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Abstract. Among the concepts of sustainable nature management, forest conservation is considered as an important element. The state of forest ecosystem depends on the development trend of the mining and industrial area and the complex of social, ecological, and economic problems of Kryvyi Rih District. The object of this study was assessing the artificial woody plantations as a promising factor for ecological hybrid threat reduce in industrial areas on the example of the Kryvyi Rih Iron Ore Mining and Metallurgical District on standpoint of an ecosystem approach. During 2015-2020, we studied the natural forest ecosystems and the artificial forest plantations, which were located in contrast environmental conditions. Forests are located very unevenly in the Kryvyi Rih District. They are mainly concentrated in River gullies, woody stands of city parks, woody stands of health protection zones, woody stands of city protection forest and woody stands of river protection forest. The woody plantations located on the territories of Kryvyi Rih District are very different in terms of coverage area and don't reach the optimal level. This woody plantations level allows effect the climate, soil, and water resources. The woody plantations also mitigate the effects of erosion processes, as well as provide more clean air. The artificial woody plantations are an important element of environmental safety in Kryvyi Rih District. The main function of the artificial woody plantations is to maintain the soil in an optimal form for operation. It is also the protection of ground water and the stability of the meso- and microclimate in the region, moreover preserving the biodiversity of the territory's ecosystems. The artificial woody plantations perform an anti-stress function for residents. It was established that the quality of reforming the ecological approach to greening the city's territories, as well as preserving artificial woody plantations, was determined by the choice of such a management model and nature management policy. These models together should ensure the competitive ability and long-term development of the artificial woody plantations in Kryvyi Rih District. The maine industrial areas in the world should develop as an environmentally stable and safety metallurgical region in accordance with the principles of sustainable development in the world.

1. Introduction

Now the role of forests for maintaining ecological stability is generally recognized in Ukraine and the world [1–4]. Among other natural ecosystems only forests have the maximum property for environmental protection in industrial areas [5–8]. They are considered as one of the decisive factors in ensuring mankind's activities and also as an important part in the system of sustainable development of the Kryvyi Rih Iron Ore Mining and Metallurgical District. In addition, artificial woody plantation stands provide people with a softened microclimate in their residential areas and other positive changes in urbanized areas [9–11]. Local communities are slowing down the pace of global warming and generally reducing their negative impact on the microclimate by using artificial forest stands in mining districts [12–15].

Artificial woody plantations aren't directly used in the form of wood resources, technical, medical raw materials and other forest products for population and industry needs. Nevertheless, they must reproduce at forming region natural complexes. Forest resources also include the beneficial properties of forests used to meet public needs. Such properties are the ability of forests to reduce the negative effects of natural phenomena, protect soils from erosion, prevent environmental pollution and purify it, help regulate water runoff, improve the health of the population and its aesthetic education [16–19].

Among the concepts of sustainable nature management, forest conservation is considered as an important element. Forest stands make up 36% of European territory. In different natural areas it cover has significant differences and doesn't reach the optimal level at which forests most positively effect the climate, soil, water resources, mitigate erosion processes consequences, and also provide a greater amount of wood growth [20–22].

The state of the artificial woody ecosystem depends on the development trends and the complex of socio-ecological and economic problems of Forestry in Ukraine. This makes it necessary to reform the forestry management system. The quality of reform is determined by the choice of a management and forest policy model. Studying foreign experience in forest management and comparing typical management models will help to avoid over-evaluating them and potential implementation mistakes. It will also highlight those aspects of management that can be taken into account in the process of reforming the forest ecosystem in Kryvyi Rih District and in Ukraine [7, 11, 23, 24].

The object of this study was on standpoint of an ecosystem approach to assess the artificial woody plantations as a promising factor for ecologicall hybrid threat reduce in industrial areas on the example of the Kryvyi Rih Iron Ore Mining and Metallurgical District on standpoint of an ecosystem approach.

