# Soil Carbon, Nitrogen, and Phosphorus and Their Stoichiometric Characteristics Under Typical Artificial Vegetation in Qingshuihe County, Inner Mongolia (Postprint)

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## Abstract

The stoichiometric relationships of soil carbon (C), nitrogen (N), and phosphorus (P) in vegetation are critical for understanding the ecological functions of different vegetation types. Using four typical artificial vegetation types (poplar, Pinus sylvestris var. mongolica, Pinus tabuliformis, and Caragana korshinskii) in Qingshuihe County as research subjects and natural grassland (gramineous grassland) as a control, this study investigated soil C, N, and P contents and their stoichiometric ratio characteristics within the 0–100 cm soil layer in typical artificial vegetation communities. The results showed: (1) Across the five vegetation types, surface layer (0–20 cm) soil C, N, and P contents were 3.29–6.02 $g \cdot kg^{-1}$, 0.52–0.69 $g \cdot kg^{-1}$, and 0.37–0.62 $g \cdot kg^{-1}$, respectively, with soil C and N contents being lower than the national average for surface soils in China, indicating low soil fertility. (2) In the 0–20 cm layer, soil C, N, and C/N ratios of all artificial vegetation types were lower than those of gramineous grassland, with Pinus sylvestris var. mongolica and Caragana korshinskii showing significantly lower soil C and C/N ($P<0.05$); in the 20–50 cm and 50–100 cm layers, Pinus tabuliformis had the highest soil C and N, while other artificial vegetation types remained lower than grassland, and Pinus sylvestris var. mongolica had the lowest C/N; soil P content in artificial vegetation was significantly higher than in grassland across all layers, while soil C/P and N/P ratios were markedly lower than in grassland. (3) Correlation analysis indicated extremely significant positive relationships between soil C and N, and between C/P and N/P ($P<0.001$); soil C, N, and P were significantly influenced by vegetation type and soil depth ($P<0.001$); soil C, N, and P contents decreased with increasing soil depth, demonstrating a clear surface accumulation effect. Given that high soil phosphorus availability in the study area favors herbaceous growth, and that herbaceous vegetation exhibits superior soil nutrient conservation compared to artificial arbor-shrub vegetation, ecological restoration in this region should prioritize conservation and restoration of native herbaceous vegetation. These findings enhance understanding of soil nutrient cycling patterns, facilitate assessment of vegetation ecological benefits, and provide a scientific basis for regional ecological restoration and resource management.

## Full Text

# Soil Carbon, Nitrogen, and Phosphorus Stoichiometric Characteristics of Typical Artificial Vegetation in Qingshuihe County, Inner Mongolia

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### Abstract

The stoichiometric relationship of carbon (C), nitrogen (N), and phosphorus (P) in vegetation soils is crucial for understanding the ecological functions of different vegetation types. This study examined four typical artificial vegetation types (*Populus* L., *Pinus sylvestris*, *Pinus tabulaeformis*, and *Caragana korshinskii*) in Qingshuihe County, Inner Mongolia, China, with natural gramineous grassland as the control. The concentrations of soil C, N, and P along with their stoichiometric ratios within the 0–100 cm soil profile were investigated. The key results were as follows. (1) In the surface-soil layer (0–20 cm), C, N, and P levels across the five vegetation types were 3.29–6.02 $g \cdot kg^{-1}$, 0.52–0.69 $g \cdot kg^{-1}$, and 0.37–0.62 $g \cdot kg^{-1}$, respectively. Soil C and N levels were below the national surface-soil average, indicating poor soil fertility. (2) In the 0–20 cm layer, soils under artificial vegetation had lower C content, N levels, and C/N ratios compared with those under grassland, with significantly lower C and C/N observed in *P. sylvestris* and *C. korshinskii* ($P<0.05$). At depths of 20–50 cm and 50–100 cm, C and N levels were highest under grassland and lower under artificial vegetation, with *P. tabulaeformis* showing the lowest C/N ratio. Soil P content was significantly higher under artificial vegetation than under grassland at all depths, whereas C/P and N/P ratios were significantly lower than those under grassland. (3) Correlation analysis revealed strong positive relationships between soil C and N and between C/P and N/P ($P<0.001$). Soil C, N, and P levels were significantly affected by vegetation type and soil depth ($P<0.001$) and all decreased with increasing depth, indicating strong surface accumulation. Given the high soil phosphorus availability in the study area, which favors herbaceous growth, and the superior soil nutrient conservation capacity of herbaceous vegetation relative to artificial tree-shrub vegetation, ecological restoration efforts in this region should prioritize conserving and restoring native herbaceous vegetation. This study contributes to understanding soil nutrient cycling patterns, assessing vegetation ecological benefits, and providing a scientific basis for regional ecological restoration and resource management.

