



GIS-based assessment of tree oxygen release potential in the desert landscape of Uzbekistan: evidence from saxaul and tamarix stands

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ABSTRACT

This study assesses tree oxygen release potential in the desert landscape of Uzbekistan using a GIS-based analytical framework supported by remote sensing indicators and species-level ecological coefficients. The analysis focuses on saxaul and tamarix stands, which are among the main drought- and salinity-tolerant woody plants used in arid-land restoration. The empirical dataset includes area, precipitation, air temperature, soil salinity, and oxygen-release values expressed as $\text{kg ha}^{-1} \text{yr}^{-1}$. The results show that oxygen release in the analyzed desert observations ranged from 130 to 155 $\text{kg ha}^{-1} \text{yr}^{-1}$, with a simple mean of 144 $\text{kg ha}^{-1} \text{yr}^{-1}$. Saxaul showed a higher mean value, 148.3 $\text{kg ha}^{-1} \text{yr}^{-1}$, compared with tamarix, 137.5 $\text{kg ha}^{-1} \text{yr}^{-1}$. The table-based evidence suggests that species selection, moisture availability, and soil salinity jointly influence tree performance in desert restoration sites. The GIS map, scatter plots, and correlation heatmap show that spatial assessment can help interpret oxygen release as a practical ecological indicator, although the statistical relationships should be treated as exploratory because of the limited dataset. The study contributes to dryland restoration planning by showing how GIS, vegetation indices, and site-level ecological variables can support more careful identification of suitable areas for saxaul and tamarix-based afforestation in Uzbekistan’s desert territories.

Keywords:

GIS, oxygen release, saxaul, tamarix, desert restoration, NDVI, Uzbekistan, dryland afforestation

1. Introduction

Tree planting in dryland territories is usually discussed through its role in carbon sequestration, land stabilization, dust reduction, microclimate regulation, and restoration of degraded ecosystems. Oxygen release is also related to photosynthesis and biomass formation, but it should be interpreted carefully. It is not always the most economically valuable ecosystem service of trees, because the atmosphere already contains a very large

oxygen stock. However, oxygen-release potential can still be useful as an indirect ecological indicator of vegetation productivity, canopy development, and site suitability when it is combined with other spatial and environmental variables (Bonan, 2008; Nowak et al., 2007).

In arid and semi-arid landscapes, tree growth is strongly limited by moisture deficit, high summer temperature, soil salinity, wind erosion, and poor soil structure. These

constraints are especially important in Central Asia, where large desert areas and the consequences of the Aral Sea crisis have created serious ecological and socio-economic challenges. The restoration of degraded desert lands in Uzbekistan cannot rely only on the number of planted seedlings. It also requires attention to species tolerance, soil condition, local moisture availability, and the spatial distribution of restoration sites (Micklin, 2007, 2016; Toderich et al., 2013; World Bank & ICARDA, 2021).

Saxaul and tamarix are highly relevant for this type of analysis because both are adapted to harsh desert conditions. Saxaul, commonly represented by *Haloxylon* species in Central Asian restoration practice, is widely used for sand fixation, desert greening, and restoration of degraded areas. Tamarix species are also known for drought and salinity tolerance, although their performance varies depending on soil moisture, salt concentration, and local environmental stress (Dawalibi et al., 2015; Novitskiy et al., 2023; Toderich et al., 2013). For this reason, comparing their oxygen-release potential under desert conditions provides a useful starting point for GIS-based ecological evaluation.

Remote sensing and GIS provide a practical basis for such work because they allow vegetation condition, land cover, climate indicators, and soil-related constraints to be examined spatially. NDVI and EVI are widely used as indicators of vegetation vigor and canopy greenness, while GIS makes it possible to combine field tables, satellite-derived layers, and environmental variables in one analytical framework (Gorelick et al., 2017; Huete et al., 2002; Jensen, 2014; Pettoirelli et al., 2005; Tucker, 1979). In Uzbekistan, these methods are especially useful because restoration territories are large, heterogeneous, and often difficult to monitor through field surveys alone.

The objective of this article is to assess tree oxygen release potential in Uzbekistan's desert landscape using GIS-supported ecological indicators and species-level observations for saxaul and tamarix stands. Unlike broader national landscape assessments, this study

focuses only on the desert zone because the available empirical data and visual materials are desert-specific. The article addresses three questions: how oxygen-release values differ between saxaul and tamarix observations, how precipitation, temperature, and salinity help explain variation in oxygen-release potential, and how GIS-based visualization can support restoration planning in desert territories.

