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Ecological Stoichiometric Changes and the Synergistic Restoration of Vegetation Concrete Restoration Systems under Different Precipitation Conditions

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Abstract: Based on vegetation-soil nutrient monitoring data under different precipitation conditions, this study investigated the impact of precipitation changes on the ecological restoration process of disturbed slopes. Precipitation change, to a certain extent, changed the carbon (C), nitrogen (N) and phosphorus (P) content and the stoichiometric ratio of the soil–plant system. With the increase of the weekly precipitation from 10 to 20 mm, the C content of Cynodon and Indigofera Amblyantha Craib on each slope gradually increased, increased by 8.69% and 4.28%, respectively, compared with the initial recovery period, and the N/P of Cynodon increased from 3.81 to 4.94, and the N limit gradually decreased, while the limit of P increased continuously. The efficiency of the coordinated utilization of N and P of the Indigofera Amblyantha Craib increased, which had a certain adaptability to changes in precipitation. The C/N and C/P in the soil first increased and then decreased, and reached the peak at the slope of 15 mm precipitation, while the N/P fluctuated around 0.35 overall. N was an important element restricting the growth of grass, while P was an important influencing element limiting the growth of shrubs. This also showed that soil C, N and P had a good promoting effect on plant growth, and the self-regulating nutrient utilization strategies of different growth forms of plants under different precipitation conditions differed. There was a coupling effect in the contents of C, N, P and their stoichiometric ratio in the soil–plant system, and stoichiometry and elastic ecological interactions jointly controlled the supply and demand of elements in the plants, but there was no consistent temporal pattern of nutrient ecological stoichiometric ratio in the plant–soil system during the recovery process, thus requiring further research and evaluation.

Keywords: slope engineering; ecological restoration; vegetation-concrete; precipitation condition; ecological stoichiometry

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1. Introduction

Engineering construction not only promotes social and economic development but also easily cause various environmental geological problems, especially the exposure of a large number of slopes caused by traffic, mining, hydropower and other engineering construction practices. Ecosystem degradation of these slopes is serious, which seriously endangers the engineering safety and stability and sustainable development of the ecological environment around the disturbed area. Therefore, it is necessary to carry out artificial ecological restoration [1–3]. At present, several commonly used typical slope protection technologies mainly include vegetation concrete ecological protection technology, thick-layer base material spraying vegetation slope protection technology and thick substrate spraying slope protection technology [4–7]. Combined with the function of engineering protection and ecological restoration, vegetation concrete ecological protection technology achieves rapid restoration of the ecological environment in the disturbed area of the project and promotes the coordinated development of engineering construction and environmental protection [8]. Its core is the base material mixture formed by mixing planting soil, organic matter, cement and an activation modifier in a certain proportion, and the mixing proportion of each component is determined by the geographical position, slope, rock mass properties and landscape requirements of the slope [2,9]. The mixture has strong anti-erosion ability, good physical and chemical properties, strong water and fertilizer retention capacity and it is suitable for the growth of slope plants [10,11]. The technology is especially suitable for disturbed damaged slopes with gradients between 45° and 85° and has been applied to more than 11 million square meters in water conservancy, transportation, mining, municipal projects and other fields [12].

The self-sustaining nature and stability of ecosystems after artificial restoration are key factors ensuring the sustainability of ecological engineering [13]. The stable succession of the vegetation and its community is the key to the success of ecosystem restoration. Vegetation and soil are critical to the material transformation and energy exchange of the terrestrial surface system, which determines the distribution, transmission, accumulation and transformation of nutrient elements, such as the mutual feedback cooperative control of the process and efficiency of ecological restoration [14,15]. As the core component of nutrient exchange, utilization and accumulation in vegetation restoration systems, carbon, nitrogen and phosphorus play an important role in the system energy and material cycle and multielement balance [16,17]. Therefore, it is of great scientific value and practical significance to study the balance and coordination between the plant–soil system and carbon, nitrogen and phosphorus to understand the biochemical process of the nutrient cycle and nutrient restriction mechanism of the system.

As the science of energy and chemical element balance in biological systems, the core of ecological stoichiometry is to use the balance relationship of various elements in ecosystem processes to reveal the influence of different element compositions on ecological functions from the perspective of the element cycle. This not only provides a new perspective for the study of the cooperation and nutrient cycle of vegetation–soil systems at the microscopic level but also provides a new idea for evaluating ecosystem service functions driven by scale [18–21]. Most of the current studies focus on forest, desert and wetland ecosystems, which deepen understanding of the land ecosystem material cycle and energy flow, but there is not enough research on the ecological protection of slopes [22,23]. In the process of vegetation concrete slope restoration, different types of functional groups and changes in environmental conditions can affect the characteristics of ecological stoichiometry, and the moisture content of the substrate, as an important influencing factor, affects the growth and development of plants and the community composition, which then affects the process and effect of ecological restoration. There have been few studies on the impact of precipitation on the transformation trend and distribution pattern of C, N and P in vegetation–soil systems and the environmental differentiation rule and limited transformation of the chemometrics of vegetative organs. Therefore, this paper intends to conduct an in-depth analysis of the change characteristics and the relationship between the stoichiometry of carbon, nitrogen and phosphorus in the plant–soil system of vegetation concrete under different precipitation models, focusing on the following three issues: (1) the response characteristics of the stoichiometry distribution pattern of carbon, nitrogen and phosphorus to the precipitation model; (2) the changes in the characteristics of the stoichiometry of soil carbon, nitrogen and phosphorus under different precipitation models and (3) the synergistic effect and limiting factors of the plant–soil system.

2. Materials and Methods

2.1. Study Site and Materials

To accurately master the ecological stoichiometric changes and synergistic restoration effects of vegetation concrete restoration systems under different precipitation patterns, a controlled simulation experiment was carried out at the China Three Gorges University (111°18′47.24″ E; 30°43′36.74″ N) in Yichang, Hubei province. This area has a subtropical continental monsoon climate, the annual average temperature, annual average rainfall and annual average frost-free period are 16.8 °C, 1164.10 mm and 272.4 days, respectively. Typical vegetation, Cynodon dactylon (Linn.) pers. and Indigofera Amblyantha Craib, which are commonly employed in a slope protection project, were chosen as the experimental vegetation. The tested soil was yellow soil from the surface of the cultivated land. The soil mechanical composition was analyzed using a TopSizer laser diffraction device (Zhuhai OMEC Instrument Co., Ltd., Zhuhai, China), and the soil was composed of 9.8% sand, 69.6% silt and 20.6% clay. The organic content in the soil measured by the potassium dichromate oxidation external-heating method was 3.5%. According to the local rock content distribution, the tested rock was sandstone.