**Keywords:** artificial vegetation; natural grassland; soil nutrients; ecological stoichiometry

Ecological stoichiometry reveals the dynamic equilibrium and interaction mechanisms of elements in ecosystems by studying the coupled cycling of soil carbon (C), nitrogen (N), and phosphorus (P). As the foundation for plant and microbial community survival, soil nutrient supply ratios govern community structure and functional changes. Soil C and N primarily originate from biological processes such as plant litter decomposition and root exudates, whereas P mainly derives from mechanical weathering of rocks with relatively stable reserves. Vegetation restoration serves as a core strategy for rehabilitating degraded ecosystems in ecologically fragile regions, playing a key role in enhancing ecosystem service functions. Research demonstrates that vegetation restoration not only significantly improves ecosystem service capacity through carbon sequestration, soil and water conservation, hydrological regulation, and soil improvement, but also profoundly influences the distribution patterns and storage characteristics of soil nutrients. The functions of restored vegetation directly reflect soil nutrient cycling, balance characteristics, and quality indicators. The biogeographical patterns of soil nutrient stoichiometry are significantly influenced by topography and vegetation type, while spatial distribution characteristics of plant roots and nutrient uptake strategies further promote spatial heterogeneity of soil nutrients, profoundly affecting ecosystem functional expression. Differences in vegetation performance regarding water conservation, soil retention, ecological stability maintenance, and nutrient cycling participation highlight the complexity of vegetation restoration strategies. However, the relationship between soil C, N, P stoichiometric characteristics and vegetation restoration in ecologically fragile regions remains unclear, as existing studies have largely focused on single systems of either artificial or natural vegetation, lacking comparative analyses of both. Therefore, investigating soil C, N, P stoichiometric characteristics of different artificial vegetation types through comparison with natural grassland is essential for sustainable management of degraded ecosystems.

Qingshuihe County represents a typical ecologically fragile region, located in the transition zone between the Loess Plateau and Inner Mongolia Plateau, severely affected by water erosion. Since the 1980s, extensive afforestation activities have been implemented to reduce soil erosion, improve soil nutrient conditions, and enhance ecosystem services, making it an ideal region for studying soil C, N, P contents and stoichiometry under artificial vegetation. This study examined four typical artificial vegetation types—*Populus*, *Pinus tabulaeformis*, *Pinus sylvestris*, and *Caragana korshinskii*—in Qingshuihe County, using natural grassland as a control. By measuring soil C, N, P contents and their stoichiometric ratios within the 0–100 cm profile, we aimed to reveal the vertical distribution characteristics of soil nutrients under different artificial vegetation types. The results provide fundamental data for estimating soil nutrient storage and assessing nutrient limitations under various vegetation types, offering a scientific basis for selecting vegetation restoration types and optimizing strategies in the region.

