

Ecological Stoichiometric Characteristics of Soil Carbon, Nitrogen, and Phosphorus in Different Marsh Wetlands and Their Influencing Factors: Postprint

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Abstract

Wetlands in arid regions play an important role in improving the ecological environment and maintaining ecological stability of the region. Studying the ecological stoichiometric characteristics of soil carbon (C), nitrogen (N), phosphorus (P) and other elements in arid region wetlands facilitates a deeper understanding of the nutrient supply capacity, cycling, and balance mechanisms of wetland soils in arid regions. This study investigated the soils of herbaceous swamps (T1) and seasonal saline swamps (T2) in the western Hexi Corridor, middle and lower reaches of the Shule River, and analyzed the ecological stoichiometric characteristics of soil C, N, P and their influencing factors in these two types of swamp wetlands. The results show: Soil C/N, N/P, and C/P in the 0-100 cm layer are all higher in T2 (15.07, 5.94, 98.01) than in T1 (12.49, 2.50, 30.22); with increasing soil depth, soil C/N, N/P, and C/P in T1 have two peak values (0-10 cm and the middle layer), while T2 has one peak value (the middle layer).

Soil C/N, N/P, and C/P in the 0-100 cm layer exhibit high spatial variability, and all are higher in T2 than in T1. N/P ratios in both T1 and T2 soils are extremely significantly positively correlated with soil moisture ($P < 0.01$), C/P ratios are extremely significantly positively correlated with soil moisture and total N ($P < 0.01$), and significantly positively correlated with alkali-hydrolyzable N ($P < 0.05$); in T2 soils, C/N, N/P, and C/P ratios are extremely significantly positively correlated with soil bulk density ($P < 0.01$), C/N ratio is extremely significantly positively correlated with soil moisture ($P < 0.01$), and N/P ratio is significantly positively correlated with soil organic C ($P < 0.05$); in T1 soils, N/P ratio is extremely significantly positively correlated with soil organic C ($P < 0.01$). Soil moisture is the key factor affecting soil C, N, P stoichiometric ratios in both types of swamp wetlands. Therefore, the key to protecting wet-

land soils in arid regions lies in implementing rational water-saving measures. These results can provide a scientific basis for the protection, management, and ecological restoration of wetland soils in arid regions.

Full Text

Results and Discussion

2.1 Vertical Distribution Characteristics

The vertical distribution of soil C/N, N/P, and C/P ratios exhibited distinct patterns between the two marsh types. In T1 soils, C/N and C/P ratios reached maximum values in the 60–80 cm depth interval (20.08 and 130.08, respectively), while N/P peaked at 40–60 cm (7.63). In T2 soils, N/P and C/P ratios showed no significant variation with depth ($P > 0.05$). Both marsh types displayed peak values in interlayer soils, suggesting that subsurface biogeochemical processes significantly influence nutrient stoichiometry.

2.2 Spatial Variability

Across the 0–100 cm soil profile, C/N, N/P, and C/P ratios demonstrated considerable spatial variability, with coefficients of variation consistently greater in T2 than in T1 ($P < 0.01$). This enhanced spatial heterogeneity in the seasonal saline marsh likely reflects the dynamic influence of fluctuating water levels and salinity on nutrient distribution patterns.

2.3 Correlation Analysis

2.3.1 Relationships with Soil Physicochemical Properties Pearson correlation analysis revealed differential relationships between stoichiometric ratios and soil properties across marsh types. In T1 soils, N/P ratio was significantly positively correlated with soil moisture, soil total nitrogen, and alkali-hydrolyzable nitrogen ($P < 0.01$), while C/P ratio showed significant positive correlation with soil moisture ($P < 0.01$). In T2 soils, C/N, N/P, and C/P ratios were all significantly positively correlated with soil bulk density ($P < 0.01$). Additionally, C/N ratio was significantly positively correlated with soil moisture ($P < 0.01$), and N/P ratio was significantly positively correlated with soil organic carbon ($P < 0.05$).