2. Methodology

Kryvyi Rih Iron Ore Mining and Metallurgical District, Central Ukraine, was chosen for the present study. It is situated between 47°53′54″ and 48°8′52″ north latitude and 33°19′52″ and 33°33′38″ west longitude. During 2015-2020, we studied the natural forest ecosystems and the artificial forest plantations located in contrast environmental conditions. They represent the main types of tree-shrub stands, in particular garden and park facilities, sanitary, water protection and urban forest protection tracts. Natural phytocenoses from the Gurovsky forest (Dolinsky district, Kirovograd region), located in the floodplain of the Bokova River and 30 km away from industrial enterprises, were used as conditional control.

The test plot study was designed to evaluate all factors controlling the natural phytocenoses and artificial woody plantation state, i.e. air pollution, soil properties, topography, local microclimate conditions and time. The 35 sample plots (20*20 m) were selected by this information base. The sampled locations are shown in figure 1. Field data were collected through direct enumeration and measurement of all trees in every plot. In each plot, all woody stems of diameter at breast height (dbh) $>$ 10 cm were recorded and: 1) their diameter at 1,3 m

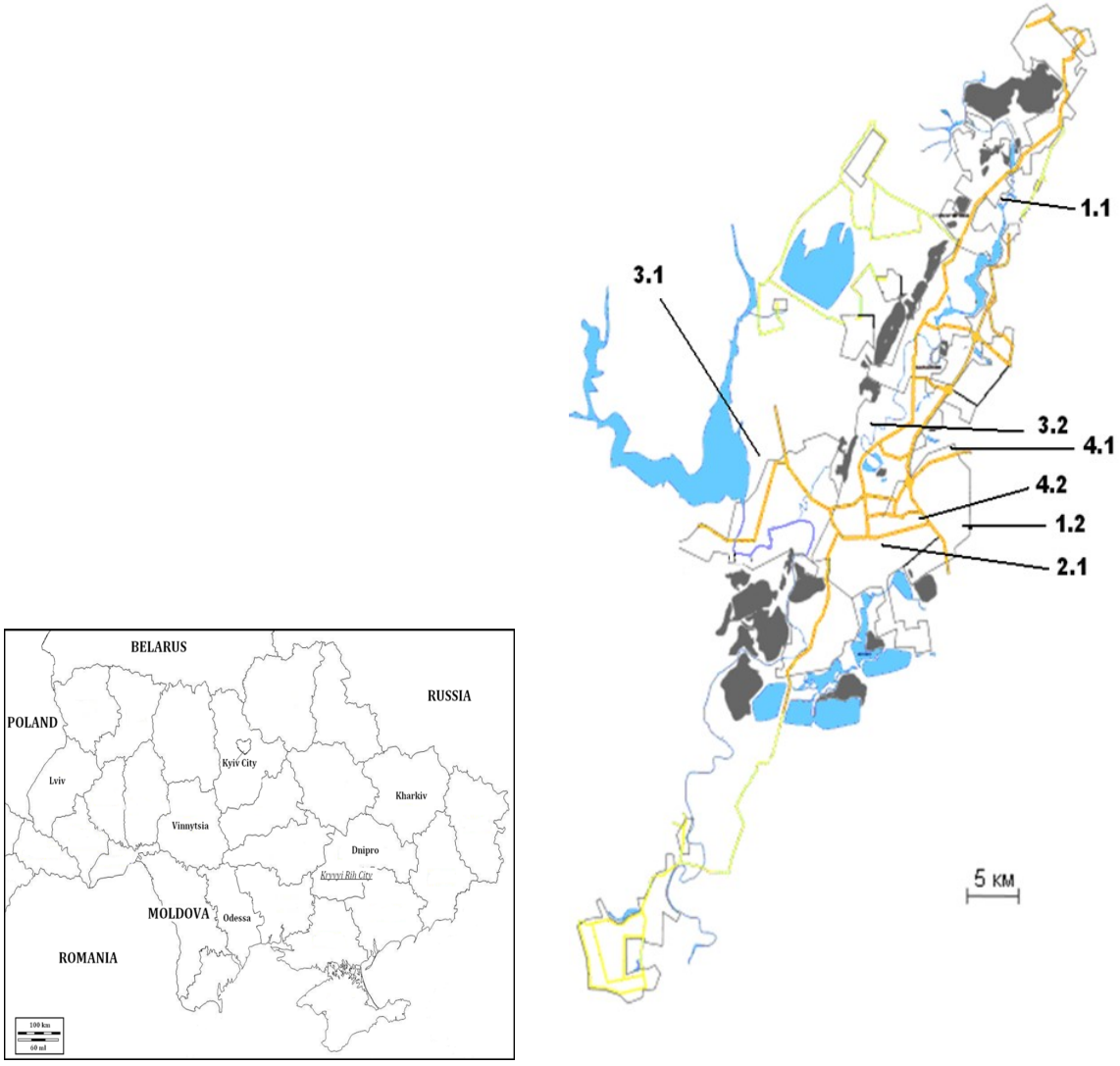

Figure 1. Sketch of the study area. (*a.Kryvyi Rih Iron Ore Mining and Metallurgical District, Central Ukraine*) and (*b.Kryvyi Rih Legend: 1 – City parks: 1.1 – Veseloternivsky arboretum, 1.2 – Dovgintsivsky arboretum; 2 – Health protection forests: 2.1 – protection zones of PJSC "ArcelorMittal Kryvyi Rih" 3.– River protection forests: 3.1 – Karachuny forest tract, 3.2 – Dubki forest tract; 4. – City protection forests: 4.1 – Lisove forest tract, 4.2 – Sotsmisto forest tract*).

above ground (in two perpendicular directions by a caliper); 2) their height (by a hypsometer) were measured [25,26]. In natural phytocenoses and artificial woody plantation the relative vital tree state was assessed by V.A. Alekseev [27]. The ecomorphic analysis of woody plant species was carried out according to classic and innovative approach [11].

All data were submitted to descriptive statistics and analysis of variance (ANOVA). The statistical analysis was performed using the program SPSS for Windows. For all statistical analysis, significance was considered $P < 0{,}05$ [28, 29].