# 1 Materials and Methods

## 1.1 Study Area

The study area is located in Qingshuihe County, Hohhot City, Inner Mongolia Autonomous Region (111°18 –112°07 E, 39°35 –40°12 N), situated in the transitional zone between the Inner Mongolia Plateau and the Shanxi-Shaanxi Loess Plateau. This typical semi-arid region experiences severe river erosion, with terrain gradually decreasing from southeast to west and an average elevation of 1373.6 m. The region has a temperate continental climate with a mean annual temperature of 7.1 °C and mean annual precipitation of 413.8 mm, concentrated during July–September. The area features diverse vegetation types, with dominant tree species including *Populus*, *Pinus tabulaeformis*, *Pinus sylvestris*, and *Caragana korshinskii*. Animal husbandry is well-developed, with natural pasture grasses primarily consisting of *Leymus chinensis* and *Stipa capillata*. Soil types are mainly chestnut soil, chestnut-cinnamon soil, and gray-cinnamon soil.

## 1.2 Field Sampling

Field investigations and sampling were conducted in July 2022. Based on the principles of regional vegetation species representativeness and typicality, we selected four artificial vegetation types (*Populus*, *Caragana korshinskii*, *Pinus tabulaeformis*, and *Pinus sylvestris*) with similar planting ages and densities, along with natural gramineous grassland (*Stipa capillata* and *Leymus chinensis*) as the control. The number of sample plots for each vegetation type was determined according to their proportional area in the study region. For each vegetation type, we selected plots with similar disturbance levels: five plots each for *Populus*, *Caragana korshinskii*, and grassland; four plots for *Pinus tabulaeformis*; and three plots for *Pinus sylvestris*, totaling 21 plots. Each plot established a 20 m × 20 m standard sampling quadrat, recording basic characteristics including elevation, slope, and vegetation coverage (Table 1 ). Within each quadrat, we set up a 1 m × 1 m herbaceous subplot and soil profile. Aboveground herbaceous biomass and litter within the subplot were collected and placed in separate labeled envelopes. Soil profiles were sampled across three layers (0–20 cm, 20–50 cm, and 50–100 cm), collecting both ring knife samples and bulk soil samples. Soil samples from the same layer across three profiles within each plot were thoroughly mixed, sealed in bags, and transported to the laboratory for processing.

### 1.3 Sample Processing and Determination

Ring knife samples were used to determine soil bulk density via the ring knife method. Mixed soil samples were air-dried, impurities removed, and ground to pass through a 2 mm sieve. Soil C content was measured using the potassium dichromate oxidation-copper sulfate titration method. N and P contents were determined by $H_2SO_4$ digestion followed by analysis with an automated chemistry analyzer. Litter and aboveground herbaceous biomass were oven-dried at 65 °C to constant weight before weighing.

### 1.4 Data Analysis

SPSS 27 and Origin 2022 software were used for statistical analysis and graphing, with values presented as mean ± standard error. One-way ANOVA was employed to analyze differences in soil C, N, P contents and stoichiometric ratios among vegetation types and soil layers, with Duncan's test for multiple comparisons. Two-way ANOVA was used to examine the effects of vegetation type and soil depth on soil C, N, P and their stoichiometric ratios. Pearson correlation analysis, linear regression, and principal component analysis were applied to identify factors influencing soil C, N, P contents and stoichiometric ratios across vegetation types.

## 2 Results

### 2.1 Distribution Characteristics of Soil C, N, and P Contents

Figure 1 [Figure 1: see original paper] shows the variation characteristics of soil C, N, and P contents and their ecological stoichiometry under five vegetation types. Across the 0–100 cm soil profile, C, N, and P contents ranged from 1.34–6.02 $g \cdot kg^{-1}$, 0.25–0.62 $g \cdot kg^{-1}$, and 0.27–0.69 $g \cdot kg^{-1}$, respectively. In the 0–20 cm surface layer, soil C and N contents under artificial vegetation were lower than under grassland, following the order: grassland > *Populus* > *Pinus tabulaeformis* > *Pinus sylvestris*, with C contents in *Pinus sylvestris* and *Caragana korshinskii* significantly lower than in grassland and *Pinus tabulaeformis* ($P<0.05$). Soil P content showed the pattern: grassland < *Populus* < *Pinus tabulaeformis* < *Pinus sylvestris* < *Caragana korshinskii*, with no significant differences among vegetation types. In the 20–50 cm and 50–100 cm layers, C and N contents under artificial vegetation were lower than under grassland. In the 20–50 cm layer, *Populus* had the highest C and N contents, and *Pinus tabulaeformis* showed significantly higher P content than *Pinus sylvestris* and *Caragana korshinskii* across all layers ($P<0.05$). Soil C/N ratios under *Populus*, *Pinus sylvestris*, and *Caragana korshinskii* were lower than under grassland at all depths, with *Pinus sylvestris* showing the lowest C/N ratio among all vegetation types. Soil C/P and N/P ratios under artificial vegetation were higher than under grassland across all layers, with significant differences observed for *Pinus sylvestris* in the 0–20 cm layer ($P<0.05$). Except for *Pinus tabulaeformis* in the 20–50 cm layer, C and N contents in all vegetation types decreased with increasing soil depth, and significant differences in P content among layers existed for all vegetation types except *Pinus tabulaeformis* ($P<0.05$).

