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Investigation and evaluation of ecological destruction in a mining area in Mongolia

Zijun Li, Purevsuren Tsogt*

School of Resources and Safety Engineering, Central South University, Changsha Hunan 410083, China

**Corresponding author. Email: ptsogt@yahoo.com, ORCID: 0000-0002-8303-5983*

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ABSTRACT

Aim of this study was to calculate economic value of destructed land in Mongolia in order to facilitate restoration of mining area. Total economic value is a universal framework for estimating and evaluating economical damage cause to environment due to mining activities and other technogenic production activities. Compensation for environmental and financial damage can be determined based on the following three categories: initia restoration, restoration by compensation and evaluation of ecological damage. Main object of this study is direct economic value of destructed environment due to Tumurtei iron ore mine activity. All estimations in this paper are made according to Mongolian legislation and laws. During that project a total of 511.9 hectares of area are exposed to environment destruction. Estimation of ecological damage are consisting of following parts: damage to soil, damage to surface and groundwater resources, damage to forest resources, damage to vegetation and damage to animal fauna. The assessment of ecological and financial damage to the environment is performer in following stages: 1. determine the amount of potential damage to the environment; 2. calculate and determine the amount of damage reduced as a result of measures to reduce or eliminate damage to the environment during production activities; 3. estimate the amount of actual damage resulting from the operation. Results of this study concerning interests of mining entities and public entities, who are in charge of regulating such activities.

Keywords: *Ecological damage, Economical value, Environment, Tumurtei iron ore*

INTRODUCTION

There is still no established system for incurring liability for amount of environmental destruction and conducting appropriate ecological and financial evaluations, which makes it very difficult to compensate environmental damages and hold responsibility for accountables (Chen et al., 2018). Once damaged environmental assets makes it difficult to evaluate ecological and financial numerical damages and has huge negative impact on country's socio-environmental development (Allington et al., 2018). Therefore its crucial to evaluate ecological damages in regulation of natural resources usage and its further compensation by mining entities (Reeves, 2011).

Ecological and financial evaluation of destruction area due to mining activities should be made prior to the commencement of mineral exploration and mining activites (Gao et al., 2016; Fisher, 2008; Boyd et al., 2009). According to this, such prior estimations have following positive impacts: 1) prevent risk of further ecological and financial damage to mining companies, 2) invest in modern environmentally friendly techniques and technologies, 3) save huge amount of money spend by state budget on rehabilitation of already damaged environment (Han et al., 2009).

This paper will cover a methodology for evaluation of financial damage to environment from the mining industry. The objectives of this work are defined as follows:

- Study actual requirements and possibilities of developing and applying methodology for estimation of financial damages to environment
- Evaluate ecological damages caused by Tumurtei iron ore mining activities and estimate future value to investigated ecological destruction

The assessment of ecological and financial damage to the environment shall be based on the amount of damage caused to the environment or natural resources and will be expressed in monetary terms (Farber et al., 2006; Shim, 2012).

Results of this paper are concern of mining companies in reference to establishment of contingency fund, prevention from being exposed by multiplied compensation of ecological damage and establishment of financial accountability mechanism for state entities (Son et al., 2009).

LITERATURE REVIEW

This concept of total economic value is based on a detailed approach to the value of nature in an attempt to take into account in the assessment not only direct use values from the use of natural resources (Plottu and Plottu, 2007). Various other usefulness's are also taken into account, which are associated with the preservation and improvement of other qualities of the natural environment: assimilation ability, human environment and livelihoods, conditions for the development and distribution of productive forces, gene pool and species diversity of the plant and animal world (World bank, 2009).

The concept of total economic value is the most relevant to the environmental worldview and fundamental in the theory of economic valuation of natural resources (Flores et al., 2015). It does not contradict existing approaches and methods in economic valuation and, combining them, is not closed, open to the development and development of new approaches and methods. Total value of environmental assets consists