3. Results and discussion

In Dnipropetrovsk region the forest cover is one of the lowest in Ukraine and amounts 4,8%, with an optimal value of 8,0%. More than 80% of the region's forests are artificial plantings, but the existing areas don't provide sufficient ecological balance and sustainable development of the region. A number of reforestation, afforestation and landscaping activities aimed at fostering respect for nature are planned to be carried out in the region [30, 31].

The State Forestry Agency, which owns 73% of the forests, should be the main driver of environmental initiatives. According to the decision of the Dnipropetrovsk Regional Forestry and Hunting Department the board, it plans to create new forest stands of more than 70 hectares up to 332 hectares planned in 2022. By the end of 2024, foresters will land more than 166 thousand hectares of trees. Robinia pseudoacacia L., Quercus robur L., Pinus nigra, Juglans nigra Hulls will be dominated in Forest crops [7]. An important element among the concepts of sustainable nature management is the preservation of artificial woody plantations in the Kryvyi Rih District. In this area the state of the forest ecosystem in depends on the development trend of the mining and industrial region and the complex of social, ecological and economic problems [10, 11].

Simultaneously with the creation of a new artificial woody plantation research and systematization of existing artificial forest ecosystems remains extremely important in Kryvyi Rih District. As we noted above, in the region artificial woody plantations have an impoverished floral composition; a simplified vertical structure; a certain imbalance in the ratio of dendrometric indicators between the first, second and third tiers of plantings, and sometimes a weakened state of life. In most cases, their trees are under stress due to the constant influence of adverse environmental factors (table 1). However, forest ecosystems have already formed a tree cover in the region. Trees are young and relatively mature. They have accumulated a significant amount of phytomass and potency to form a cenotic phytogenic environment. In addition, trees already perform important environmental, sanitary, and protective phytomeliorative and other functions.