2. Materials and Methods

The study focuses on the desert landscape of Uzbekistan, with particular attention to arid and saline environments where saxaul and tamarix are used or considered for restoration. Desert conditions in Uzbekistan are shaped by low precipitation, high summer temperature, wind activity, sandy and saline soils, and limited water availability. These factors make tree establishment difficult, but they also increase the importance of drought-tolerant woody vegetation for ecological stabilization.

The article does not analyze pasture, foothill, or mountain landscapes. Although the broader dissertation source refers to different landscape types, the empirical table and visual materials used in this manuscript are limited to desert-zone observations. Therefore, the article is framed as a desert-landscape case study rather than a comparative assessment of all landscape zones of Uzbekistan.

The analysis is based on dissertation-derived observations for saxaul and tamarix stands. The dataset includes five main variables: area, precipitation, air temperature, soil salinity, and oxygen release. Oxygen release is expressed in $\text{kg ha}^{-1} \text{ yr}^{-1}$. Because the original table reports common names rather than fully verified botanical species names, the article uses "saxaul" and "tamarix" as functional restoration groups. Where needed, these can later be specified as *Haloxylon* spp. and *Tamarix* spp. if the original field records confirm the exact species.

Remote sensing indicators, especially NDVI and vegetation-cover mapping, were used as spatial support layers. Such indicators are suitable for assessing vegetation condition and greenness, but they do not directly measure oxygen release. Therefore, in this article, satellite-based

vegetation information is interpreted as supporting evidence for canopy presence and vegetation vigor, while oxygen release values come from the species-level ecological table and related dissertation calculations (G'oziev, 2026; Huete et al., 2002; Pettorelli et al., 2005).

The GIS component was used to visualize vegetation cover and restoration-relevant territories. The table-based analysis was used to compare oxygen-release values between saxaul and tamarix observations. Scatter plots were used to examine the relationship between oxygen release and precipitation, and between oxygen release and temperature. A correlation heatmap was used to summarize relationships among area, precipitation, temperature, soil salinity, and oxygen release.

The statistical interpretation is descriptive and exploratory. The dataset is too small for strong causal claims, and the figures appear to include more plotted points than the five observations shown in the table. Therefore, the study emphasizes ecological interpretation, consistency of patterns, and restoration

relevance rather than formal prediction modelling. This is acceptable for a short article or preliminary GIS-based case study, but future work should expand the number of field plots, add seasonal biomass data, and validate oxygen-release coefficients through direct or modelled productivity estimates.

3. Results

Table 1 presents the main desert-zone observations used in the analysis. The values show that oxygen release varied from 130 to 155 kg ha⁻¹ yr⁻¹. The lowest value was recorded for tamarix under 110 mm precipitation, 39°C air temperature, and 2.8% soil salinity. The highest value was recorded for saxaul under 130 mm precipitation, 41°C air temperature, and 2.7% soil salinity. The total observed area of the five records was 2,577 ha. The simple mean oxygen-release value was 144 kg ha⁻¹ yr⁻¹, while the area-weighted mean was approximately 144.4 kg ha⁻¹ yr⁻¹. This confirms that the table is internally consistent and that oxygen-release potential is moderate but ecologically important under desert conditions.

Table 1. Desert-zone observations for GIS-based assessment of oxygen release potential in saxaul and tamarix stands

Species	Area (ha)	Precipitation (mm)	Air temperature (°C)	Soil salinity (%)	Oxygen release (kg ha ⁻¹ yr ⁻¹)
Saxaul	552	120	40	2.5	150
Saxaul	711	100	38	3.0	140
Tamarix	347	110	39	2.8	130
Saxaul	458	130	41	2.7	155
Tamarix	509	115	39	2.6	145

Saxaul records ranged from 140 to 155 kg ha⁻¹ yr⁻¹, with an average of 148.3 kg ha⁻¹ yr⁻¹. Tamarix records ranged from 130 to 145 kg ha⁻¹ yr⁻¹, with an average of 137.5 kg ha⁻¹ yr⁻¹. This difference should not be interpreted as a universal biological rule, because the number of observations is small. Still, it suggests that saxaul may provide stronger oxygen-release potential under the sampled desert conditions. The table also shows that soil salinity remained within a relatively narrow range, 2.5–3.0%, while precipitation varied from 100 to 130 mm. These two variables are important because drought and salinity are among the main

constraints for tree establishment in arid restoration sites (Dawalibi et al., 2015; Khamzina et al., 2008; Toderich et al., 2013).

