify the process of soil formation (mineral and organic fertilizers, irrigation, etc.), lead to a slight increase in the rise of the capacity of the humus horizon, which reduces the economic efficiency of such works.

Evaluation of the efficiency of the reclamation of the disturbed lands of the Alexandrovskoye quarry shows that it is more rational to apply in practice a model of land reclamation based on mining engineering works with further self-overgrowing of reclaimed sites.

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