### 2.2 Stoichiometric Ratio Characteristics

Figure 1 [Figure 1: see original paper] shows the variation characteristics of soil C/N, C/P, and N/P ratios under five vegetation types. Across the 0–100 cm soil profile, C/N, C/P, and N/P ratios ranged from 3.80–16.67, 4.36–8.79, and 0.70–2.59, respectively. In the 0–20 cm layer, soil C/N ratios under artificial vegetation were lower than under grassland, with C/N ratios in *Pinus sylvestris* and *Caragana korshinskii* significantly lower than in grassland ($P<0.05$). In the 20–50 cm and 50–100 cm layers, C/N ratios under artificial vegetation were lower than under grassland, with *Pinus tabulaeformis* showing the lowest C/N ratio in the 20–50 cm layer. Soil C/P and N/P ratios under artificial vegetation were lower than under grassland across all layers, with *Pinus sylvestris* C/P and N/P significantly lower than grassland in the 0–20 cm layer ($P<0.05$). In the 20–50 cm and 50–100 cm layers, C/P and N/P ratios under artificial vegetation were lower than under grassland; in the 20–50 cm layer, *Pinus tabulaeformis* had the highest C/P and N/P ratios while other artificial vegetation types remained lower than grassland, and *Pinus sylvestris* C/P and N/P ratios were significantly lower than grassland.

### 2.3 Relationships Between Soil C, N, P, Stoichiometry, and Influencing Factors

Table 2 presents the two-way ANOVA results for the effects of vegetation type and soil depth on soil C, N, P and their stoichiometric ratios. Vegetation type significantly affected soil C and N contents ($P<0.001$) and significantly influenced soil P content, C/N, C/P, and N/P ($P<0.01$). Soil depth significantly affected soil C, N, P contents and their stoichiometric ratios ($P<0.001$), while the interaction between vegetation type and soil depth was not significant. Table 3 shows the Pearson correlation analysis between soil bulk density and environmental factors and C, N, P stoichiometric characteristics. Soil C, N, and P contents showed extremely significant positive correlations ($P<0.001$), and soil C, N, P contents were significantly negatively correlated with soil bulk density ($P<0.01$) and positively correlated with elevation ($P<0.01$), while correlations with stoichiometric ratios and slope were weak. Figure 2 [Figure 2: see original paper] illustrates the correlations among soil C, N, and P across different vegetation types, showing extremely significant positive correlations among soil C, N, and P contents ($P<0.001$). Linear regression results revealed a strong positive correlation between soil C and N contents ($R^2=0.556$, $P<0.001$) and a significant positive correlation between soil C/P and N/P ratios ($R^2=0.073$, $P<0.004$). Principal component analysis results (Figure 3 [Figure 3: see original paper]) showed that the first two principal components explained 30.9% and 23.6% of the total variance, respectively, with a cumulative explanation of 54.5%, adequately capturing the main variation characteristics of soil nutrients and environmental factors in the study area. PC1 primarily reflected the spatial variation of soil nutrient contents and their stoichiometric characteristics, showing positive correlations with soil C, N, and P contents, negative correlations with soil bulk density and slope, and weak correlations with aspect and slope. PC2 reflected the regulatory effects of topographic factors and vegetation productivity on soil nutrient distribution, showing positive correlations with elevation, aboveground biomass, and litter quantity, and negative correlations with slope and aspect. *Populus* distribution along PC2 was significantly influenced by soil C, N, P, aboveground biomass, and litter quantity.

