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# Assessing the Possibility of Use Waste Rock Dumps as Elements of Ecological Network to Deter Agricultural Land Degradation and Promote Biodiversity in Mining Regions

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## ABSTRACT

The paper considers the methodological approaches to the use of waste rock dumps of mining enterprises as elements of regional ecological networks. Such use of dumps will promote their biological reclamation and application of measures aimed at prevention of erosion and pollution of soil cover of agricultural lands located in the zone of influence of dumps. The aim of the research was to develop a methodology for the selection of waste dumps for their inclusion in the ecological networks of Ukraine. The objects of the research were waste dumps of coal mines of the Donetsk coal basin (Donbas). The main research method is the analysis of space images using Google Earth tools. It is shown that in the conditions of the lack of forest and land resources, waste dumps can be used in the ecological network of coal mining districts and towns not only as "restorable territories", i.e. reserve territories, but also as "interactive elements" of "key territories" ("natural kernels") and ecological corridors. A three-stage scheme for assessing the suitability of waste dumps as elements of the ecological network is proposed, which includes 3 indicators of the suitability of dumps for the requirements of restorable territories, 2 indicators of the suitability for the requirements of kernels, and 2 indicators of the suitability for the requirements of interactive elements. The system of evaluation of dumps in points for their ranking by the order of their inclusion in the schemes of the local ecological network is developed. Biological engineering measures have been proposed to better integrate the dumps into the local ecological network. These measures will result in improved protection of agricultural land from pollution, water and wind erosion.

**Keywords:** soil pollution, erosion, ecological network, biodiversity, animal migration.

## INTRODUCTION

According to scientists' assessment, the state of land resources in Ukraine is approaching a critical level [Baliuk et al., 2017]. Agricultural land is subject to soil degradation processes, the most large-scale of which are erosion and pollution. The area of eroded land in Ukraine is 12 million ha [Koliada et al., 2022] or 36.2% of arable land. For comparison, in Europe, erosion processes cover 12% of its territory [Radu and Burcea, 2023]. The area of arable land contaminated with heavy metals is 8% [Baliuk et al., 2017]. The humus content decreases in eroded soils. Therefore, in Ukraine, as well as all over the world [Radu and Burcea, 2023], soil erosion negatively affects the amount of agricultural production, and as a result of soil pollution, its quality is reduced.

Most land pollution is caused by mining enterprises, of which there are more than 2000 in Ukraine. As a result of their operations, a very large amount of waste has been generated, mainly in the form of high dumps. These include coal mine dumps, called terricones in Ukraine. On the territory of the Lviv-Volyn coal basin (western part of the country) there are 30 dumps [Yatsukh and Demchyshyn, 2009], occupying more than 350 hectares. In the Western Donbas (eastern part of the Dnepropetrovsk region) there are 9 dumps occupying more than 190 ha [Petlovanyi et al., 2023]. The majority of the dumps (1290) are located in the central part of the Donetsk coal basin (Donbas). They occupy more than 6000 ha, and due to the catastrophic development of water and wind erosion on the surface of the dumps, 35765 ha of land is polluted [Zubov et al., 2023].

Soil pollution from coal mining is typical for Ukraine [Petlovanyi et al., 2023; Yatsukh and Demchyshyn, 2009], as well as for China [Guo et al., 2011], USA [Chugh and Behum, 2014], India [Mishra and Pujari, 2005], Indonesia [Yuningsih et al., 2023] and many other coal producing countries [Alekseenko et al., 2018; Marcisz et al., 2021; Ribeiro and Flores, 2020; The Coal Resource, 2005].

As a result of soil pollution, plant products are contaminated [Alekseenko et al., 2018; Guo et al., 2011; Khan et al., 2015], and the yield of agricultural crops decreases [Kumar, 2013; Mishra and Pujari, 2005], which threatens the health [Khan et al., 2015] and food security of the population [Lu et al., 2015]. Biodiversity is declining [Yuningsih et al., 2023].

According to the Law «On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the period up to 2030» [The draft law…, 2018], in order to stop the processes of environmental degradation and achieve ecological balance of the territory of Ukraine, the task of increasing the area of the National Ecological Network is raised. A significant problem of the creation of eco-network in the mining areas is the lack of land.

According to scientists of Ukraine [Mudrak et al., 2022; Shapar and Skripnik, 2004; Zubova et al., 2010], this situation can be improved by including waste dumps in the ecological network. And there is a legitimate reason for this. In the «Methodological Recommendations for the development of regional and local schemes of eco-networks», approved by Order No. 604 of the Ministry of Natural Resources of Ukraine dated 13.11.2009, there is an indication to include degraded areas, such as quarries and waste rock dumps, into the eco-network as so-called «restorable territories» [Methodological recommendations…, 2009]. These include areas where it is "necessary and possible to renew natural vegetation cover" and repatriate plant and animal species. This is a reserve, at the expense of which it will be possible to increase the area of other elements of the eco-network. For them, priority measures to restore the primary natural state should be carried out. Thus, the inclusion of dumps in the eco-network will increase the degree of their coverage with protective herbaceous and tree cover. This will lead to a sharp decrease in the intensity of erosion and deflation of the dumps surface; the ecological hazard of the dumps will be sharply reduced.

Waste dumps are very different in shape and size, location relative to other elements of the eco-network and agricultural lands with different sensitivity to pollution. Therefore, the aim of the performed research was to develop a methodology for selection of waste dumps for their inclusion into regional eco-networks. To achieve this aim, the following tasks were solved: (a) to clarify the possible status of dumps in the eco-network; (b) to estimate the resources of additional afforested and non-afforested area resulting from the use of dumps; (c) to develop and test the criteria for assessing the degree of suitability of dumps for inclusion in the eco-network.