Figure 1 presents the GIS-based vegetation-cover map used as spatial context for the oxygen-release assessment. The map uses Sentinel-2-based vegetation information and shows the distribution of green vegetation cover across Uzbekistan. In the context of this article, the figure should be interpreted as a support layer rather than as a direct oxygen-release map. It helps demonstrate where vegetation cover is spatially visible and how GIS

can support ecological assessment at landscape scale.

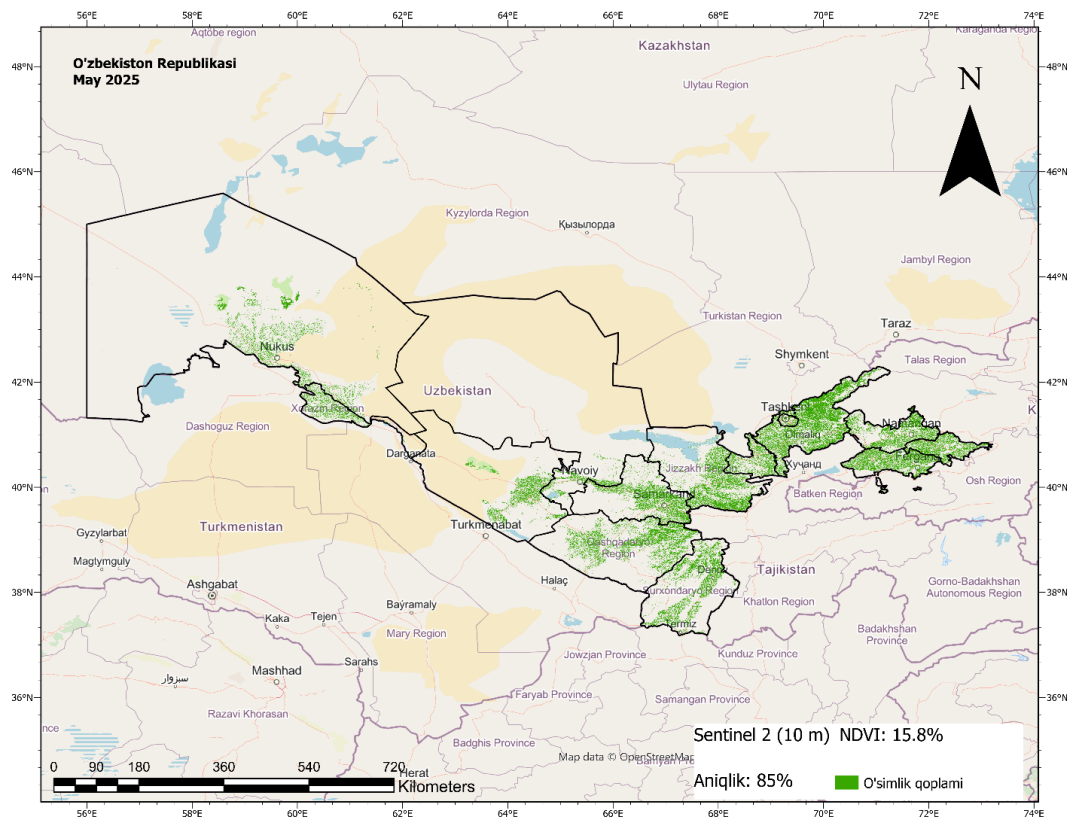


Figure 1. GIS-based vegetation-cover map used as spatial context for assessing tree oxygen release potential in Uzbekistan's desert restoration framework.

The green areas represent detected vegetation cover, while the map frame, administrative boundaries, scale bar, and north arrow make the figure suitable for spatial interpretation. The map is useful because oxygen-release potential cannot be understood only from tabular values. It must also be linked to the spatial distribution of vegetation, restoration territories, and environmental constraints. However, the caption should not claim that the map directly measures oxygen release. A more accurate interpretation is that the figure visualizes vegetation-cover patterns that can be combined with species coefficients and environmental variables to estimate or prioritize oxygen-

release potential. This clarification makes the article more scientifically reliable and avoids overstatement.