2.2. Experimental Design

According to the Chinese energy industry standards (NB/T 35082—2016), the "Technical code for eco-restoration of vegetation concrete on steep slope of hydropower projects" [24], and considering the hydrometeorological conditions, slope conditions, slope and vegetation types of the vegetation concrete ecological restoration project, three controlled experimental plots were set up, with slopes of 60°, a plant configuration of Cynodon and Indigofera Amblyantha Craib mixed planting and precipitation levels of 10 mm, 15 mm and 20 mm per week (10-JS, 15-JS, 20-JS). Precipitation control was realized by an artificial sprinkler irrigation device. The outlet of the device was equipped with a water meter to measure and accurately record the amount of water sprayed each time. When spraying water, the established precipitation was converted into a water spray amount, and the water was sprayed at a fixed time every week (Figure 1). The size of each plot was 2 m × 2 m according to the experimental index determination plan, the thickness of the argillaceous sandstone was 20 cm and the thickness of the vegetation concrete was 10 cm. A certain proportion of the mass of each component was used during the vegetation concrete collocation. When 100 kg of planting soil was used, 6 kg, 8 kg and 3 kg of cement, organic matter and activation additive were used, respectively. The vegetation concrete was laid in two layers of base (8 cm) and a surface layer (2 cm). There were no plant seeds in the base layer, and the surface layer was planted with 15 g/m^2 of single or mixed plant seeds. The vegetation was watered normally during the emergence period, and the control experiment was started when the plant height was 10 cm. Figure 2 shows the structural diagram of the slope system. The contents of C, N and P in the plants and soil were determined.

Figure 1. Experimentally simulated slope.

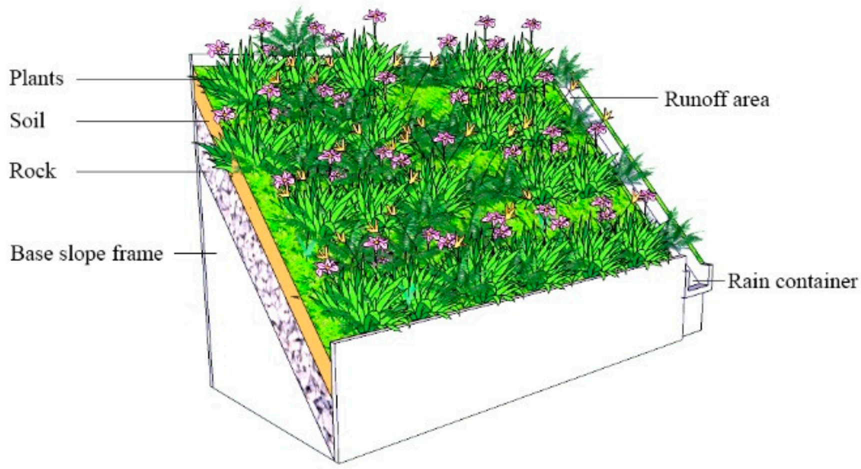


Figure 2. Structural diagram of the slope system.

2.3. Experimental Method

The sample plot indicators of different precipitation conditions were divided into soil and plant C, N and P, and the experimental samples were collected once in the middle of June, September and December 2018 and March 2019 (summer, autumn, winter and spring). The ring knife method was employed for soil sampling, and the aboveground parts of the plant (stem and leaf) were sampled by the quadrat harvesting method, while the underground parts of the plant roots were sampled by the root drilling method. Organic carbon (C) was determined by the $K_2Cr_2O_7$ volumetric method and external heating method. The Kjeldahl method was used to determine the nitrogen (N) of plants, and vanadium molybdenum yellow colorimetry was used to determine the phosphorus (P) [25]. The nitrogen and total phosphorus in the soil were determined by a SKALAR SAN++ continuous flow analyzer (SKALAR analytical instrument Co., Breda, the Netherlands). Ecological stoichiometric indicators (C/N, C/P, N/P) were obtained by the ratio between C, N and P.

2.4. Statistic Analysis

Data were analyzed and presented in Excel and SPSS 22.0, and the average difference and significance level of each index under different precipitation modes were analyzed and tested. MATLAB was used to simulate and analyze the grey relation of plants and substrate to explore the synergistic recovery effect of the plant soil.

Assuming that the comparison sequence of plant factors of each slope corresponds to the soil factor column, the correlation coefficient between the plant factors and soil factors (carbon, nitrogen and phosphorus contents and stoichiometric ratios of plants and soil) of each slope can be expressed by ε_{ti} indicates the correlation between plant factors and soil factors [26].

$$\varepsilon_{ti} = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_{ti}(k) + \rho\Delta(\max)} \tag{1}$$

where, ε_{ti} is the t-th plant factor, $p_t(k)$ is the k-th index and the i-th soil factor, $s_i(k)$ is the correlation coefficient of the k-th index, $p_t'(k)$ is the k-th index and the i-th dimensionless soil factor, $s_i'(k)$ is the correlation coefficient of the k-th dimensionless index, $\Delta_{ti}(k) = \left|p_t'(k) - s_i'(k)\right|$ denotes the absolute difference of each index between the t-th plant factor and the i-th soil factor, $\Delta(\max)_i = \max\limits_i \max\limits_k \left|p_t'(k) - s_i'(k)\right|$ denotes the maximum value of the absolute difference between the t-th plant factor and the i-th soil factor, $\Delta(\min)_i = \min\limits_i \min\limits_k \left|p_t'(k) - s_i'(k)\right|$ denotes the minimum value of the absolute difference between the t-th plant factor and the i-th soil factor and ρ is resolution ratio, which is the grey number between 0 and 1 (generally 0.5). Then, their association degree can be expressed as:

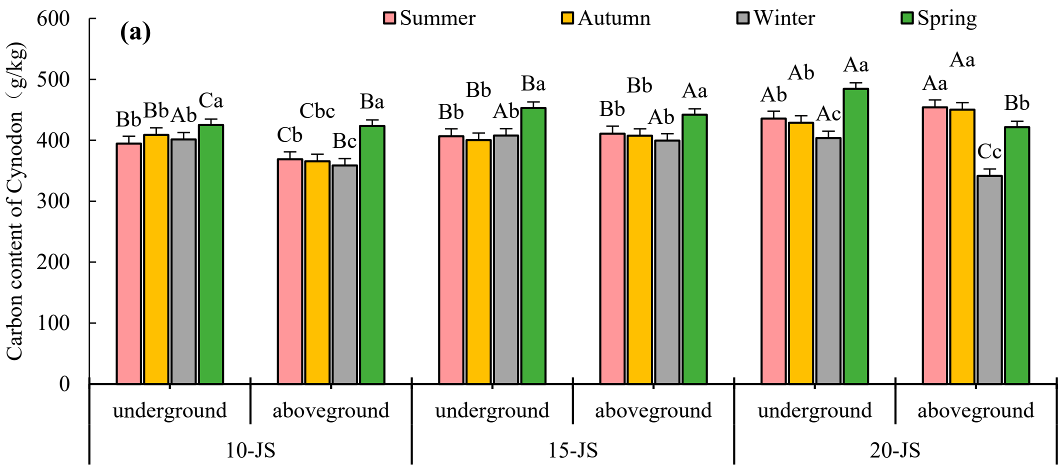
$$r_{ti} = \frac{1}{n}\sum_{k=1}^{n} \varepsilon_i(k) \qquad k = 1,\ 2,\ 3, \ldots,\ \mathrm{n} \tag{2}$$

The size of r_{ti} can be used to analyze the overall degree of correlation between the plants and the soil system, and the larger r_{ti} is, the greater their correlation.

3. Results

3.1. Ecological Stoichiometric Characteristics of Plant Carbon, Nitrogen and Phosphorus under Different Precipitation Patterns

As shown in Figure 3a–c, under different rainfall patterns, the contents of C, N and P of the Cynodon were 341.61–484.42, 4.93–14.28 and 1.42–4.20 g/kg, respectively, while those of the Indigofera Amblyantha Craib were 221.83–534.61, 7.05–19.57 and 0.73–5.54 g/kg, respectively (Figure 3d–f). There were significant differences ($p < 0.05$) in the contents of C, N and P of the Cynodon and Indigofera Amblyantha Craib in other periods, except for the N of the aboveground parts and the C of the underground parts of the Cynodon in winter, the N, C and P of the roots of the Indigofera Amblyantha Craib in winter, the C of the stems in summer and spring and the P of the leaves in summer and autumn. The C and P of the Cynodon on each slope were higher in the underground parts than in the aboveground parts, and N showed the opposite pattern. The C increased with increasing precipitation and increased gradually with recovery time in all seasons except winter. The N and P contents fluctuated with increasing precipitation, and the lowest peak appeared in winter. The C, N and P contents of Indigofera Amblyantha Craib were, from highest to lowest, in the following order: root > stem > leaf. The C first increased and then decreased slightly, while the P increased with increasing precipitation. The C and P fluctuated with the season, and the N first decreased and then remained stable with increasing precipitation and continued to increase except in spring (Figure 3).



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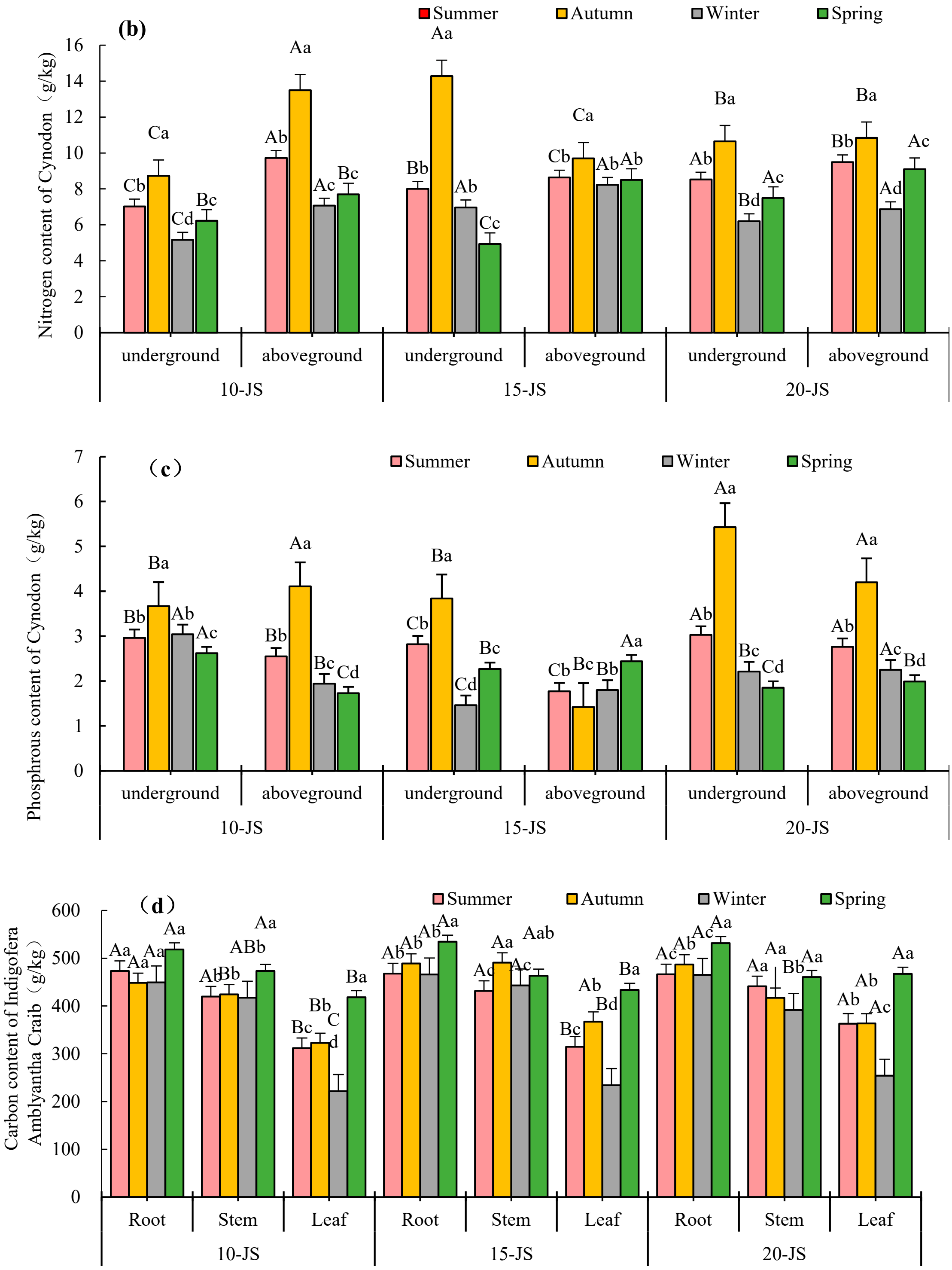