## MATERIALS AND METHODS

The objects of research were waste rock dumps of coal mines in Central Donbas (let's call it CD). The territory of dumps location is bounded from the north and south by latitudes 49°4.2' and 47°47.6', from the west and east by longitudes 35°59.8' and 39°54.2'. The length of the area is 149 km from north to south and 226 km from west to east (as measured by the authors). There are 694 dumps in the north-eastern part of the CD – in the Luhansk Region (let's call it LPCD), for which the studies were carried out (Figure 1). Of all, 219 dumps have a conical shape (Figure 2), 475 dumps have a flat top (Figure 3). The dumps are located in the North-Steppe zone. The annual precipitation for the year is 525 mm. The soil cover: ordinary chernozem on eluvium of chalky-mergel and rubbly rocks. According to the authors' measurements, the area of the territory with dumps is equal to 1300 km$^2$.

The studies were carried out by measurements on space images obtained using Google Earth application. Using the tools of this application, for each of 694 dumps the area of their base BA, the area of forest plantations FA projection on the surface of the dumps were determined.

The area of plateau (flat top) PlA was determined for randomized sample No.1 consisting of

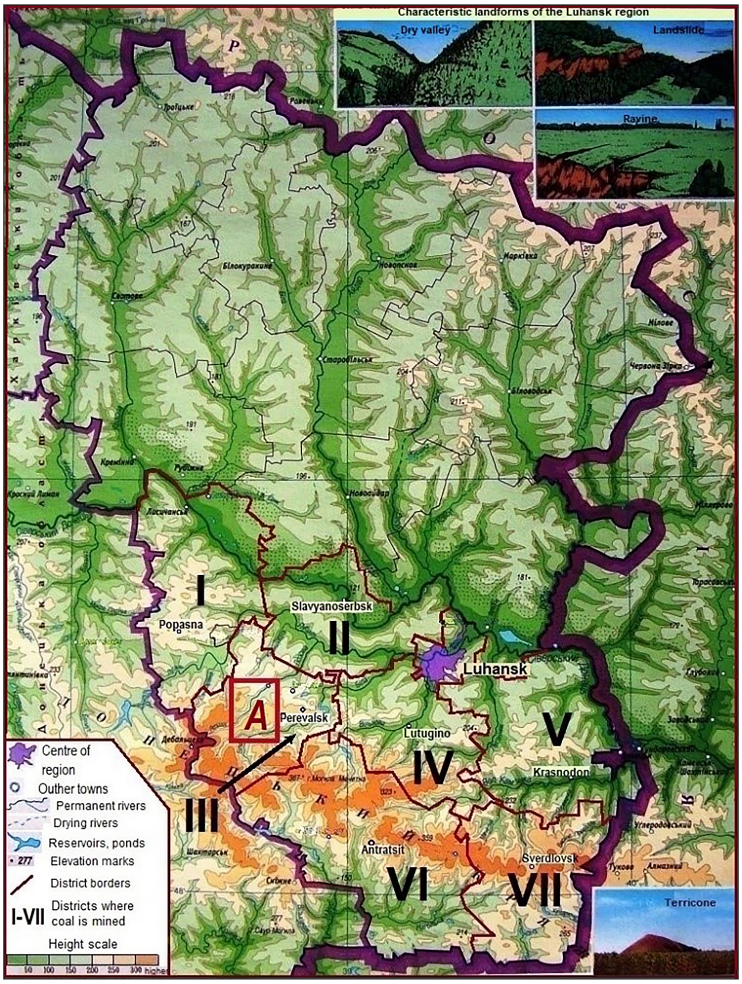


**Figure 1.** Coal mining districts of Luhansk Region (the map from [14] converted by the authors) I – Popasnaya district, II – Slavyanoserbsk district, III – Perevalsk district, IV – Lutugino district, V – Krasnodon district, VI – Anthracite district, VII – Sverdlovsk district; *A* – athe part of the area selected for a more detailed study of the waste dumps role in the local eco-network

**Figure 2.** Conical waste dumps of Donbas

234 dumps. Subtracting the plateau area from the area of the base of waste dumps BA, we determined the area of the slope projection SlA’. The area of the slopes SlA was determined as the ratio of SlA’ and cosα, where α is the steepness of the waste dump slope (35°). The area of forest on the side surface $FA_{SL}$ was determined as the ratio of the area of forest projection $FA_{SL}$’ and cosα. Forest cover on dump slopes and plateaus ($FC_{Sl\%}$ and $FC_{PL\%}$) was determined as the ratio of forest area $FA_{SL}$ and $FA_{PL}$ on these elements to their area multiplied by 100%. To assess the difference in afforestation of dump slopes of different exposures, the side surface of dumps of sample No.2 consisting of 100 pcs was divided into 8 sectors with the exposures N, NE, E, SE, S, SW, W, NW. The scoring method used in [Mudrak et al., 2022] was used to rank waste dumps.

**Figure 3.** A waste dump with a flat top overgrown with woody vegetation

## RESULTS AND DISCUSSIONS

### Status of mining dumps in the ecological network

According to the Law of Ukraine "On ecological network of Ukraine", in addition to restorable territories, the structural elements of the ecological network include key, connecting and buffer territories [Law of Ukraine…, 2004].

Key territories ensure the preservation of the most valuable and typical for the region components of landscape and biological diversity. Connecting territories (ecological corridors) connect key territories, ensure animal migration and exchange of genetic material. Buffer territories provide protection of ecosystem elements from external influences. In the concept of the ecological network of Ukraine [Shelyag-Sosonko et al., 2004], the key territories are called "natural kernels" and the concept of "interactive areas" is proposed. These are areas branching off from the kernels and eco-corridors and fulfilling the function of spreading their influence on the environment.