Figure 2 shows the relationship between precipitation and oxygen release for desert species. In the five table observations, the highest oxygen-release value occurred at 130 mm precipitation, while the lowest was recorded at 110 mm. Saxaul generally maintained higher values across the observed range. However, the scatter pattern should be treated cautiously because the plotted points appear to represent an expanded figure series rather than only the five values shown in Table 1.

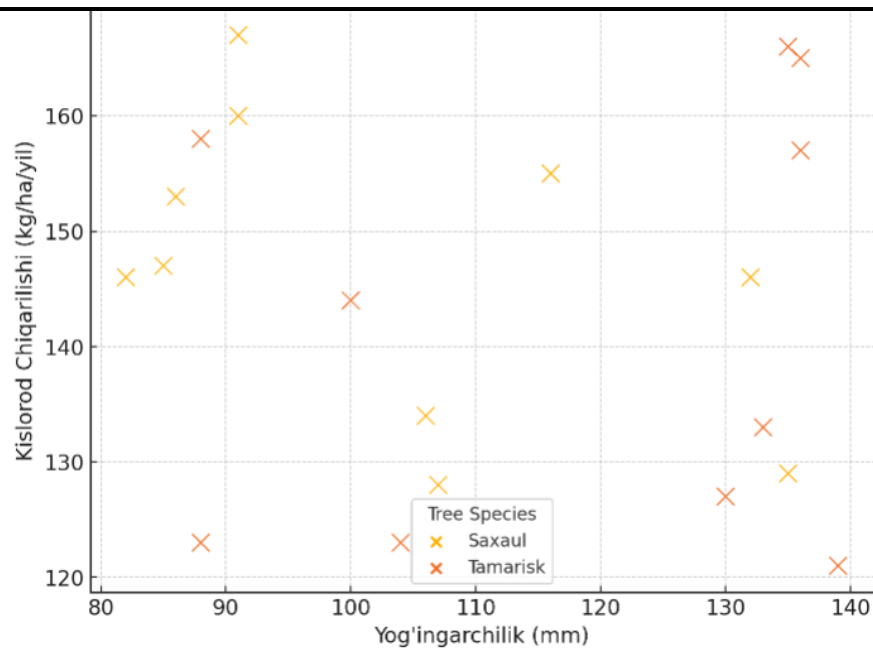


Figure 2. Relationship between precipitation and oxygen release in saxaul and tamarix observations from Uzbekistan's desert landscape.

Figure 2 suggests that precipitation is relevant for oxygen-release potential, but the relationship is not perfectly linear. This is expected in desert ecosystems because vegetation performance depends not only on rainfall amount, but also on soil salinity, rooting conditions, groundwater availability, species tolerance, and stand age. In practical terms, the figure indicates that restoration planning should not simply select areas with slightly higher precipitation. It should combine precipitation with salinity screening and species suitability. This interpretation is consistent with dryland restoration studies showing that tree establishment in the Aral Sea Basin and similar arid landscapes depends on site quality and water limitation rather than planting area alone (Khamzina et al., 2006, 2008; Kumar et al., 2021).

Figure 3 presents the relationship between air temperature and oxygen release. The observed temperature range is high, which reflects the thermal stress typical of Uzbekistan's desert

landscapes. In the table, values range from 38°C to 41°C, while the figure series appears to include a wider range of points. The relationship is mixed, suggesting that temperature alone does not explain oxygen-release variation.

Figure 3 shows that high temperature is an important stress factor, but it does not operate separately from moisture and salinity. Some high-temperature observations still show relatively high oxygen-release values, especially for saxaul. This may reflect the drought adaptation of the species and the influence of other local conditions. Therefore, the figure should be discussed as evidence of thermal stress under desert conditions, but not as proof of a simple negative temperature effect. For restoration practice, the result means that species such as saxaul and tamarix can survive under high-temperature regimes, but their productivity and oxygen-release potential still depend on micro-site conditions and salinity control (Dawalibi et al., 2015; Novitskiy et al., 2023; Toderich et al., 2013).