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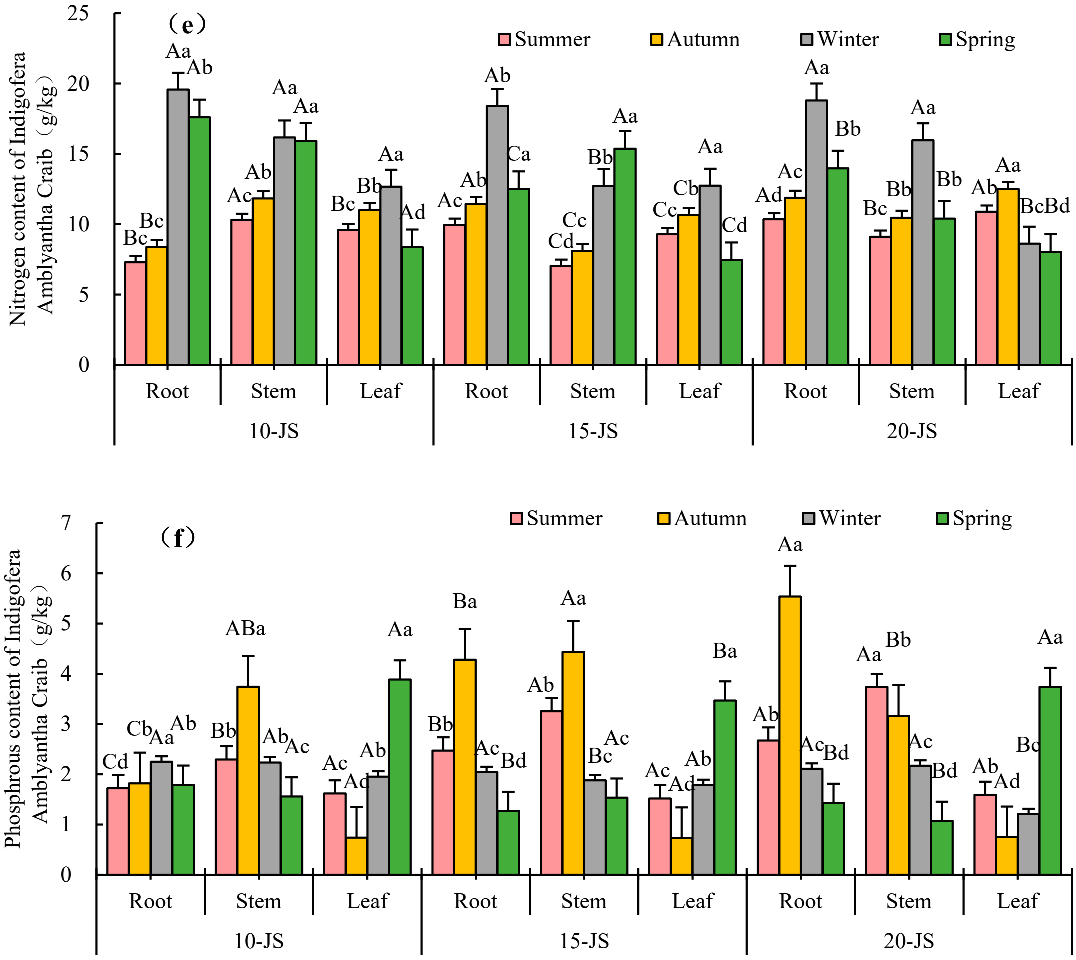
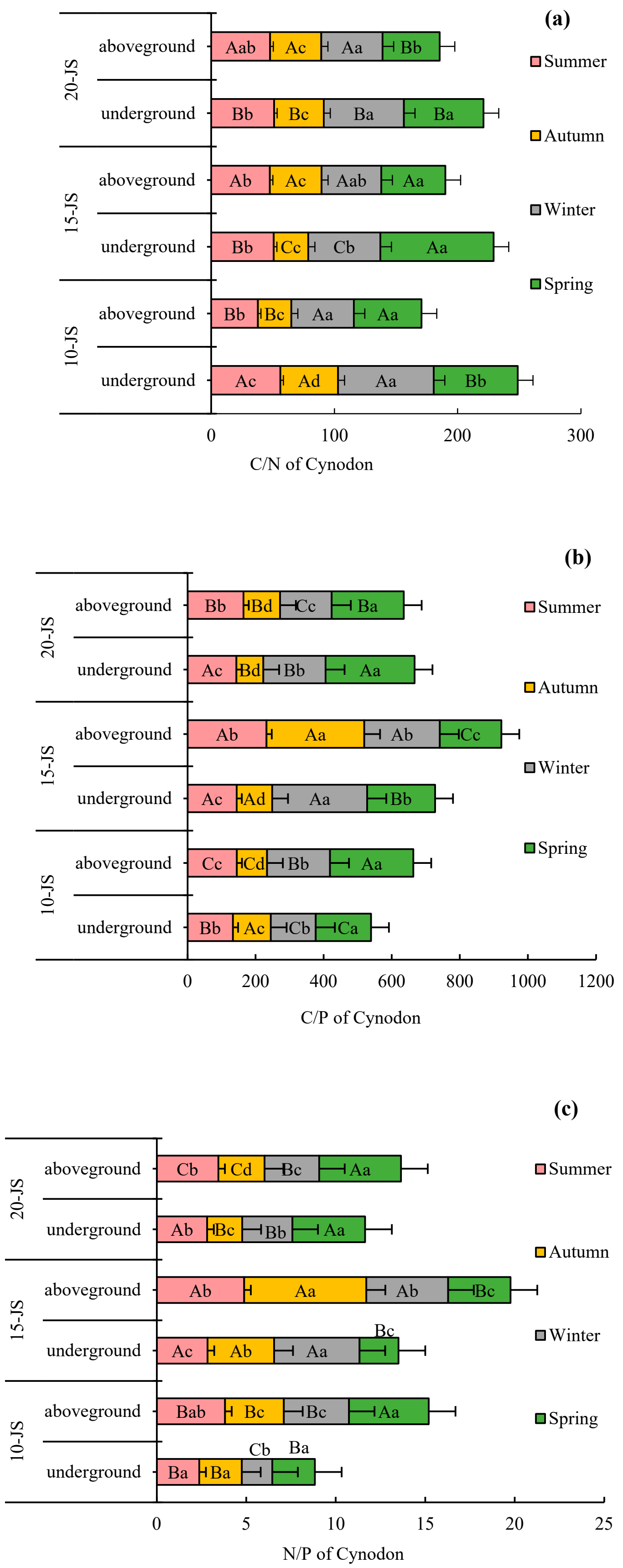