According to their significance, key territories are divided into three groups: (a) territories characterised by the diversity or uniqueness of biota; (b) territories with well-preserved natural landscapes of national or regional value; (c) transformed landscapes of significant natural and historical-cultural value [Methodological recommendations…, 2009]. To the latter group, in our opinion, we can include well forested waste dumps, where a large species diversity of unique flora and fauna has been formed. Such dumps are of great interest for science. The peculiarity of the dumps is a great variety of forest conditions, as their slopes of different exposures differ greatly in the arrival of solar radiation – of insolation [Zubov and Zubov, 2022].

Therefore, we can conclude that "restorable territories" is not the only possible status of waste dumps in the eco-network. If there is sufficient vegetation cover, they can serve as interactive zones of key territories.

The main criterion for selecting an area for an ecological corridor is its ability to provide a migratory function and serve as a shelter for animals. Eco-corridors should have places suitable for resting and feeding of migrating animals and birds. [Methodological recommendations…, 2009]. An important feature of waste dumps is the inaccessibility of most of their surface due to the high height of waste dumps (up to 110 m) and the steepness of their slopes (35–40°). Therefore, the surface of waste dumps is valuable for the conservation of wild flora and fauna in close proximity to settlements. Consequently, even not fully forested waste dumps can serve as interactive sections of ecological corridors. Many waste dumps are located within mining towns, so if sufficiently forested, they can also be natural kernels of an urban eco-network, providing safe shelter for birds and some animals.

### Quantifying the potential role of waste dumps in the LPCD eco-network

For each of the two main types of waste dumps, the total areas of their base, plateau and slopes were determined (Table 1). To assess the resource potential of waste dumps in the administrative districts of LPCD, the indicators presented in Table 2 can be used.

Ecological stress in the districts is characterised by the indicators N*'* and LA. The first is the average number of waste dumps per 100 $km^2$. The second indicator is the average land area per waste dump. According to both indicators, the greatest danger takes place in the district III (Perevalsk district). It can be considered as a priority in terms of the need to use waste dumps in the eco-network. The distribution of the number of waste dumps by the area of their base and plateau

**Table 1.** Base and surface area of all dumps of LPCD

| Dump shape | N | $BA_{\Sigma}$, ha | $PlA_{\Sigma}$, ha | $SlA_{\Sigma}$, ha | $DEA_{\Sigma}$, ha |
|---|---|---|---|---|---|
| I | 219 | 628.5 | - | 766.5 | 766.5 |
| II | 475 | 2486.8 | 770.0 | 2110.8 | 2889.8 |
| In total | 694 | 3115.3 | 770.0 | 2877.3 | 3647.3 |

**Notes:** I – conical dumps; II – flat-topped dumps; N – number of dumps; $BA_{\Sigma}$ – total area of dump bases; $PlA_{\Sigma}$, $SlA_{\Sigma}$, $DEA_{\Sigma}$ – the areas of the flat tops, slopes and the entire surface of the dumps.

**Table 2.** Indicators of resource potential of waste dumps in coal mining districts of LPCD

| Districts | district area, km$^2$ | N, pcs | N', pcs | $LA_{\Sigma}$, ha | $BA_{\Sigma}$, ha | $FA_{\Sigma}$, ha | $FC_{\%}$ |
|---|---|---|---|---|---|---|---|
| I | 1467 | 116 | 7.9 | 1264.7 | 483.7 | 110.4 | 22.8 |
| II | 830 | 30 | 3.6 | 2766.7 | 126.3 | 21.7 | 17.2 |
| III | 800 | 139 | 19.2 | 520.1 | 686.7 | 77.0 | 11.2 |
| IV | 1057 | 51 | 4.8 | 2072.5 | 182.1 | 23.3 | 12.8 |
| V | 1400 | 82 | 5.9 | 1707.3 | 489.5 | 32.2 | 6.6 |
| VI | 170 | 177 | 10.4 | 960.5 | 709.8 | 47.1 | 6.6 |
| VII | 1132 | 99 | 8.7 | 1143.4 | 436.6 | 17.7 | 4.1 |
| Sum or average | 8309 | 694 | 8.4 | 1197.0 | 3115.0 | 329.4 | 10.6 |

**Note:** I–VII – districts shown in Figure 1; N – number of dumps, pcs; N' – number of dumps per $10^4$ ha, $LA_{\Sigma}$ – land area per 1 dump, ha; $BA_{\Sigma}$ – total area of dumps bases, ha; $FA_{\Sigma}$ – total forest area on the dumps, ha; $FC_{\%}$ – weighted average forest cover of dumps, %.

BA and PlA, by height $H_D$ and forest area *FA* is shown in Figures 4–7. The northernmost and southeastern districts (I and VII) differ the most in terms of forest cover $FC_{\%}$ and forest area on waste dumps.