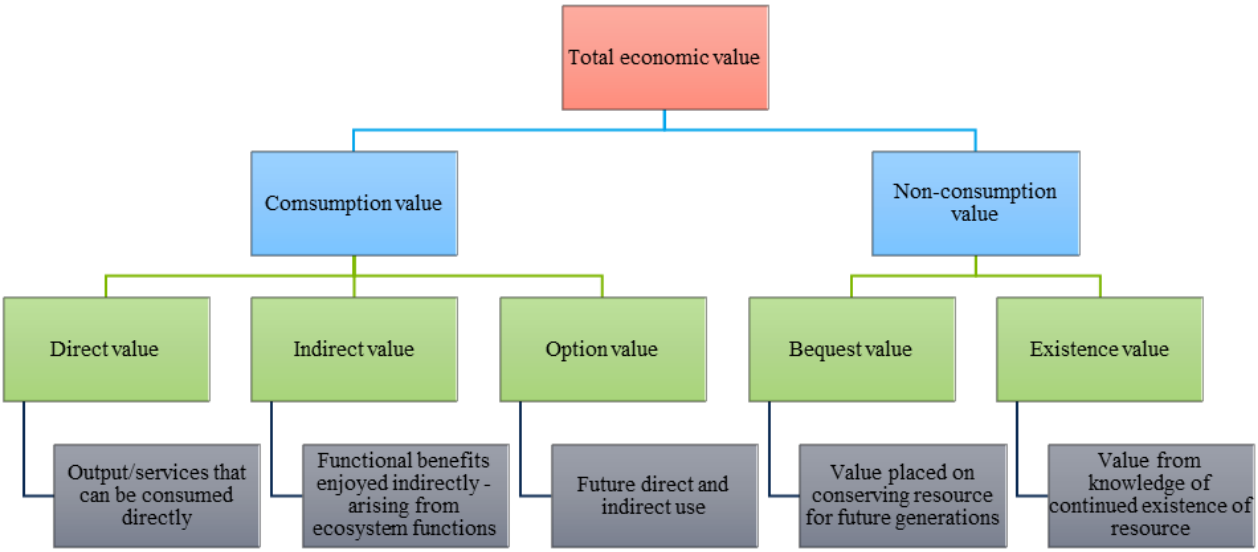

Fig. 1. Breakdown of total economic value of ecological destruction. Source: Davis et al., 2019

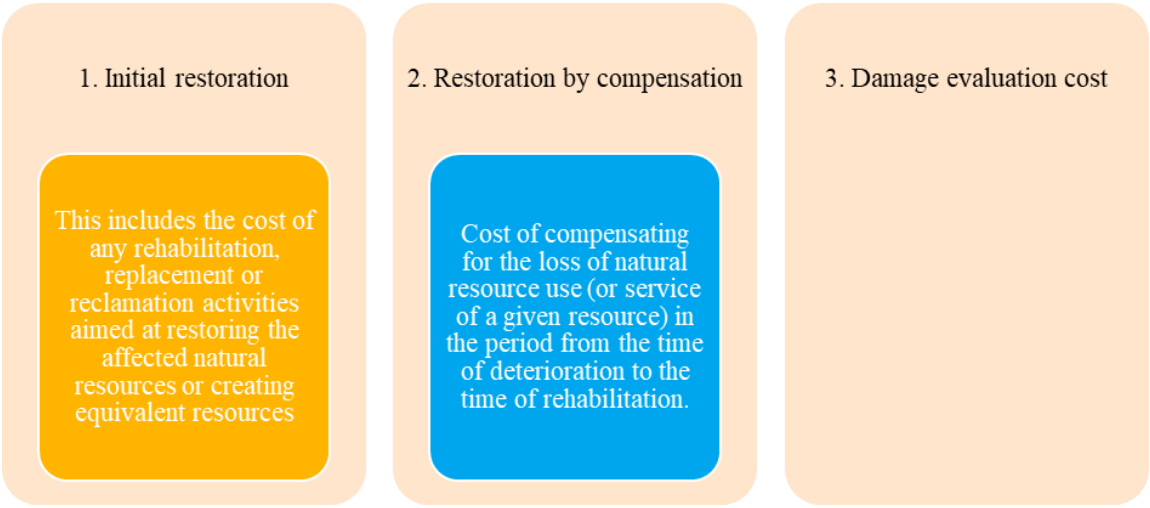

Fig. 2. Types of environmental destruction compensation activities

from following (Fig. 1; Davis et al., 2019):
The concept of total economic value is in good agreement with economic categories and concepts of public consumption of natural resources and goods, adopted by the system of accounting for natural resources and their classification into categories. Such a classification is carried out depending on the degree of intelligence, the economic feasibility of preparing for operation and inclusion in the economic turnover (Ganzorig et al., 2017).
In a region with a developed mining industry, it is important to follow the principles of correctly identifying natural resources, ecological carrying capacity, putting observation, monitoring and management information into circulation, and resolving technological financing issues step by step (Isakawa et al., 2012).
Compensation for environmental and financial damage can be determined based on the following three categories in Fig. 2. (Galindev et al., 2016).