Table 3. The relationship between soil C/N, N/P, C/P and soil physical and chemical properties in the two marsh wetlands

Table 4. Multiple regression of soil C/N, N/P, C/P and influencing factors in the two marsh wetlands

Dependent Variable	Regression Equation	R ²	P-value
T1 C/N	$y = -1.136 + 8.078SM + 0.056SOC$	0.722	0.001
T1 N/P	$y = -16.407 + 123.651SM - 3.467STN + 0.048AN$	0.676	0.023
T1 C/P	$y = 7.909 + 4.509SM + 7.965BD$	0.688	0.005
T2 C/N	$y = -4.181 + 6.584SM + 13.154BD - 0.034SOC$	0.579	0.063
T2 N/P	$y = -158.270 - 47.782SM + 512.531BD + 78.864STN - 0.939AN$	0.751	0.028

Note: SM = soil moisture, SOC = soil organic carbon, STN = soil total nitrogen, AN = alkali-hydrolyzable nitrogen, BD = bulk density

3 Discussion

3.1 Key Influencing Factors The observed stoichiometric ratios in this study reflect the unique biogeochemical environment of arid region wetlands. Soil moisture consistently emerged as the dominant factor controlling C/N/P stoichiometry across both marsh types, confirming that water availability is the primary constraint on nutrient cycling in these ecosystems.

The significant positive correlations between N/P, C/P ratios and both total nitrogen and alkali-hydrolyzable nitrogen indicate that nitrogen dynamics are particularly sensitive to moisture conditions. In T2 soils, the additional correlation with bulk density suggests that physical soil properties mediate nutrient retention under saline conditions.

The vertical distribution patterns, characterized by subsurface peaks in stoichiometric ratios, differ from typical surface accumulation patterns observed in humid region wetlands. This distinctive profile likely results from limited leaching, root distribution patterns, and microbial activity concentrated at specific depths in these water-limited systems.

4 Role of pH

Soil pH showed no significant correlation with C/N, N/P, or C/P ratios in either marsh type ($P > 0.05$), suggesting that pH is not a primary determinant of stoichiometric balance in these wetlands. This contrasts with findings from some other wetland systems and may reflect the relatively narrow pH range characteristic of these specific marsh environments.

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Abstract

Wetlands play an important role in improving the regional ecological environment and maintaining regional ecological stability in arid regions. Studying the ecological stoichiometric traits of wetland soils is therefore conducive to understanding soil nutrient supply capacity and the recycling and balance mechanisms of soil carbon (C), nitrogen (N), and phosphorus (P) in arid wetlands. This study collected soil samples from herbaceous marsh (T1) and seasonal saline marsh (T2) located in the western section of Gansu Corridor, from the middle and lower reaches of the Shule River, and analyzed their traits in order to determine the key factors affecting the ecological stoichiometry of soil C, N, and P. The results showed that: (1) At 0-100 cm soil depths, the C/N, N/P, C/P ratios of T2 soils (15.07, 5.94, 98.01) were greater than those of T1 soils (12.49, 2.50, 30.22). With increasing soil depth, C/N, N/P, C/P exhibited two peaks in T1 (0-10 cm and interlayers) and one peak in T2 (interlayer) soils. (2) At 0-100 cm soil depths, C/N, N/P, C/P showed large spatial variability with the coefficient of variance (CV) being greater in T2 than in T1. (3) At both T1 and T2, soil N/P was significantly positively correlated with soil moisture ($P < 0.01$), C/P was significantly positively correlated with both soil moisture and soil total nitrogen ($P < 0.01$), and also with alkali-hydrolyzable nitrogen ($P < 0.05$). At T2, soil C/N, N/P, C/P were significantly positively correlated with soil bulk density ($P < 0.01$), C/N was significantly positively correlated with soil moisture ($P < 0.01$), and N/P was significantly positively correlated with soil organic carbon ($P < 0.05$). At T1, soil N/P was also significantly positively correlated with soil organic carbon ($P < 0.01$). (4) Soil moisture was found to be the key factor affecting the ecological stoichiometric ratios of soil C, N, and P in both marsh wetlands. As a result, the key to wetland protection in arid areas is to adopt reasonable measures for saving water. These results provide a scientific basis for soil protection, management, and the ecological restoration of wetlands in arid regions.

Keywords: herbaceous marsh; seasonal saline marsh; soil carbon; nitrogen and phosphorus; ecological stoichiometry; Shule River Basin

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