Based on the sample No. 2, it was found that while the average afforestation of the plateau is 26.5%, the average afforestation of the slopes is 35.4%. On slopes with exposure from E and W to N the afforestation is higher than the plateau afforestation from 1.17 to 2.35 times (Figure 8). These differences are due to differences in slope insolation. As we found earlier, on average from April to September insolation (total solar radiation) at latitude 48° varies from 63% (northern slope) to 120% (southern slope) of the insolation on the waste dump plateau [Zubov and Zubov, 2022]. Thus, reduction of insolation on the slopes of the northern part of the waste dump below its level on the plateau in the conditions of the Northern Steppe favourably affects the growth of tree plantations. Even plants atypical for the region can grow on such slopes. Therefore, the potential biodiversity on waste dumps is higher than in the rest

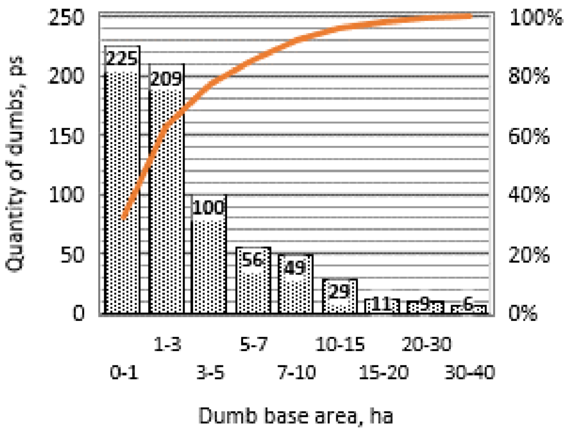


**Figure 4.** Distribution of the number of all waste dumps in relation to their base area *BA*

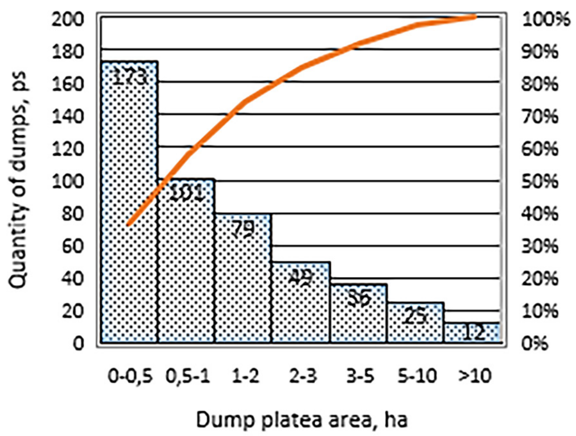


**Figure 5.** Distribution of the flat-topped waste dumps in relation to the area of their plateau

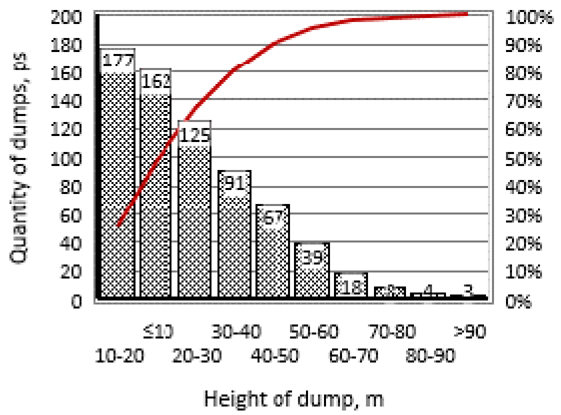


**Figure 6.** Distribution of the number of all waste dumps in relation to their height

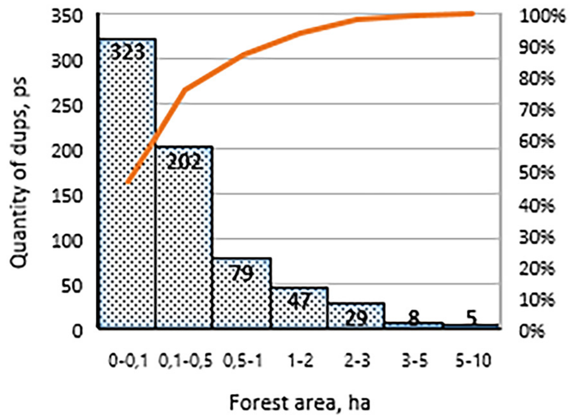


**Figure 7.** Distribution of the number of all waste dumps in relation to the area of forests on them

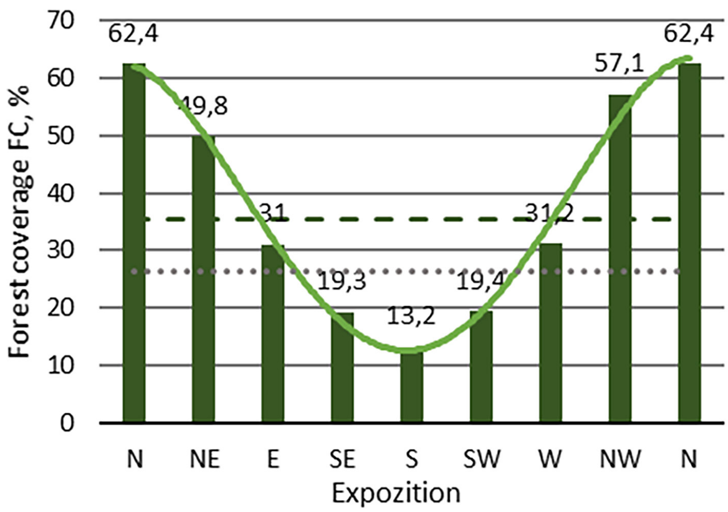


**Figure 8.** Forest cover of dump slopes of different exposures. The upper dashed line corresponds to the average forest cover of slopes, the lower one – to the forest cover of the dump plateau

of territory. The data shows that even if the average afforestation of the waste dump plateau is less than 31%, there are significant areas with twice as much afforestation on the waste dump slopes.

## Criteria for selecting of the dumps for the eco-network

A three-stage scheme and three groups of indicators are proposed to assess the possible status of dumps in the eco-network.

Group I serves to select dumps suitable for inclusion in restorable areas (the first stage of selection). The group includes such indicators: BA – the area of dump base; PlA – dump plateau area; SEW – the distance from the foot of the dump to areas that are sensitive to pollution – to household plots of the population and agricultural lands.