Figure 3. The plant C, N and P contents under different precipitation patterns. Note: (**a**) C content of the Cynodon, (**b**) N content of the Cynodon, (**c**) P content of the Cynodon, (**d**) C content of the Indigofera Amblyantha Craib, (**e**) N content of the Indigofera Amblyantha Craib, (**f**) P content of the Indigofera Amblyantha Craib; capital letters on different columns indicate that the same plant organ in the same season were significantly different under different precipitation ($p < 0.05$); lowercase letters on different columns indicate that the same plant organ had significant differences in different seasons under the same precipitation ($p < 0.05$).

Under different precipitation models, the C/N (carbon nitrogen ratio), C/P (carbon phosphorus ratio) and N/P (nitrogen phosphorus ratio) of the Cynodon were 27.11–91.89, 78.98–286.90 and 1.70–4.88, respectively (Figure 4a–c), while those of the Indigofera Amblyantha Craib were 17.51–64.86, 87.97–503.15 and 1.82–16.74, respectively (Figure 4d–f). Precipitation had a significant influence on the C/N, C/P and N/P of the Cynodon and Indigofera Amblyantha Craib ($p < 0.05$). With the increase in precipitation, the overall C/N of the Cynodon showed a downward trend, while the C/P and N/P first increased and then decreased. With the addition of 10-JS in autumn and 15-JS and 20-JS in winter and spring, the aboveground part of the C/P was higher than the underground part in all seasons. Except for at a 15-JS precipitation level in winter, the N/P in the aboveground part was higher than that in the underground part. Both the C/N and C/P of Indigofera Amblyantha Craib first increased and then decreased with increasing precipitation, while the N/P fluctuated steadily overall. The C/N of each slope was the lowest in winter. At a 10-JS precipitation level, the C/N was root > stem > leaf, at a 15-JS precipitation level, it was stem > root > leaf and at a 20-JS precipitation level, it was stem > leaf > root. The C/P was highest in the leaves in autumn. The N/P was higher in the leaves in summer and autumn and in the roots in winter (Figure 4).



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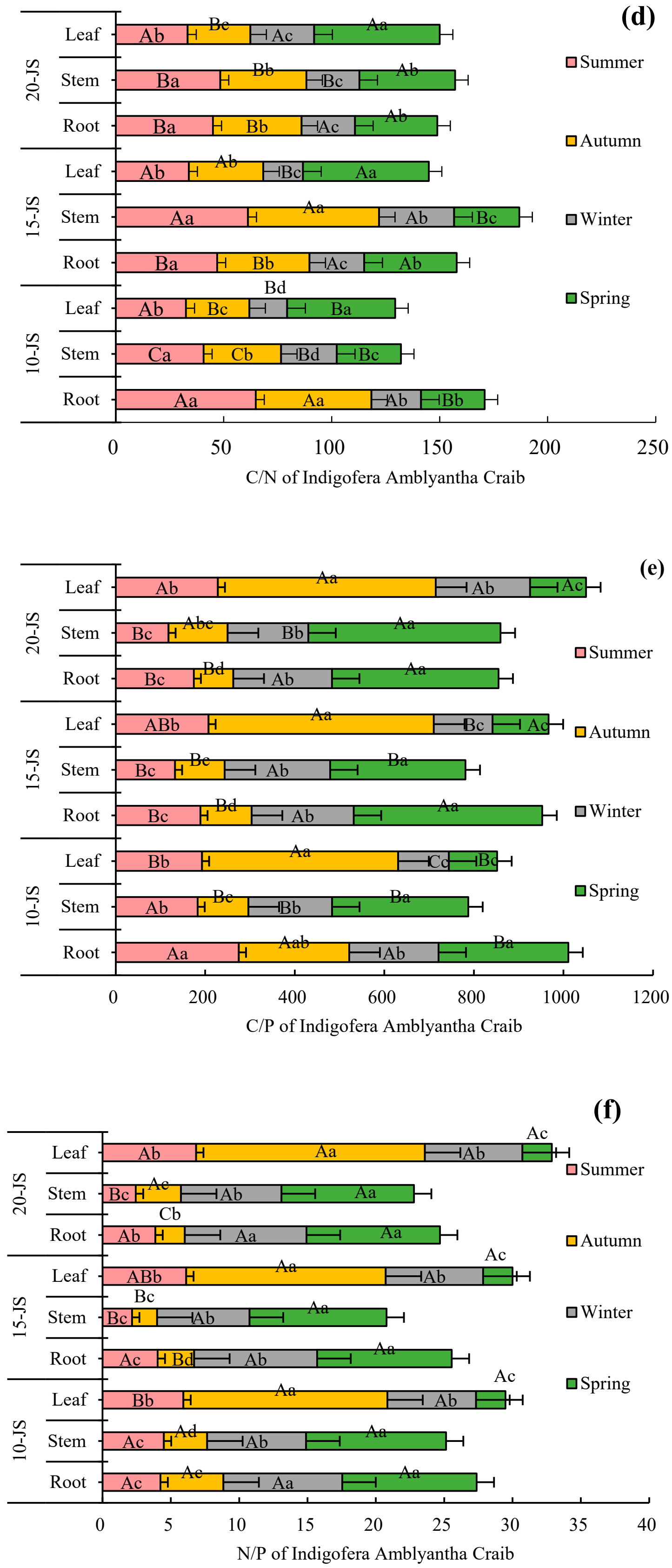

Figure 4. The C/N, C/P and N/P of plants under different precipitation patterns. Note: (**a**) C/N of the Cynodon, (**b**) C/P of the Cynodon, (**c**) N/P of the Cynodon, (**d**) C/N of the Indigofera Amblyantha Craib, (**e**) C/P of the Indigofera Amblyantha Craib, (**f**) N/P of the Indigofera Amblyantha Craib;

capital letters on different columns indicate that the same plant organ in the same season were significantly different under different precipitation ($p < 0.05$); lowercase letters on different columns indicate that the same plant organ had significant differences in different seasons under the same precipitation ($p < 0.05$).