## 3 Discussion

### 3.1 Distribution of Soil C, N, and P Nutrients Under Different Vegetation Types

Soil nutrient characteristics exhibit spatial variation, with this variability differing substantially across scales and regions. In the surface layer (0–20 cm), soil C, N, and P contents under *Populus*, *Pinus tabulaeformis*, *Pinus sylvestris*, *Caragana korshinskii*, and grassland were 4.05, 6.02, 3.29, 6.01, and 6.01 $g \cdot kg^{-1}$; 0.60, 0.59, 0.52, 0.69, and 0.53 $g \cdot kg^{-1}$; and 0.57, 0.62, 0.48, 0.37, and 0.62 $g \cdot kg^{-1}$, respectively. Soil C and N contents were markedly lower than the national surface soil averages (24.56 $g \cdot kg^{-1}$ and 1.88 $g \cdot kg^{-1}$), while P content was similar to the national average (0.38 $g \cdot kg^{-1}$). Low soil C and N contents result from the fragmented terrain, arid climate, and severe water erosion in the study area, leading to low soil productivity and water/nutrient retention capacity, consistent with previous studies in arid regions. Across the five vegetation types, C/N, C/P, and N/P ratios ranged from 3.80–16.67, 4.36–8.79, and 0.70–2.59, respectively, falling within normal ranges but lower than those in Inner Mongolia grasslands and the Loess Plateau. This reflects the study area's location in the northern Loess Plateau, where drought and soil conditions limit stoichiometric ratios below national averages. C/N ratios reflect organic matter decomposition rates, indicating high mineralization rates and faster decomposition than accumulation in the study area. Results show that *Pinus tabulaeformis* and grassland had significantly higher soil C/N ratios than *Pinus sylvestris* and *Caragana korshinskii*, suggesting lower mineralization and decomposition rates and relatively greater C and N accumulation in the former. C/P ratio indicates mineralization capacity of C and P elements; lower C/P signifies lower P effectiveness, while N/P serves as an effective predictor of nutrient limitation. The significantly lower N/P ratio compared to the national average indicates high N effectiveness in the study area, creating favorable conditions for herbaceous growth. Surface soil C and N contents under artificial vegetation were lower than under grassland because herbaceous plants possess denser, more extensive shallow root systems than artificial vegetation. The substantial root exudates and complex root networks promote soil organic matter and N accumulation, enhancing nutrient retention that extends to deeper soil layers. Across all layers, *Populus*, *Pinus sylvestris*, and *Caragana korshinskii* showed low C and N contents, possibly due to sparse, woody litter in *Caragana korshinskii* that decomposes slowly, limiting soil C and N accumulation. In semi-arid regions, water is a key factor limiting soil nutrients; as a water-demanding species, insufficient precipitation restricts *Populus* growth and hinders soil nutrient accumulation. Differences in C and N contents between *Pinus tabulaeformis* and *Pinus sylvestris* may relate to variations in understory litter quantity. Soil nutrient cycling primarily involves microbial uptake and vegetation extraction; P contents under artificial vegetation were higher than under grassland across all layers because grassland has greater P demand during growth and faster nutrient cycling that reduces P effectiveness. In the 0–20 cm layer, *Pinus tabulaeformis* and *Pinus sylvestris* had significantly higher P contents than grassland due to greater P enrichment from decomposed litter. Overall, artificial vegetation showed weaker C, N, P conservation capacity than grassland, which more effectively combined with the notably low soil C and N contents, reflecting regional N limitation that negatively impacts primary productivity and ecosystem processes. Therefore, improving soil N fertility should be the focus of ecological restoration in this area. Grassland C/P and N/P ratios were significantly higher than those under artificial vegetation because sufficient, effective P creates favorable conditions for herbaceous development. Unlike artificial tree-shrub vegetation, dense grassland cover and intensive shallow root systems with root exudates effectively retain soil moisture, resist erosion, and provide better nutrient retention and ecological benefits. Therefore, ecological restoration in Inner Mongolia should prioritize conserving and planting native herbaceous species, with artificial tree-shrub vegetation as a secondary consideration.