Group II serves to select dumps that can be used as kernels, without taking into account the degree of their connection with the elements of the existing eco-network. The group includes such indicators: FA – the area of the dump occupied by tree plantations; $H_D$ – the height of the dump.

Group III serves to select dumps that have a connection with the kernels and eco-corridors of the eco-network and can become their interactive elements. The group includes: NEW – the distance from the dump to other elements of the ecological network (to the kernels and eco-corridors); GCW – the distance from the dump to the "green corridors" leading to the kernels and eco-corridors. To green corridors we include various elongated areas with herbaceous or woody vegetation: forest belts and other forest plantations; uninhabited and undeveloped areas occupied by developed natural herbaceous and shrub vegetation.

The BA and PlA indicators determine the resource potential of the dump. The SEW indicator determines the degree of danger of the dump to crops; the relevance of biological reclamation of the dump depends on it.

The FA indicator characterizes the size of the animal's shelter area. According to [Popescu et al., 2022], forest areas are important habitat for the wild animals, offers protection against natural hazards. The $H_D$ indicator determines the degree of protection of plants, birds and animals from people and domestic animals.

The NEW and GCW indicators characterize the degree of connection of the dump with the kernels or eco-corridors of the ecological network. The same indicators characterize the need for additional measures to biologically link the dump to the existing ecological network, on which the costs of its development depend.

The degree of connection of dumps with other structural elements of eco-networks of different levels depends primarily on their connection with ecological corridors. The largest in Ukraine are the corridors of the National Eco-network [Shelyag-Sosonko et al., 2004]. They link eco-networks of Ukrainian regions among themselves and with eco-networks of other countries. The main type of these eco-corridors is the valleys of medium and large rivers. Therefore, they do not form a sufficiently dense network. Legislatively, densification of the network of corridors and key areas of the National Eco-Network is carried out by designing regional and local (district and city) eco-networks using [Methodological recommendations…, 2009]. As in [Rinaldo et al., 2018], it is proposed to use the local river network as eco-corridors in them. In the case of using waste dumps in the eco-network, our work [Zubova et al., 2010] proposes to additionally use a network of dry valleys as eco-corridors. The dry valleys are usually covered with meadow and woody vegetation, which serves as a good shelter for migrating animals. In case of insufficient proximity of dry valleys to waste dumps, we also propose the above-mentioned "green corridors" as a connecting element between them.

## A scoring system for assessing the role of waste dumps in the local eco-network

Based on the initial data and Figures 4–7, the ranges of variation in the criteria for assessing the suitability of dumps for use in the eco-network and their values corresponding to four quintiles were determined (Table 3). As it is known, a guintile is a statistical value of a data set that represents 20% of a given set of numbers.

**Table 3.** Statistical characterisation of indicators' values

| Indicators | Average value | Quintiles and their values | | | | Maxi-mum value | Median value |
|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | | |
| BA, ha | 3.6 | 0.5 | 1.4 | 2.8 | 5.4 | 34.0 | 2.00 |
| PlA, ha | 1.7 | 0.3 | 0.6 | 1.0 | 2.4 | 1.2 | 0.80 |
| $FC_{\%}$, % | 15.8 | 2.0 | 5.0 | 12.0 | 26.0 | 99.0 | 7.00 |
| FA, ha | 0.49 | 0.02 | 0.07 | 0.20 | 0.7 | 10.4 | 0.12 |
| Hd, m | 25.7 | 9.0 | 17.0 | 26.0 | 40.0 | 113.0 | 25.0 |

**Table 4.** Indicators and their evaluation scores

| Indi-cators | Scores and intervals of variation of indicators | | | | | Weight coeff. |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| BA, ha | 0.2–0.5 | 0.5–1.5 | 1.5–3.0 | 3.0–5.5 | > 5.5 | 1 |
| PlA, ha | 0.1–0.25 | 0.25–0.5 | 0.5–1.0 | 1.0–2.5 | > 2.5 | 1 |
| SEW, m | 200–500 | 100–200 | 50–100 | 20–50 | ≤ 20 | 1 |
| FA, ha | 0.02–0.1 | 0.1–0.2 | 0.2–0.5 | 0.5–1.0 | > 1.0 | 1 |
| $H_D$, m | 5–10 | 10–15 | 15–25 | 25–40 | >40 | 1 |
| NEW, m | 200–500 | 100–200 | 50–100 | 20–50 | ≤20 | 1 |
| GCW, m | 200–500 | 100–200 | 50–100 | 20–50 | ≤20 | 1 |

Based on the Table 3 we compiled a table of points corresponding to different intervals of values of all indicators (Table 4).

Since the statistical distribution of the values of indicators (Figures 4–7) is very uneven, we divided the ranges of their values not into equal intervals, but into parts with the same number of dumps, i.e. by quintiles. The intervals for varying the SEW, NEW and GCW criteria, corresponding to scores from 1 to 5, were established by experts (based on personal experience). The weighting coefficient taken into account when summing up scores, in this study were taken equal to 1.

## Verification of the developed methodology

The developed system for assessing the role of the dumps in the eco-network was tested on the example of 42 dumps located on a section of the territory of the Perevalsk district, indicated by the letter A on the Figure 1. The section is bounded from the north and south by latitudes 48°31.2' and 48°22.4', from the west and east by longitudes 38°32.8' and 38°46.1' (Figure 9).