DATA AND METHODOLOGY

Research basis
Research calculation and estimations are made according to Mongolian law and legislations, which includes:

- Law on Environmental Protection
- Law on Subsoil
- Law on Land
- Law on Forests
- Law on Toxic and Hazardous Chemicals

Data processing method.
The assessment of ecological and financial damage to the environment during any production process is calculated by direct and indirect methods.

Direct method of ecological and financial damage assessment.
The direct method of estimating ecological and financial damage is usually determined by the amount of costs required to rehabilitate and restoration activities. Direct estimates of the amount of damage require the collection and processing of a large number of statistical data.

Indirect method of ecological and financial damage assessment.
Indirect methods shall be used when it is not possible to directly estimate the damage to the environment as a whole, and when it is not possible to take measures to improve the environmental conditions. The indirect method is based on the negative impact on the environment and the normative ratio.
The assessment of ecological and financial damage to the environment will be carried out in the following stages. This includes:

1. To determine the amount of potential damage to the environment
2. To calculate and determine the amount of damage reduced as a result of measures to

reduce or eliminate damage to the environment during production activities
3. Estimate the amount of actual damage resulting from the operation

The ecological and financial damage caused by mining to the environment can be classified into the following components. These include:

1. Soil damage
2. Damage to surface and groundwater resources
3. Damage to forest resources
4. Damage to vegetation
5. Damage to animal fauna

RESULTS

Estimation of ecological destruction by indirect method

Below table shows decomposition of area to be destructed by Tumurtei iron ore mine, where total area of exposed environment is calculated at 511.9 hectares (Table 1).

Estimation on soil destruction

The economic value of the soil distributed at the Tumurtei mine site is calculated using the base market price approved in Mongolia. The estimated value of soil humus resources for 193.2 hectares of moderately degraded land is 756,519.4 thousand MNT. Total environmental damage caused to soil is 1,570981.6 thousand MNT. In other words, average 1 hectare is priced at 2,804.5 thousand MNT (Table 2).

Evaluation of damage to surface and groundwater resources

A total of 12,037,242 m^3 of groundwater will be used for industrial purposes during the life of the project. The amount of damage was calculated based on the current market value of water (Table 3). Based on the Government Resolution No. 302 of 2011 and Resolutions 326 and 327 of September 21, 2013, the water use fee shall be paid based on the basic ecological and economic assessment of water and the percentage to be imposed on it. 156.6 MNT.

Table 1. Decomposition of destructed land caused by Tumurtei iron ore mine

№	Exposed area	Area		Topsoil thickness, m	Topsoil volume, $м^3$
		m^2	ha		
1	Open pit mining	851,986	85.2	0.3	255,673
2	Dump №3	663,329	66.3	0.3	198,999
3	Dump №2	752,787	75.3	0.3	225,836
4	Dump №1	588,535	58.9	0.3	176,561
5	Dumps №4	386,067	38.6	0.3	-
6	Tailings dam /wet/	506,663	50.7	0.3	151,999
7	Road	198,446	19.8	0.3	59,534
8	Dry concentrator 1, 2	124,200	12.4	0.3	37,260
9	Ore stockpile /Oxidized/	47,232	4.7	0.3	14,170
10	Ore stockpile /Low sulfur/	7,956	0.8	0.3	2,387
11	Ore stockpile /with sulfur/	117,747	11.8	0.3	35,324
12	Wet concentrator	124,800	12.5	0.3	37,440
13	Repair shop	10,000	1.0	0.3	3,000
14	Dry waste stockpile	259,024	25.9	0.3	77,707
15	New camp	184,264	18.4	0.3	-
16	Concentrate area	159,316	15.9	0.3	36,900
17	Export concentrate area	37,000	3.7	0.3	11,100
18	Gas station	27,000	2.7	0.3	8,100
19	Piles of intermediate products	72,879	7.3	0.3	21,864
	TOTAL	5,119,231	511.9		1,353,852

Table 2. Ecological and financial assessment of the soil damage

Ecosystem	Degree of destruction	Exposed area, ha	Loss of soil resources, tons	Valuation, thousand MNT	Valuation of 1 hectare of soil, thousand MNT
Forest	High	65.8	3,308.6	165,431.7	2,515.8
Forest	High	151.7	9,985.1	499,254.2	3,290.0
Mountain steppe	High	101.2	2,9995.5	149,776.3	1,480.5
Mountain steppe	Medium	142.6	12,884.5	644,225.1	4,516.3
Steppe	Medium	50.6	2245.9	112,294.3	2,220.0
Total damage		511.9	31,419.6	1,570,981.6	