### 3.2 Distribution of Soil C, N, and P Stoichiometric Ratios Under Different Vegetation Types

Soil is a tightly coupled system, with nutrient elements directly influenced by plant growth and development, microbial proliferation, and ecosystem nutrient cycling. Ecological stoichiometry serves as a key indicator of ecosystem nutrient cycling, profoundly affecting ecosystem functions and services. The tight coupling between C and N is primarily mediated by microbial decomposition processes, with the C/N ratio being a critical factor regulating organic matter decomposition rates. This explains the generally consistent trends in soil C, N, and P across vegetation types. The strong correlation between C/P and N/P mainly stems from the regulatory effects of soil C and N on P elements. The well-developed herbaceous industry in the study area creates microenvironments that promote P cycling, resulting in tight coupling between C/P and N/P. Vegetation and environmental factors significantly influence soil C, N, P and their stoichiometric ratios. Two-way analysis showed that vegetation type significantly affected soil C, N, P and their stoichiometric ratios ($P<0.01$), reflecting differential nutrient uptake, allocation, and return strategies among vegetation types. Significant differences among artificial vegetation types were influenced not only by inherent factors but also by management practices such as thinning and organic fertilizer application. Soil depth significantly affected soil C, N, P and their stoichiometric ratios ($P<0.001$) because surface and deep soils accumulate different nutrients, with deep soil nutrients primarily derived from leaching and vegetation uptake. Correlation analysis revealed that soil C, N, and P contents were significantly negatively correlated with soil bulk density, as bulk density indicates soil compaction—higher bulk density reduces water content and porosity, thereby affecting nutrient percolation and plant growth. Elevation was significantly negatively correlated with bulk density, indicating that at small scales, elevation indirectly affects soil nutrients primarily through its influence on bulk density. As elevation increases, soil looseness improves, enhancing nutrient retention and maintaining soil nutrient balance. Soil C, N, and P contents were positively correlated with elevation, aboveground biomass, and litter quantity because soil nutrients derive not only from parent material weathering but also from vegetation nutrient return. Higher elevations facilitate rock weathering, increasing soil P content and inhibiting organic matter decomposition. *Populus* nutrients were more strongly influenced by vegetation biomass and litter, likely because as a broadleaf species, it has greater litter input and nutrient consumption than other vegetation types. Microtopography affects water storage and heat distribution, creating nutrient differences. Aspects closer to shady slopes have weaker light conditions, favoring soil moisture retention, reducing evaporation, and promoting humus decomposition and nutrient accumulation. Slope affects soil nutrients by influencing surface runoff and soil particle transport, with steeper slopes facilitating nutrient loss. Correlations between soil C, N, P stoichiometry and microtopographic factors were weak in the study area, possibly due to relatively uniform terrain characteristics, indicating that vegetation and soil factors exert more significant influence on nutrient distribution at small scales. Soil C, N, P stoichiometric ratios are comprehensively affected by soil properties, vegetation type, and geographic environment. Factors not included in this study, such as stand age, vegetation density, and microorganisms, may play important roles in soil nutrient distribution. Future research should incorporate these factors to comprehensively analyze nutrient distribution mechanisms, helping establish criteria for evaluating soil nutrient limitations under different vegetation types within the same natural ecological zone, which is significant for revealing soil nutrient supply capacity and guiding ecological restoration.