The length of the part A is 16.4 km from north to south and 16.4 km from west to east. The area of the part A is 268.0 km$^2$. Two river eco-corridors pass through it: the Lozovaya and Belaya rivers. Both rivers are tributaries of the Lugan River, which flows into the Seversky Donets River (Figure 1). According to the scheme of the eco-network of the Luhansk Region [Zagorodnyuk et al., 2014] the Seversk-Donetsk eco-corridor is confined to the Seversky Donets River. This eco-corridor connects Luhansk Region with Kharkiv Region of Ukraine, as well as with Belgorod and Rostov Regions of Russia. In addition to the two above-mentioned rivers, the network of eco-corridors of the site A includes their tributaries and the network of dry valleys and forest belts. There are many forest areas that can be considered as the kernels of the site's eco-network. Characterisation of eco-network elements of the site A is given in Table 5. The fragment B of section A with three dumps is shown in Figure 10. Centre coordinates: 48°27.44' latitude and 38°38.34'longitude.

According to the Table 5, the density of the river and dry valley ecological corridor network

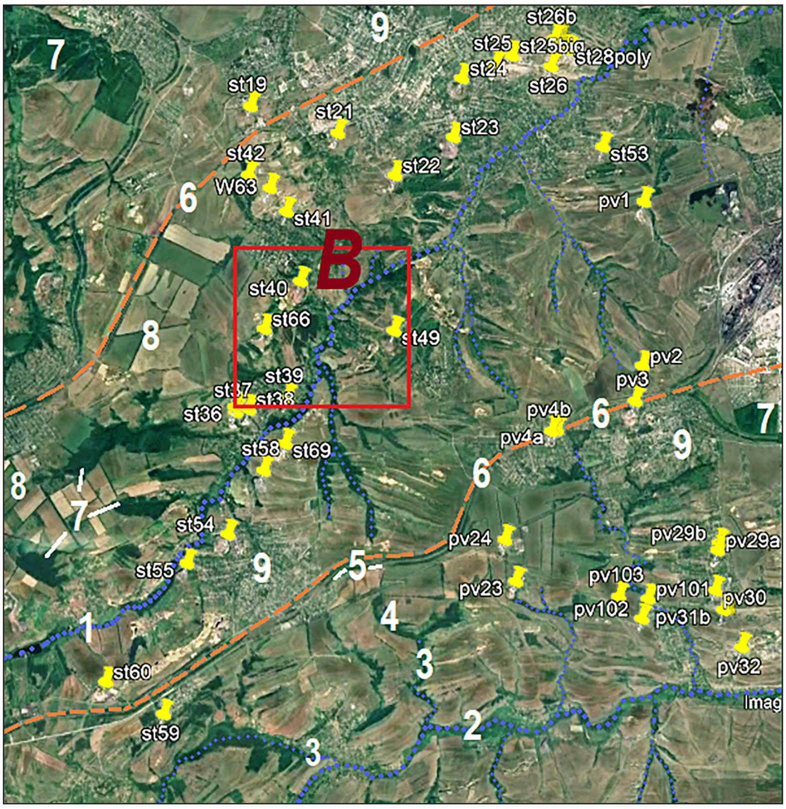


**Figure 9.** Part A of the Perevalsk district territory with the natural eco-network and 42 waste dumps: 1 – Lozovaya River; 2 – Belaya River; 3 – river tributaries; 4 – dry valleys; 5 – forest belt at the railway; 6 watershed between river catchments; 7 – forest massifs (local kernels); 8 – fields with protective forest belts; 9 – settlements; st24…pv103 – waste dumps. B – a part of the Lozovaya River catchment area with three dumps

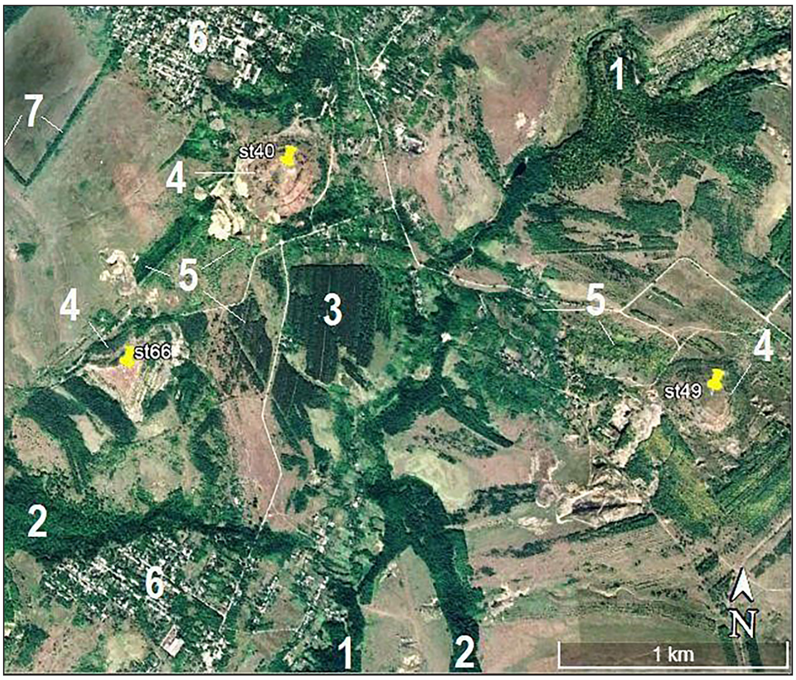


**Figure 10.** Part B of Figure 9 with dumps st66, st40, st49 on the Lozovaya River catchment: 1 – forested river flood lands; 2 – forested dry valleys (eco-corridors); 3 – forest massif (kernel of eco-network); 4 – waste dumps; 5 – green corridors; 6 – settlements; 7 – fields and forest shelter-belts