Therefore, for the present their systematization/ordering are extremely relevant and important. The first stage for depth study of artificial tree ecosystems can be a scientific justification for the possibility of using the biogeochemical characteristics of the "leaf litter-soil system" as markers and predictors of the state of trees in forest ecosystems. Thus, according to the results of our research [10, 11], in leaf sediments concentrations of alkaline earth metals (Ca, Mg, K, and Na) should be considered as an accurate ecological and biogeochemical marker. This marker informatively reflects the vital state of woody plant species in the forest ecosystems at industrial areas.

At comparing the indicators of the woody vegetation vital condition, taking into account the indicators of the volume of raw materials for all tiers, it can note the preservation of general trends.

The analysis of the woody plant species from artificial forest communities at Kryvyi Rih region shows that: 1) among the trophomorphs megatrophs(48,1-100%) and oligomezotrophs (1,53-28,71%) are dominated, 2) among the hygromorphs mesophytes (32,73-94,57%) and mesohygrophytes (3,25-41,7%) are dominated, 3) among heliomorphs heliophytes (33,33-89,89%) and sciogeliophytes (5,43-39,67%) are dominated. In most cases, the ecomorphic spectra obtained by classic approach and innovative approach coincide in ordering rankings of the ecomorphic specific weight. However, the contrast between the leading ecomorphs increases. In some cases, the change of dominant ecomorphs and their ranking were detected.

In all major woody tiers, except for tier III, the highest biomass indicators are identified by forest ecosystems in areas with relatively environmentally favorable conditions. The bonitet of a stand depends on the soil-hydrological and climatic characteristics of the biotope reflected by the difference in the growth and accumulation of biomass; thus, accordingly, the bonitet is considered

Table 1. Vertical structure of the stand. Natural(Background) - Gurivsky natural forest; Natural, artificial(Buffer1) - 1.1. – Veseloternivsky arboretum, 3.1. – Karachuny forest tract, 3.2. – Dubki forest tract; Artificial(Buffer2) - 1.2. – Dovgintsivsky arboretum), 3.1. – Karachuny forest tract, 4.1. – Lisove forest tract; Artificial(Impact) - 2.1. – protection zones of PJSC "ArcelorMittal Kryvyi Rih", 4.2. – Sotsmisto forest tract).

	Natural Background age of stand 150-170 years	Natural, artificial Buffer1 age of stand 50-120 years	Artificial Buffer2 age of stand 40-80 years	Artificial Impact age of stand 50-90 years
		Available (%)		
Emergent layer	100	100	100	100
Canopy layer	100	100	75	100
Understory layer	100	75	75	75
Shrub layer	100	75	25	25
Herb layers	100	100	75	–

as an indicator of the stand natural productivity [7,30,31]. Therefore, in the Arboretum "Vesely Terni" and tree stands near the Volovoe village, Artyom 1 tree stands, as well as some areas of water-proof treestands of the Karachunovsky reservoir, the indicators of sites are the highest in terms of total biomass indicators and amount to 87,01 conditional points. This condition of trees corresponds to the category of "healthy". Also crown biomass (88,4 conditional points), leaves (87,7 conditional points) and branches indicators (80,9 conditional points) correspond to the "healthy".

It is proved that in the region the forest cultivar phytocenoses tree species are in a stressful state, because they are constantly affected by adverse environmental factors. We have made the assumption that in the Kryvyi Rih District the artificial forest communities should become one of the key environmental factors determining its ecological safety, both individually in this region and in Ukraine as a whole. To solve this problem, it is necessary to achieve optimal forest cover of this district (8-10%) by creating new plantations and taking into account scientific prerequisites and ordering existing ones.