### 3.3 Relationships Between Stoichiometric Characteristics and Influencing Factors Under Different Vegetation Types

This study shows that soil C, N, and P contents were highest in the surface layer and decreased with increasing soil depth, primarily due to higher microbial activity in the surface layer and abundant surface litter, resulting in greater nutrient accumulation in surface soil, consistent with Wang et al. Soil C, N, and P contents showed extremely significant positive correlations, indicating tight coupling in terrestrial nutrient cycling. The tight coupling between soil C and N is mainly mediated by microbial decomposition processes, with the C/N ratio being a key factor regulating organic matter decomposition rates. This explains the generally consistent trends in soil C, N, and P across vegetation types. The strong correlation between C/P and N/P mainly stems from the regulatory effects of soil C and N on P elements. The well-developed herbaceous industry in the study area creates microenvironments that promote P cycling, resulting in tight coupling between C/P and N/P. Vegetation and environmental factors significantly influence soil C, N, P and their stoichiometric ratios. Two-way analysis showed that vegetation type significantly affected soil C, N, P and their stoichiometric ratios ($P<0.01$), reflecting differential nutrient uptake, allocation, and return strategies among vegetation types. Significant differences among artificial vegetation types were influenced not only by inherent factors but also by management practices such as thinning and organic fertilizer application. Soil depth significantly affected soil C, N, P and their stoichiometric ratios ($P<0.001$) because surface and deep soils accumulate different nutrients, with deep soil nutrients primarily derived from leaching and vegetation uptake. Correlation analysis revealed that soil C, N, and P contents were significantly negatively correlated with soil bulk density, as bulk density indicates soil compaction—higher bulk density reduces water content and porosity, thereby affecting nutrient percolation and plant growth. Elevation was significantly negatively correlated with bulk density, indicating that at small scales, elevation indirectly affects soil nutrients primarily through its influence on bulk density. As elevation increases, soil looseness improves, enhancing nutrient retention and maintaining soil nutrient balance. Soil C, N, and P contents were positively correlated with elevation, aboveground biomass, and litter quantity because soil nutrients derive not only from parent material weathering but also from vegetation nutrient return. Higher elevations facilitate rock weathering, increasing soil P content and inhibiting organic matter decomposition. *Populus* nutrients were more strongly influenced by vegetation biomass and litter, likely because as a broadleaf species, it has greater litter input and nutrient consumption than other vegetation types. Microtopography affects water storage and heat distribution, creating nutrient differences. Aspects closer to shady slopes have weaker light conditions, favoring soil moisture retention, reducing evaporation, and promoting humus decomposition and nutrient accumulation. Slope affects soil nutrients by influencing surface runoff and soil particle transport, with steeper slopes facilitating nutrient loss. Correlations between soil C, N, P stoichiometry and microtopographic factors were weak in the study area, possibly due to relatively uniform terrain characteristics, indicating that vegetation and soil factors exert more significant influence on nutrient distribution at small scales. Soil C, N, P stoichiometric ratios are comprehensively affected by soil properties, vegetation type, and geographic environment. Factors not included in this study, such as stand age, vegetation density, and microorganisms, may play important roles in soil nutrient distribution. Future research should incorporate these factors to comprehensively analyze nutrient distribution mechanisms, helping establish criteria for evaluating soil nutrient limitations under different vegetation types within the same natural ecological zone, which is significant for revealing soil nutrient supply capacity and guiding ecological restoration.

## 4 Conclusions

This study examined several typical artificial vegetation types in Qingshuihe County, Inner Mongolia, measuring soil C, N, and P contents within the 0–100 cm profile to investigate the effects of different artificial vegetation on soil C, N, P and their stoichiometric ratios. The results indicate: (1) Soil C and N contents under both artificial vegetation and grassland in the study area were below national averages, with soil nutrients limited by N. (2) The capacity of artificial vegetation to improve soil fertility and accumulate soil C, N, and P was lower than that of grassland. (3) The demand for soil N by artificial vegetation growth was lower than that of grassland, while soil P effectiveness was high in the study area, favoring herbaceous plant survival and development. Considering the high soil phosphorus availability that favors herbaceous growth and the superior soil nutrient conservation capacity of herbaceous vegetation relative to artificial tree-shrub vegetation, ecological restoration in this region should prioritize conserving and restoring native herbaceous vegetation.

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