**Table 5.** Characterisation of the natural ecological network of the site A

| Indicators | Types of ecological corridors | | | Forest areas (nature kernels) | In the sum |
|---|---|---|---|---|---|
| | Rivers network | Dry valleys | Rivers and dry valleys | | |
| L, km | 81.0 | 31.8 | 112.8 | | |
| D, km/km$^2$ | 0.356 | 0.140 | 0.496 | | |
| FA, ha | 826.2 | 597.3 | 1423.5 | 726.9 | 2150.4 |
| $FC_{\%}$, % | 3.63 | 2.63 | 6.26 | 3.20 | 9.46 |

**Note:** L – length, D – network density, FA – forest area, $FC_{\%}$ – forest area share of the total catchment area of the Lozovaya and Belaya rivers; D is calculated taking into account not the whole site A area, but the catchment area of the rivers (227.4 km$^2$).

is 0.5 km/km$^2$. This means that on average these corridors are 2 km apart. As can be assumed, this results in their remoteness from the waste dumps. A more detailed characterisation of all kernels of the eco-network (forest areas) is shown in the Table 6.

As a result of measurements on space images of all 42 dumps (Figure 9), the values of each of the 7 indicators corresponding to the groups I–III were established. Their statistical characterisation is shown in Table 7. Based on Table 4, these values were converted into scores. In each group for each dump the sum of scores was calculated. These sums were plotted in descending rows, which were divided into 5 equal parts, each of

**Table 6.** Statistical characterisation of forest area values

| Type of site | N | Quartiles | | | Average value | Diapason | |
|---|---|---|---|---|---|---|---|
| | | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | | Min | Max |
| $FA_1$ | 19 | 13.3 | 23.7 | 38.9 | 31.4 | 5.37 | 177.3 |
| $FA_2$ | 29 | 6.5 | 17.5 | 35.4 | 25.1 | 3.83 | 96.1 |

**Note:** $FA_1$ – forest areas in the dry valleys, $FA_2$ – forest massifs outside dry valleys.

**Table 7.** Statistical characterisation of the indicators

| Quartiles and other characteris-tics | Group I | | | Group II | | Group III | |
|---|---|---|---|---|---|---|---|
| | BA, ha | PIA, ha | SEW, m | FA, ha | Hd, m | NEW, m | GEW, m |
| $1^{st}$ | 0.77 | 0.00 | 0.0 | 0.07 | 13.0 | 67 | 0 |
| $2^{nd}$ (median) | 2.27 | 0.32 | 14.0 | 0.31 | 20.0 | 138 | 0 |
| $3^{rd}$ | 3.20 | 0.77 | 27.0 | 0.54 | 28.0 | 347 | 18 |
| Max. value | 33.10 | 11.30 | 420.0 | 5.67 | 71.0 | 3233 | 754 |
| Mean value | 6.03 | 1.53 | 55.9 | 0.93 | 25.7 | 518 | 84 |
| Total area | 253.0 | 64.2 | | 39.1* | | | |

**Note:** *to this area you can add 61.0 ha of forest growing at the foot of the dumps and in the immediate vicinity around them.

which was assigned a rank from $1^{st}$ to $5^{th}$. Thus, from the total number, the dumps were identified that corresponded to a particular role both to the greatest extent (ranks $1^{st}$ and $2^{nd}$) and to the least extent (rank $5^{th}$). The best 24 dumps are presented in Table 8. Analysis of the Table 8 allows us to conclude that dumps Nos. 1–10 are most suitable for the role of restorable territories (group I). Dumps Nos. 4–6 are also highly ranked as the kernels. Without taking into account the connection with eco-corridors, dumps Nos. 11–13, 14–17 are most suitable for the role of kernels (group II). And considering the linkage to eco-corridors, the dumps Nos. 11–13 (pv102, st40 and st26b) are the best for the role of the interactive areas of the eco-network.

By analysing Table 6, it should be noted that half of all waste dumps are no more than 14 m away from the sensitive elements of agricultural landscape and ¾ are no more than 25 m away. The average distance of dumps from the natural eco-corridors is 518 m, i.e. dumps are poorly connected to them. The connective role of the green corridors should be noted – half of the dumps are 0 m away and ¾ are no more than 18 m away them.

As an additional way of linking waste dumps to the river and dry valleys network it is also possible to use elements of the primary hydrographic network – hollows (Figure 11). On sloping lands, hollows are not more than 200 m apart on average [Zubov et al., 2010], so they are always present near the dumps. All hollows located on arable land near dumps should be planted with grass or, if possible, forested. This will ensure the connection of phytocenoses present on the dumps with the net of dry valleys and rivers.

As a result of the grassing of hollows, linear erosion of their bottoms will be stopped [Tarariko et al., 2015]. As another measure to protect soils from water and wind erosion, it is advisable to plant additional shelterbelts, as shown in Figure 11. As noted by Academician of the NAAS O.H. Tarariko [2015], the forest belts and other elements of the system of soil protection measures against water erosion have a positive value for