3.2. Ecological Stoichiometric Characteristics of Soil Carbon, Nitrogen and Phosphorus under Different Precipitation Patterns

Under different rainfall patterns, the contents of C, N and P in the slope soil were 3.05–11.25, 0.39–0.78 and 1.46–2.69 g/kg, respectively. Precipitation had a significant influence on the C and N in the soil ($p < 0.05$) but no significant influence on the P in the soil ($p > 0.05$). With the increase in precipitation, the C and P in the slope soil presented an overall increasing trend, while N decreased slightly. Under different precipitation patterns, the C increased gradually with time except at 15-JS in autumn, while the N and P tended to be stable after increasing in winter (Figure 5).

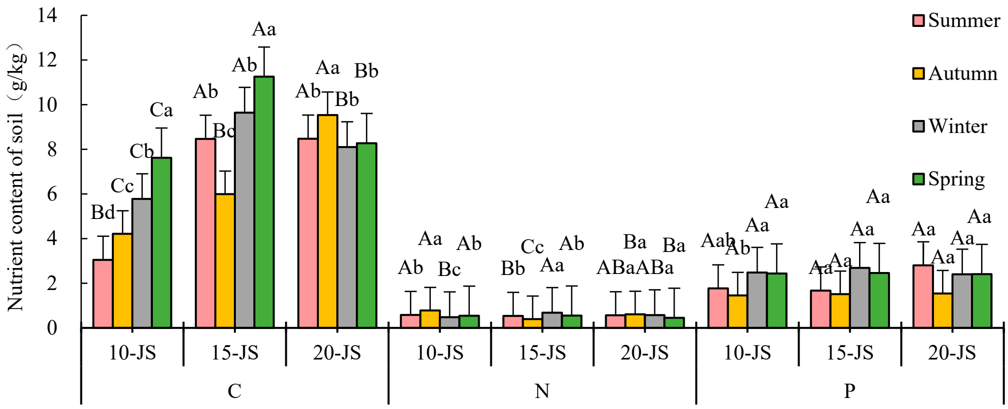

Figure 5. The contents of soil C, N and P under different precipitation patterns. Note: capital letters on different columns indicate that the soils in the same season were significantly different under different precipitation ($p < 0.05$); lowercase letters on different columns indicate that the soils in the same precipitation had significant difference in different seasons ($p < 0.05$).

Under different precipitation patterns, the C/N, C/P and N/P in the soil were 5.42–20.49, 1.72–6.20 and 0.19–0.53, respectively (Figure 6a–c). Although precipitation had no significant influence on the C/N, C/P and N/P in winter or on the N/P in spring and summer ($p > 0.05$), precipitation had a significant influence on the C/N, C/P and N/P of the slope soil in other seasons ($p < 0.05$). With increasing precipitation, the C/N and C/P first increased and then decreased, while the N/P maintained stable fluctuations overall. The C/N of each slope increased over time, reaching its maximum value in spring. The C/P at plots with 10-JS and 20-JS treatments rose sharply in autumn, while that at 15-JS plots was the opposite. The N/P variation at each slope was different. The N/P in the 10-JS and 20-JS plots reached the maximum value in autumn, while in the 15-JS plot a decreasing trend was shown and reached the maximum value in summer (Figure 6).

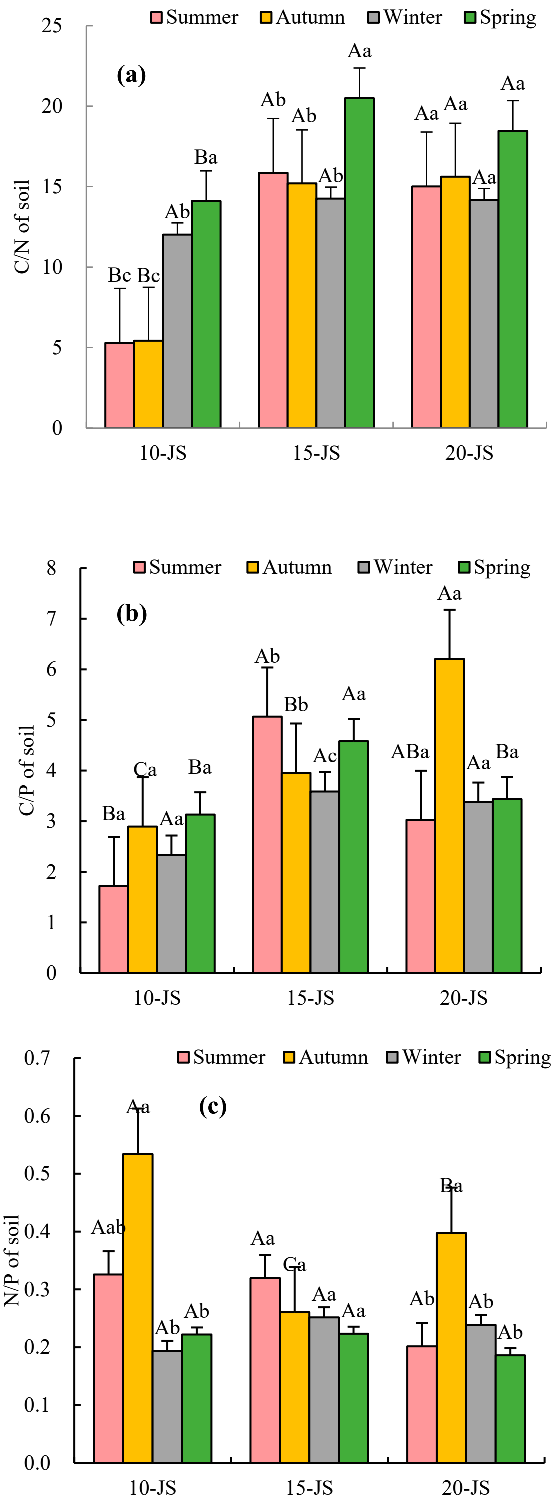

Figure 6. The C/N, C/P and N/P of soil under different precipitation patterns. Note: (**a**) C/N of soil, (**b**) C/P of soil, (**c**) N/P of soil; capital letters on different columns indicate that the soils in the same season were significantly different under different precipitation ($p < 0.05$); lowercase letters on different columns indicate that the soils in the same precipitation had significant difference in different seasons ($p < 0.05$).