Table 3. Ecological and financial assessment of the water consumption damages

Year	Ore production, tons	Water consumption, m^3/ year	Groundwater unit price, MNT/m^3	Total value, thousand MNT
3	5,000,000	1,321,075	773.9	1,022,379.9
4	5,000,000	1,321,075	773.9	1,022,379.9
5	5,000,000	1,321,075	773.9	1,022,379.9
6	5,000,000	1,321,075	773.9	1,022,379.9
7	5,000,000	1,321,075	773.9	1,022,379.9
8	5,000,000	1,321,075	773.9	1,022,379.9
9	5,000,000	1,321,075	773.9	1,022,379.9
10	5,000,000	1,321,075	773.9	1,022,379.9
11	4,370,992	1,154,882	773.9	893,763.2
12	1,187,520	313,761	773.9	242,819.6
Total	45,558,512	12,037,242		9,315,622.4

Table 4. Ecological and financial assessment of forest resources affected by mining

№	Tree type	Area, ha	Resource	Wood, m^3	1m^3 wood price	Total value, MNT
1	Birch	175.5	12,929.1	6,837.0	57,000	701,476,200.0
2	Pine	63	4,852.8	4,011.0	120,000	866,376,000.0
3	Poplar	36.6	2,552.7	1,251.0	48,000	108,086,400.0
4	Total	275.1	20,334.6	12,099.0		1,675,938,600.0

Evaluation of environmental damage to forestry

A total of 275.1 hectares of forest will be affected by the mining of the western ore body in the eastern part of the Tumurtei iron deposit (Table 4). The ecological and economic assessment of the forest resources to be mined was calculated based on the methodology approved by the Order No. A/176 of the Minister of Nature, Environment and Tourism on "Approval of Forest Ecological and Economic Assessment" in 2020.

The ecological and economic assessment of the damage to the forest area related to the mine operation is 1,675,938.6 thousand MNT (Table 5).

Assessment of damage to vegetation

Unit land price for 1 m^2 is taken as equal to 54820 MNT. According to internal survey, useful plants cover 4.16% of total area, pasture plants 80.3% and anthropophyte plants account for 30.6% of total area. Pasture and

Table 5. Ecological and economic assessment of the forest area affected by mining

№	Tree type	Area, ha	1 ha forest value	Total value, MNT
1	Birch	175.5	3,997.0	701,476,200.0
2	Pine	63	13,752.0	866,376,000.0
3	Poplar	36.6	2,953.2	108,086,400.0
4	Total	275.1		1,675,938,600.0

Table 6. Estimation of environmental damage to vegetation and plants

№	Type	Area, ha	Unit	Unit price	Area coverage	Value per year, MNT
1	Useful plants	511.9		548,200	4.16%	11,673,940.93
2	Pasture plants	511.9	35000 kg/ha	4,000	80.30%	57,547,798.00
3	Anthropophyte plants	511.9	35000 kg/ha	4,000	30.60%	21,929,796.00
4	Total annual value					91,151,534.93
5	Project total value					1,093,818,419.1

Table 7. Consolidation of ecological and financial evaluation

Natural resources affected by the project	Note	Measurement unit	Amount	Valuation of 1 hectare, thousand MNT, annual	Total value, thousand MNT, for 10 year period
Ecological and financial assessment of soil	Total mining activity site area	ha	511.9	3,068.9	15,709,816.0
Ecological and financial assessment of plants and vegetation	Total vegetation destroyed during open pit operation	ha	511.9	2,136.8	10,938,184.0
Ecological and financial assessment of forests	Forests to be destroyed during the project implementation	ha	511.9	3,274.0	16,759,386
Ecological and financial assessment of water	Water drainage during the project	Thousand m^3	12,037.4		9,315,622.4
Ecological and financial assessment of biodiversity	Extinction of wildlife	P	N/A		
Total ecological and financial assessment		ha	511.9	26,677.8	52,723,008.4

anthropophyte plants have output of 35000 kg per hectare. Total environmental destruction evaluation to vegetation is estimated as 1,093,818.4 thousand MNT (Table 6).

Total ecological and financial assessment

During the operation of the Tumurtei deposit, the soil cover, vegetation cover and forest fund of 511.9 ha of forest area will be damaged. During ore mine operating timeframe, 15,709,816.0 thousand MNT accountable for soil damage, 9,315,622.4 thousand MNT accountable for groundwater, 10,938,184.0 thousand MNT accountable for vegetation and plants, 16,759,386.0 thousand MNT for the forest. Total environmental damage estimated at 52,723,008.4 thousand MNT (Table 7).