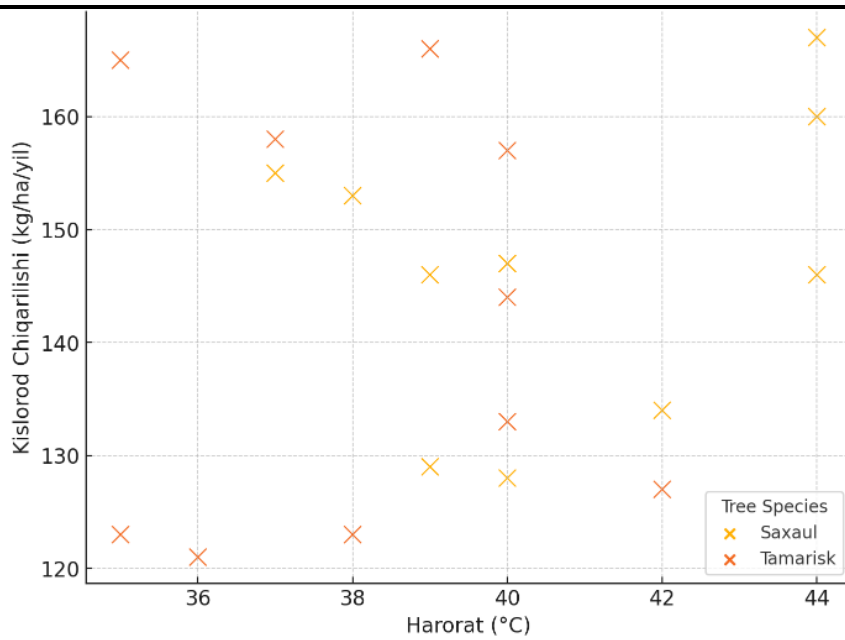


Figure 3. Relationship between air temperature and oxygen release in saxaul and tamarix observations from Uzbekistan’s desert landscape.

Figure 4 summarizes the correlation structure among area, precipitation, temperature, soil salinity, and oxygen release. The most important point is that the displayed correlations are weak. Oxygen release has a negative relationship with soil salinity, $r = -0.22$, and area, $r = -0.21$. It also has a weak negative

relationship with precipitation, $r = -0.13$, and a weak positive relationship with temperature, $r = 0.17$. These values should not be treated as strong statistical evidence. Instead, they show that the available dataset is exploratory and that more observations are needed.

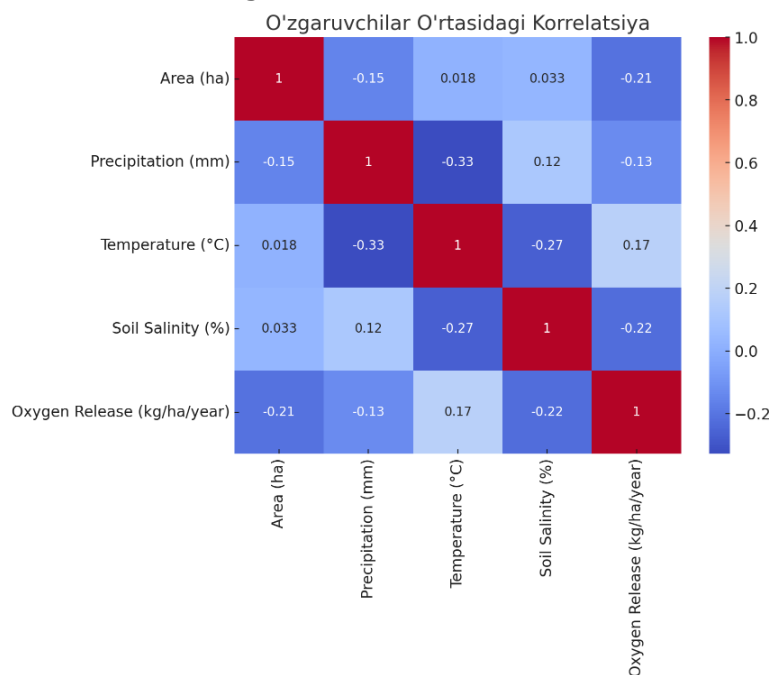


Figure 4. Correlation heatmap of area, precipitation, temperature, soil salinity, and oxygen release in desert-zone observations.

While the table suggests that higher precipitation may support better oxygen-release values in some saxaul observations, the

heatmap shows that the broader relationship is weak and inconsistent. The negative correlation between soil salinity and oxygen release is the

most ecologically meaningful pattern, even though it is also weak. This agrees with the general understanding that salinity limits plant growth, biomass accumulation, and restoration success in arid soils. The weak correlation values also indicate that oxygen-release potential is probably controlled by several factors together, including species, stand condition, age, soil depth, salinity, and moisture availability. For future research, a larger plot-level dataset would allow regression modelling or machine-learning classification of high- and low-potential restoration areas.