The results obtained, taking into account statistical processing of the stand viability indicators, show artificial forest stands outside the scope of industrial emissions can be rated as "healthy". The total coefficient of vitality of these plantings is 85,7 conditional points on the V. A. Alekseev scale (the confidence interval is m (+or-) 2,9; the coefficient of variation is 9,8%). Overall vitality indicators are the highest among all identified ecological zones. The crown and branches of woody plants are also "healthy" as they are equal to 85,6 and 86,9 conditional points. The leaves, however, can be considered "weakened", their indicators are equal to 78,1 conditional points.

The vitality indicators obtained by taking into account statistical processing in all areas within territories with relatively low levels of atmospheric pollution are generally quite high. The indicators are equal to 82,9 conditional points, and by V. A. Alekseev scale it is rated as "healthy" (the confidence interval is m (+or-) 2,3; the coefficient of variation is 9,01%). The condition of the crown and leaves is also estimated as "healthy" and is equal to 84.2 conditional points and 83,01 conditional points. However, the condition of the branches is estimated as "weakened" and equal to 78,2 conditional points.

The results obtained in areas with moderate atmospheric pollution and unfavorable

environmental conditions for tree vitality indicate a relative "weakening" of woody plants. The viability of these trees is 63,8 conditional points (the confidence interval is m(+or-)3,01; the coefficient of variation is 17,9%). Individual indicators of the crown (63,5 conditional points), leaves (61,7 conditional points) and branches (63,7 conditional points), respectively, are also defined as "weakened". The vitality indicators are the lowest in all areas in the zone with excessive atmospheric pollution and unfavorable environmental conditions. By V.A. Alekseev scale, the condition of trees is assessed as "weakened" and equal to 62,7 conditional points (the confidence interval is m(+or-) 3,6; the coefficient of variation is 13,01%). The condition of the crown, leaves and branches is assessed as "weakened" and equal to 62,3 conditional points, 68,4 conditional points and 60,01 conditional points. All artificial woody plantations have all layers. But the tree undergrowth, shrubs are absent or underdeveloped in some areas From statistical processing of results by tier more detailed data indicate a "weakened" vital state of trees in tier i and ii. These tiers are characterized by indicators of 74,3 conditional points and 60,6 conditional points.

The relevance of our research is determined by the need for scientific understanding of the objective indicators that reflect the real current state of forest ecosystems adversely affecting by environmental conditions at industrial areas. According to leading experts ecomorphic analysis of woody plant species can be as an informative indicator for the current state of these forest ecosystems. Thus, in our opinion, it could be advisable to expand ecomorphic analysis by using woody plant species dendrometric indicators.

In the Kryvyi Rih District the forest ecosystems are located in contrasting ecological conditions. The main types of artificial urban green areas are presented, such as landscape gardening and protective forest stands (sanitary protection, protection of rivers and lakes, protection of cities). In the arid steppe conditions of this district, the ratio of woody plant species to the level of moisture is the most important indicator that determines the future state of these natural and artificial plantings [30, 31]. Therefore, it is extremely advisable to analyze the hygromorphic spectrum of woody plant species. Comparison of ecomorphs of woody plant species in forest ecosystems in Kryvyi Rih District with using tree species analysis and analysis of dendrometric characteristics gave clearer results.

4. Conclusions

Thus, in the Kryvyi Rih Iron Ore Mining and Metallurgical District, the current state of artificial woody plantations can be assessed as conditionally satisfactory, depending on soil conditions and levels of air pollution. A systematic approach to the application of environmental forest management policy will allow significantly reduce the ecologicall hybrid threat in this region and in the industrial areas of the world. The leading biological and dendrometric characteristics of artificial woody plantation stands have a clear ecological conditionality. Vitality State Indicators of artificial woody plantation species in Kryvyi Rih indicate a lack of moisture in the soil and an increased level of atmospheric pollution, which constantly accumulates on the leaves and soil surface, are significant environmental factors.

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