Estimation of the future value of environmental damage

The future monetary value of the total environmental and financial damage to the

Table 8. Estimation of future monetary value of the total assessment of ecological and financial damage

№	Year	Future value
1	2020	52,723,008.40
2	2021	58,522,539.32
3	2022	64,960,018.65
4	2023	72,105,620.70
5	2024	80,037,238,98
6	2025	88,841,335.27

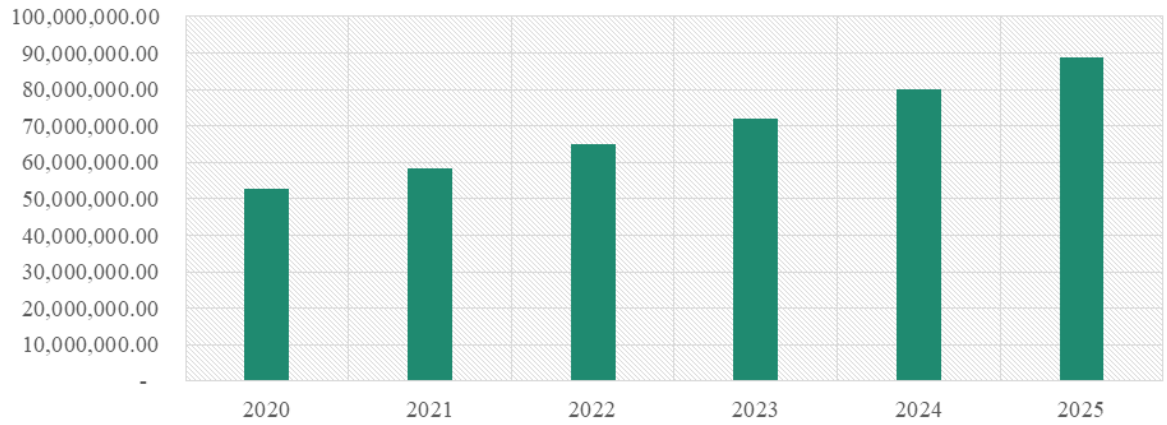

Fig. 3. The future monetary value of environmental and financial losses

Tumurtei iron ore deposit is estimated for 5 years, using the formula for the future value of the current amount of money calculated using a compound interest rate over a period of time:

$$FV = PV * (1 + i)^t$$

Here: FV - future value
i - interest rate on central bank bills
t - time

Based on the above estimates, the total environmental damage caused by mining at the Tumurtei iron ore deposit is estimated at MNT 52,723,008.4 thousand or MNT 52.7 billion. The interest rate on central bank bills is estimated at 11%. Therefore, the future monetary value of this valuation is found as follows (Table 8 and Fig. 3).

DISCUSSION

The concept of shared economic value allows:

- show the variety of environmental benefits and forms of their manifestation in space and time;
- to expand ideas about value from a single natural good to their totality, from the manifestation of direct effects to taking into account indirect effects in value;
- to complement modern approaches to the definition of value with awareness of its significance for the planet and as a duty to future generations.

General economic value inherently expresses an approach to taking into account the socio-economic efficiency of territories in which natural resources are exploited. Direct value is complemented by such socio-economic effects as a clean environment, health status, people's satisfaction with natural goods, the state of their habitats, recreation, etc. As a result, the overall economic value reflects the socio-economic value of the source of resources, natural and environmental benefits.

CONCLUSIONS

Mongolia's mining sector is one of the key sectors of the economy, which dominates not

only the industrial sector but also the economy as a whole. However, the negative impact of the mining industry on the environment is increasing year by year, and the damage caused by it is also increasing. For example, in terms of mining output, iron ore mining and coal mining have the highest environmental impacts and financial losses. Therefore, it is necessary to calculate the ecological and financial assessment of the deposit before the development of the deposit or during the development of the exploration and feasibility study.

Suggestions

If the estimate proves that the project entity is incapable of financing environmental protection measures from its mining revenues, the project should not be considered for further implementation and should not be approved.

It is necessary to estimate the future monetary value of this total assessment from the year of operation and constantly make monitoring on environmental and financial damage. According to this calculation, if the party at fault continues to lose time without paying the damages, the estimated total ecological and financial damage will increase from year to year and mining entity will be subject to greater financial risk. On the other hand, mining companies need to establish an environmental and financial damage risk fund. In doing so, a certain percentage of the mine's sales revenue will be raised.

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