4. Discussion

The results show that oxygen-release potential in Uzbekistan's desert landscape is species- and site-dependent. Saxaul had a higher average value than tamarix in the presented observations, but this result should be interpreted carefully because of the small sample size. The main scientific value of the article is not that it proves one species is always better than another. Rather, it shows that GIS-based ecological accounting can connect species-level coefficients with spatial and environmental variables. This is important for desert restoration because planting success depends on the match between species traits and local site conditions (Khamzina et al., 2006; Novitskiy et al., 2023; Toderich et al., 2013).

The oxygen-release values in Table 1, 130–155 kg ha⁻¹ yr⁻¹, should be understood as hectare-normalized ecological indicators. They do not represent total oxygen release from the whole restoration area unless they are multiplied by validated stand area and adjusted for stand age, canopy density, and survival rate. This distinction is important because restoration projects often report planted hectares or seedling numbers, while actual ecosystem-service delivery depends on survival, growth, and canopy development. Similar concerns are common in forest and dryland restoration research, where spatial extent alone does not fully describe ecosystem function (Bonan, 2008; Crowther et al., 2015; World Bank & ICARDA, 2021).

The GIS and remote sensing component improves the practical usefulness of the assessment. NDVI and related vegetation indicators are widely used because they allow vegetation condition to be monitored over large areas and repeated time periods (Huete et al., 2002; Pettorelli et al., 2005; Tucker, 1979). In this article, the GIS map supports spatial interpretation by showing vegetation-cover patterns, while the table and statistical figures provide ecological explanation. This combination is more useful than a simple table because it can guide restoration planning, identify areas requiring salinity screening, and support monitoring after planting.

At the same time, the current dataset has clear limitations. First, the number of tabulated observations is small. Second, the figures appear to contain more points than the five observations shown in Table 1, so the final manuscript should clarify whether the scatter plots come from a larger dissertation dataset. Third, oxygen-release coefficients should be explained in more detail. A strong Scopus-style article should indicate whether oxygen release was measured directly, estimated from biomass, derived from photosynthetic assumptions, or adapted from an ecological accounting model such as i-Tree. Without that clarification, the article remains useful but preliminary (Nowak et al., 2007; Sharma et al., 2024).

The results are still relevant for Uzbekistan's restoration policy. In the Aral Sea region and other desert territories, afforestation is not only about oxygen production. Its wider benefits include sand fixation, dust reduction, soil stabilization, habitat recovery, and protection of settlements and infrastructure. Saxaul and other drought-tolerant species are especially important because they can survive where conventional tree species cannot. Therefore, oxygen-release potential should be presented as one indicator within a broader restoration-benefit framework, not as the only reason for planting trees in desert zones (Micklin, 2016; World Bank & ICARDA, 2021).

5. Conclusion

This article assessed tree oxygen release potential in the desert landscape of Uzbekistan using GIS-supported ecological indicators and species-level observations for saxaul and tamarix stands. The revised scope is limited to the desert zone because the available empirical material does not support a full comparison of desert, pasture, mountain, and foothill landscapes. This correction makes the article more accurate and scientifically defensible.

The results showed that oxygen release ranged from 130 to 155 kg ha⁻¹ yr⁻¹, with a mean value of 144 kg ha⁻¹ yr⁻¹. Saxaul showed a higher mean value than tamarix in the analyzed observations. The highest value, 155 kg ha⁻¹ yr⁻¹, was recorded for saxaul under 130 mm precipitation, 41°C temperature, and 2.7% salinity. The lowest value, 130 kg ha⁻¹ yr⁻¹, was recorded for tamarix under 110 mm precipitation, 39°C temperature, and 2.8% salinity. These differences suggest that species selection and micro-site conditions should be considered together in desert afforestation planning.

The visual materials strengthen the article by showing how GIS maps, scatter plots, and correlation heatmaps can support ecological interpretation. However, the correlation results are weak and exploratory, especially for precipitation and temperature. The most practically meaningful pattern is the negative association between salinity and oxygen release. Future research should increase the number of field observations, separate stand age and canopy density classes, clarify the oxygen-release calculation method, and develop a validated GIS model for identifying high-potential saxaul and tamarix restoration areas in Uzbekistan's desert territories.

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