3.3. Collaborative Correlation Analysis and Simulation of Plant–Soil Systems under Different Precipitation Patterns

According to the results calculated for the degree of soil and plant correlation, under different precipitation modes, there was a high grey correlation between the soil factors and plant factors of each slope. The correlation degree range of C was 0.5704–0.7474, that of N was 0.6211–0.8258, that of P was 0.5330–0.7875 and that of the stoichiometric ratio was N/P > C/N > C/P overall (Tables 1 and 2), indicating that the soil nutrient content had a significant impact on the plant nutrient content, the C, N and P in the soil had a good promoting effect on plant growth and that N and P were the main limiting elements of nutrient cycling and transformation between the soil and plants. Meanwhile, the overall correlation patterns in the Cynodon were stronger than those in the Indigofera Amblyantha Craib, indicating that soil nutrients had different effects on the growth of different functional plants and that Cynodon was more sensitive than Indigofera Amblyantha Craib. With the increase in precipitation, the grey correlation between the Cynodon and soil gradually increased, reaching the highest value of 0.7156 (Table 3), while that between Indigofera Amblyantha Craib was the opposite (Table 4). The overall correlation of N and C between the Cynodon and soil was relatively large, and N was an important influencing element restricting the growth of Cynodon. The P and C of the Indigofera Amblyantha Craib and soil were closely related. P was an important factor restricting the growth of Indigofera Amblyantha Craib.

Table 1. Correlation between soil factors and Cynodon factors under different precipitation patterns.

Correlation (ε_{ti})		C	N	P	C/N	C/P	N/P
10-JS	C	0.7474	0.5679	0.7215	0.7414	0.7047	0.5635
	N	0.8258	0.7494	0.5911	0.7767	0.6677	0.6829
	P	0.7875	0.6374	0.5310	0.7248	0.7069	0.6273
	C/N	0.5887	0.5538	0.8312	0.6826	0.7835	0.5101
	C/P	0.6526	0.5995	0.7141	0.6897	0.6523	0.5518
	N/P	0.5784	0.5645	0.6105	0.5257	0.5945	0.5915
15-JS	C	0.7032	0.6119	0.7616	0.6696	0.7757	0.7519
	N	0.6338	0.6587	0.6166	0.6480	0.6373	0.6070
	P	0.7351	0.7212	0.5827	0.6125	0.6271	0.8038
	C/N	0.8226	0.6458	0.5559	0.6441	0.6841	0.8005
	C/P	0.6070	0.6882	0.7385	0.6404	0.7659	0.8444
	N/P	0.6025	0.6681	0.5797	0.6036	0.8819	0.5257
20-JS	C	0.6165	0.7369	0.6493	0.6871	0.7102	0.7095
	N	0.6719	0.6398	0.7533	0.5387	0.6865	0.5553
	P	0.5330	0.6994	0.8865	0.7201	0.6409	0.7036
	C/N	0.6611	0.7282	0.5910	0.7502	0.7213	0.7750
	C/P	0.6475	0.7327	0.6135	0.5748	0.8145	0.7347
	N/P	0.6782	0.7286	0.5676	0.5261	0.6993	0.6179

Table 2. Correlation between soil factors and shrub factors under different precipitation patterns.

Correlation (ε_{ti})		C	N	P	C/N	C/P	N/P
10-JS	C	0.6453	0.6545	0.7485	0.5986	0.5274	0.6713
	N	0.6211	0.7511	0.5369	0.5488	0.5516	0.7671
	P	0.6988	0.7836	0.5890	0.6919	0.7697	0.8266
	C/N	0.8779	0.6021	0.7985	0.8146	0.6679	0.5692
	C/P	0.5473	0.5490	0.8105	0.8311	0.8640	0.5198
	N/P	0.6088	0.7368	0.6728	0.7047	0.5891	0.7310
15-JS	C	0.5704	0.7268	0.6979	0.8232	0.5802	0.7819
	N	0.7831	0.6838	0.5622	0.6769	0.6276	0.6618
	P	0.5647	0.6077	0.6768	0.6008	0.5349	0.6917
	C/N	0.7245	0.6470	0.5560	0.5637	0.6966	0.5712
	C/P	0.5897	0.5669	0.5743	0.7320	0.7613	0.8261
	N/P	0.6506	0.7131	0.7779	0.7757	0.6300	0.7950
20-JS	C	0.6169	0.7070	0.7982	0.7187	0.6454	0.7649
	N	0.6326	0.7146	0.8256	0.6081	0.6687	0.6695
	P	0.7653	0.7060	0.7937	0.5490	0.7280	0.6145
	C/N	0.5513	0.6399	0.7085	0.7327	0.5462	0.7212
	C/P	0.5665	0.5932	0.7198	0.6779	0.6847	0.6544
	N/P	0.6101	0.7414	0.7514	0.7102	0.7327	0.6111

Table 3. Comprehensive correlation between soil factors and Cynodon factors under different precipitation patterns.

Comprehensive Correlation (r_{ti})	C	N	P	C/N	C/P	N/P
10-JS	0.6744	0.7156	0.6692	0.6583	0.6433	0.5775
15-JS	0.7123	0.6336	0.6804	0.6922	0.7141	0.6436
20-JS	0.6849	0.6409	0.6973	0.7045	0.6863	0.6363

Table 4. Comprehensive correlation between soil factors and Indigofera Amblyantha Craib factors under different precipitation patterns.

Comprehensive Correlation (r_{ti})	C	N	P	C/N	C/P	N/P
10-JS	0.6409	0.6294	0.7266	0.7217	0.6869	0.6739
15-JS	0.6967	0.6659	0.6128	0.6265	0.6751	0.7237
20-JS	0.7085	0.6865	0.6927	0.6500	0.6494	0.6928

4. Discussion

4.1. The Influence of Precipitation Patterns on the Ecological Stoichiometric Characteristics of Plant Carbon, Nitrogen and Phosphorus

C is the most basic element in plants. N and P play an irreplaceable role in the process of plant growth and development. The structural element C interacts with the functional elements N and P to jointly regulate plant growth [27,28]. Precipitation is the main factor affecting the growth and development of plants. It can affect the distribution of the carbon, nitrogen and phosphorus content of plants by affecting the photosynthesis of plants and the utilization of soil-available nutrients. In this study, the contents of C, N and P in different organs and growth stages of plants showed significant differences under different precipitation models. With the increase in precipitation, the C of the Cynodon and C and P of the Indigofera Amblyantha Craib all increased, while the N and P of the Cynodon and the N of the shrubs decreased, which was similar to the study by Reich and Oleksyn [29], who found that the N and P content of plant leaves decreased with the increase in precipitation. On one hand, possible reasons for these observations were that the addition of water might have promoted available nitrogen and phosphorus nutrients in the soil, which diluted the N and P content of plants while promoting plant growth. On the other hand, it may have been the result of the comprehensive effects of increased N consumption by the plants and microorganisms and increased N leaching loss in the soil caused by the increased water content [30,31]. The self-regulation nutrient utilization strategies of different growth forms of plants were different under water conditions.