**Table 8.** An example of assessing a group of dumps according to the criteria of their suitability in an eco-network

| Waste dumps and indicator groups | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dumps | | I | | | | | Dumps | | II | | | | Dumps | | III | | | |
| No. | Name | Ba | Pla | Sew | ∑ | Rank | No. | Name | Fa | Hd | ∑ | Rank | No. | Name | New | Gew | ∑ | Rank |
| 1 | pv2 | 5 | 5 | 5 | 15 | $1^{st}$ | 11 | pv102 | 5 | 5 | 10 | $1^{st}$ | | | 5 | 5 | 10 | $1^{st}$ |
| 2 | st23 | 5 | 4 | 5 | 14 | $1^{st}$ | 12 | st40 | 5 | 5 | 10 | $1^{st}$ | | | 4 | 5 | 9 | $1^{st}$ |
| 3 | st6 | 5 | 4 | 5 | 14 | $1^{st}$ | 13 | st26b | 5 | 4 | 9 | $1^{st}$ | | | 5 | 5 | 10 | $1^{st}$ |
| 4 | pv1 | 5 | 5 | 5 | 15 | $1^{st}$ | | | 5 | 4 | 9 | $1^{st}$ | 18 | st28 | 5 | 5 | 10 | $1^{st}$ |
| 5 | st58 | 5 | 5 | 5 | 15 | $1^{st}$ | | | 4 | 4 | 8 | $2^{nd}$ | 19 | pv101 | 3 | 5 | 8 | $2^{nd}$ |
| 6 | st24 | 5 | 4 | 5 | 14 | $1^{st}$ | | | 5 | 3 | 8 | $2^{nd}$ | 20 | pv24 | 2 | 5 | 7 | $2^{nd}$ |
| 7 | st26 | 5 | 5 | 5 | 15 | $1^{st}$ | 14 | st60 | 5 | 4 | 9 | $1^{st}$ | 21 | st29a | 2 | 5 | 7 | $2^{nd}$ |
| 8 | st49 | 5 | 4 | 5 | 14 | $1^{st}$ | 15 | pv4b | 5 | 4 | 9 | $1^{st}$ | 22 | st26a | 1 | 5 | 6 | $3^{rd}$ |
| 9 | st55 | 4 | 5 | 4 | 13 | $2^{nd}$ | 16 | pv30 | 5 | 4 | 9 | $1^{st}$ | 23 | pv31b | 2 | 4 | 6 | $3^{rd}$ |
| 10 | st25Б | 5 | 5 | 3 | 13 | $2^{nd}$ | 17 | st26a | 5 | 4 | 9 | $1^{st}$ | 24 | ст22 | 1 | 5 | 6 | $3^{rd}$ |

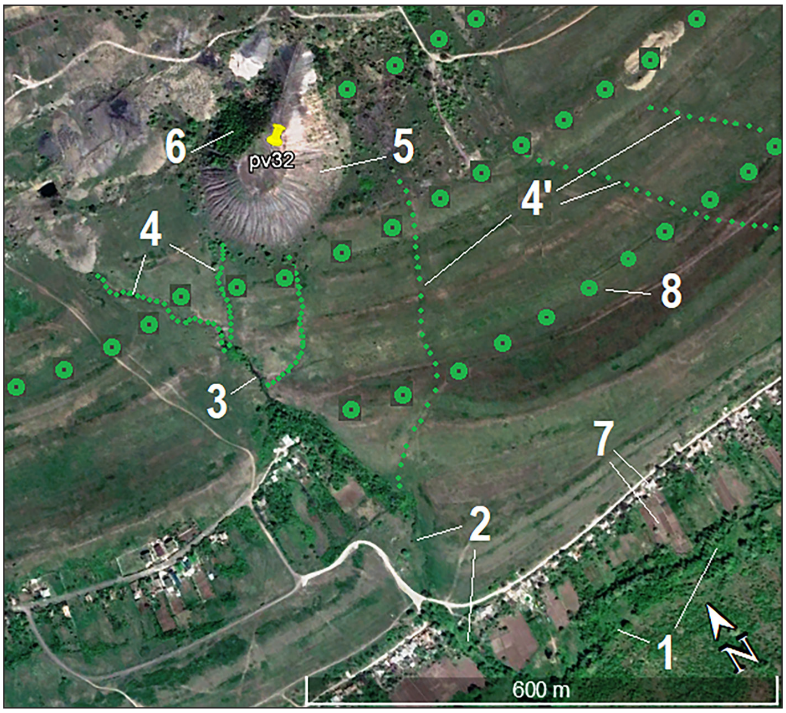


**Figure 11.** An example of strengthening the connection between a waste dump and the Belaya River valley by using the hollows: 1 – river; 2 – dry valley; 3 – small gully; 4 and 4' – hollows to be grassed for connection of dump and dry valley or for soil conservation; 5 and 6 – waste dump and forest plantation on it; 7 – houses and garden plots of the local population; 8 – proposed system of contour-parallel forest shelterbelts

promoting the vital activity of wild fauna and protecting biodiversity. Protective forest belts, continuous and clump forest plantations, areas under grass vegetation are nesting and breeding sites for wild birds and animals, as well as their food base [Tarariko et al., 2015]. This is also true for forest plantations on waste dumps.

## CONCLUSIONS

As a result of the study, it was established that the use of coal mine dumps from the Lugansk part of Central Donbass as part of a regional eco-network increases the area of its elements by 3115 hectares, including forest areas by 330 hectares. An important feature of the surface of the dumps is their inaccessibility to humans, the possibility of sheltering migrating animals and birds in close proximity to cities and towns, as well as a variety of microclimatic conditions that contribute to the preservation of biodiversity and the conservation of plant species suffering from global warming.

In conditions of scarcity of forested areas in densely populated mining areas, dumps with good vegetation cover can serve not only as restorable areas, but also as kernels of eco-network and interactive elements of key and connecting areas. Planning of costs associated with the inclusion of dumps in the eco-network should be carried out taking into account dumps importance using the system of indicators, points and ranks developed by the authors.

The insertion of waste dumps in the eco-network elements is legally justified. Thus, it will incentivise local authorities, coal mine managers and farmers to increase afforestation of waste dumps and other environmentally important activities. These measures include grassing of hollows and areas with disturbed grass cover, creation of additional field protection and anti-erosion forest belts. As a result of all these measures, the protection of agricultural land from water and wind erosion and from degradation due to pollutants from dumps will be improved.

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