The stoichiometric ratio of plant elements can reflect its ecological strategy: C/N and C/P reflect the plant growth rate and the plant absorption efficiency of N and P, and N/P is one of the indicators of nutrient elements that limit plant growth [32,33]. Precipitation regulates the soil water content and nutrient dynamics, which are closely related to the plants' N and P absorption strategies and directly affects the plants' photosynthetic capacity, C/N/P ecological stoichiometric characteristics and relative internal stability [34]. In this study, with the increase in precipitation, the C/N of Cynodon showed a downward trend, while the C/P and N/P first increased and then decreased, indicating that with the increase in precipitation, the growth rate of the plants gradually accelerated, the limit of the N element of the plants gradually decreased and the limit of the P element increased continuously. However, the increased precipitation improved the C/N and C/P of the Indigofera Amblyantha Craib to a certain extent, indicating that the N and P utilization efficiency of Indigofera Amblyantha Craib increased with increasing precipitation, while the N/P fluctuated steadily overall, reflecting characteristics of coordinated absorption of N and P by the plants and a certain adaptability to a change in precipitation.

4.2. The Influence of Precipitation Patterns on the Ecological Stoichiometric Characteristics of Soil Carbon, Nitrogen and Phosphorus

Precipitation regulates the process of soil nutrient transfer and transformation and has a direct influence on the soil nutrient content, and the degree of influence is related to precipitation and soil moisture content. Soil water can affect litter decomposition, nitrogen mineralization and soil phosphorus weathering by affecting microorganisms, thus indirectly affecting the availability and content of nutrients in the soil. Within an appropriate range, precipitation increases soil moisture, leading to an increase in soil nutrient content [35,36]. Zhao Shanyu et al. [37] found that the contents of carbon, nitrogen and phosphorus increased gradually from west to east in Horqin sandy land with increasing precipitation. In this study, the content of C and P showed a similar increasing trend. On one hand, increasing precipitation may have changed the size of soil porosity, affected the activity of microorganisms and their utilization of organic matter and accelerated the decomposition and accumulation of organic matter and the weathering of rock layers. On the other hand, the increase in precipitation may have improved the photosynthesis of plants and the utilization of available nutrients in the soil to a certain extent, which promoted the growth of plants and increased the amount of organic matter returned. However, the content of N decreased slightly, which may have been because the increase in precipitation improved soil water availability, promoted the consumption of soil N by plants and microorganisms and enhanced the leaching loss of soil N, which was similar to the findings of Li et al. [34] and reflected the strong N uptake ability of plants in arid and semiarid environments.

The C/P and C/N of soil are diagnostic indicators of the nutrient balance of C, N and P [38]. The lower the soil C/P is, the higher the soil P availability, and the higher the soil C/N is, the lower the decomposition rate of organic nitrogen [39]. Precipitation can cause changes in soil porosity and affect the activity of microorganisms and their utilization of organic compounds. It is generally believed that a high soil water content is conducive to the accumulation of C and N, while a low water content is conducive to soil respiration and mineralization of C and N [40]. In this study, with the increase in precipitation, the soil C/N and C/P first increased and then decreased, while N/P maintained stable fluctuations overall, indicating that a certain increase in water promoted the accumulation of soil C and slowed the transformation of soil organic N and P, and the nutrient limit state of N and P was relatively stable, which was mainly related to the different utilization of C, N and P elements in the growth process of plants. Studies have shown that the utilization modes and processes of soil nutrients by plants significantly affect the soil stoichiometric ratio [41].

4.3. Influence of Precipitation Patterns on the Cooperative Correlation of Plant–Soil Systems

The interaction of C, N, P and stoichiometry between plants and soil is the internal regulatory mechanism of the nutrient cycle in ecosystems [42]. The chemometric relationship between plants and soil is often used to diagnose and predict the limiting nutrients and saturation of C, N and P, and their synergistic relationship is not only determined by the availability of soil nutrients [29,43,44] but also related to plant growth needs and individual plant sizes [45]. In this study, changes in precipitation changed the contents of C, N, P and their stoichiometric ratios in the soil–plant system to some extent. With the increase in precipitation, the grey correlation between the Cynodon and soil gradually increased, while that between Indigofera Amblyantha Craib was the opposite, which may be caused by the different nutrient utilization strategies and feedback modes of different plant species.

5. Conclusions

In summary, precipitation change could significantly change the ecological stoichiometric characteristics of soil and plants in the vegetation concrete ecological restoration system and was an important factor affecting slope vegetation restoration. The contents of C, N and P in different organs and growth stages of plants showed significant differences under different precipitation patterns, and the self-regulated nutrient utilization strategies of different plant growth forms were different. With the increase of the weekly precipitation from 10 to 20 mm, the C content of Cynodon and Indigofera Amblyantha Craib on each slope gradually increased, increased by 8.69% and 4.28%, respectively, compared with the initial recovery period, and the N limit of Cynodon gradually decreased, while the limit of P increased continuously. The efficiency of the coordinated utilization of N and P of the Indigofera Amblyantha Craib increased, which had a certain adaptability to changes in precipitation. An increase in precipitation within a suitable range can promote an increase in the soil nutrient content. The C/N and C/P in the soil first increased and then decreased, while the N/P maintained a stable fluctuation overall, indicating that a certain increase in water promoted the accumulation of soil C and that the nutrient limit states of N and P were relatively stable. The relatively stable soil C/N/P was a good indicator of the nutrient limitation in the soil and plants in utilization accumulation. The C, N and P in the soil had a good promoting effect on the growth of the plants. N was an important element restricting the growth of Cynodon, while P was an important influencing element limiting the growth of Indigofera Amblyantha Craib. Precipitation change, to a certain extent, changed the C, N, and P contents and the stoichiometric ratio in the soil–plant system. There was a coupling effect on the ecological stoichiometry of the plant–soil system, and stoichiometry and elastic ecological interactions jointly controlled the supply and demand of elements from the plants, but there was no consistent time pattern of C/N/P in the plant–soil system during the recovery process. In future research, more attention should be given to how precipitation changes drive the soil nutrient supply and plant nutrient utilization efficiency to consolidate and improve ecosystem restoration.

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