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Determination of soil physicochemical properties

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Abstract: This study aimed to delve deeper into the intricate relationship between vegetation types, soil organic matter, and fertilization practices, and their influence on the chemical and biological composition of soil. By analyzing three distinct sample sites, various factors such as bulk density, nitrogen concentration, pH value, porosity, phosphorus concentration, and organic matter content were examined. The results of this study unveiled noteworthy disparities in soil moisture, organic matter content, and Olson-P concentration among the three sampling locations. These variations could potentially be attributed to contrasting water availability and nutrient application practices across the sites. Furthermore, the impact of fertilization on phosphorus concentration in the soil was found to be significant. This finding underscores the vital role of fertilization practices in shaping the phosphorus levels within the soil ecosystem. Ultimately, this investigation sheds light on the fundamental significance of soil chemistry and biological composition under diverse vegetation types and fertilization conditions. By comprehending how these factors interact and influence one another, we can better understand and manage soil health and fertility for sustainable agricultural practices and environmental stewardship.

1. Introduction

Soil is a bioactive and loose material formed by rock weathering. There is a large amount of soil on the Earth, and the formation of soil is formed under the influence of factors such as the parent material, climate, biology, terrain, time and human activities. China is located in the west coast of the eastern Asia and the Pacific Ocean, and the bioclimatic conditions are deeply influenced by the southeast monsoon. The horizontal distribution of soil varies with latitude direction and longitude. China has 14 soil orders and they include: ACRISOLS; LUVISOLS; PHAEOZEMS; CHERENOZEMS; GLEYSOLS; FLUVISOLS; KASTAZNOZEMS; SOLONCHAKS; XEROSOLS; HISTOSOLS; VERTSOLS; CAMBISOLS; LITHOSOLS; YERMOSOLS[1].

Soil and plant growth share a close and intricate relationship, with plants exerting a significant influence on soil dynamics. Notably, plants play a crucial role in mitigating and managing soil erosion. The interplay between plant roots serves to bolster the cohesion between the roots and the soil, thereby enhancing the soil's resistance to erosion. The presence of vegetation contributes to the development of a well-structured soil environment, anchoring the soil and improving its stability. Deep-rooted plants, such as trees, create channels that enhance water infiltration and reduce surface runoff, making the soil more resilient to erosive forces. Additionally, the leafy canopy of plants acts as a protective barrier against raindrop impact, minimizing their erosive potential. This is particularly evident in forested areas, where the dense foliage shields the soil from the full force of rain. Through processes like photosynthesis and organic matter deposition, plants enrich and stabilize soil structure, fostering beneficial microorganisms and improving fertility. The relationship between soil and plant growth is multifaceted, and by harnessing the beneficial effects of vegetation, we can develop sustainable land management practices that preserve soil health, support ecosystem resilience, and promote long-term productivity. Incorporating this knowledge into strategies for sustainable agriculture, forestry, and land conservation is essential to maintaining soil stability.

In addition to their role in mitigating soil erosion, plants also contribute significantly to the prevention of soil pollution through various mechanisms. Root secretions serve as a rich source of nutrients for soil microorganisms, playing a pivotal role in material migration and energy exchange within the rhizosphere microecosystem. This symbiotic relationship between plant roots and soil microorganisms contributes to the degradation and immobilization of pollutants, helping to maintain soil health and quality. Furthermore, soil microorganisms actively work to enhance the physical and chemical properties of the rhizosphere, diminishing the biological impact of pollutants and fostering the growth and development of plants. By facilitating the breakdown of contaminants and promoting the overall vitality of the soil ecosystem, plants play a crucial role in preventing the accumulation of harmful substances and maintaining the environmental sustainability of soil resources.[2]

In this study, an examination of soil water content, nitrogen concentration, pH value, porosity percentage, phosphorus concentration, bulk density, and organic matter content was conducted across three distinct sites. The aim was to elucidate the disparities in the physical and chemical properties of soil across these sites, providing valuable insights into the complex interactions between plants and soil dynamics.

2. Methods

Calculation of soil bulk density and water content: The ring knife and aluminum box were weighed before soil collection. Soil samples were collected from three places, respectively in peony flowers, low shrubs and trees. Dug out about 15~20cm pit from the ground with a shovel, and pressed the ring knife vertically into the soil. Avoid swinging from side to side to destroy the natural state of the soil. Then dug the ring knife out of the soil with a shovel, flattened the lower end more than the soil and removed the upper steel ring, and then flattened the soil at the upper end, put the ring knife into a plastic bag and took it back to the room to weigh. The soil samples were mixed evenly to remove debris, weighed 10g of soil with weighed aluminum box, added 10ml of alcohol in two times, ignited, using the formula: $\text{Soil moisture content}\ (\%)\ \frac{Wet\ soil\ (g) - Dry\ soil\ (g)}{Dry\ soil\ (g)} \times 100$ find out the soil water content, using the formula:Unit weight=$\frac{Dry\ soil\ weight(g)}{Ring\ knife\ volume\ (cm^3)}$ find the soil bulk density.

Determination of nitrogen in soil: collect fresh soil and weigh 5.00g, and added 50ml of 1 mol/L KCL solution. At about 160 revolutions per minute under the concussion for 1h, took out the filter, put into the plastic bottle and marked the number using the instrument measurement.

pH Determination: weighed 10g dried soil sample through 1mm sieved in 25ml beaker, mixed 10ml of distilled water, stand for 30min, and determined the pH value of the suspension with a corrected pH meter. When measuring, we immersed the glass electrode ball at the junction between the suspension and the mud layer, and read the number.

Determination of soil organic matter: weighed 0.50g of air-dried sample soil with 0.25mm sieve hole with a dry test tube, and then loaded a quartz sand with a test tube as a blank control group. Carefully shook, add 0.8000 ㏖ L-1 (1 / 6 K2Cr2O7) potassium bichromate solution and 5ml of concentrated sulfuric acid to each tube. Then preheated the paraffin oil to 160°C in advance, and heated the test tube in it. At this point, the temperature was controlled at 170-180°C to keep the solution boiling for 5 minutes. After cooling, we put it into a conical flask and controlled the solution at 60~80 ml. The liquid shall be yellow. Then 3-5 drops of the morphine indicator were added and titrated with 0.2 ㏖ L-1 ferrous sulfate. The solution passed from yellow through green, gray-green to brown red as the titration end point. We used formula:soil organic matter (g kg-1) $=\frac{\frac{c\times 5}{V_0}\times(v0-v)\times 10-3\times 3.0\times 1.1}{m\times k}\times 1000\times 1.724$ to estimate the soil organic matter content.

Determination of P: selected 2.5g of 1mm sieve dried sample soil (accurate to 0.001g) into 150ml conical flask, added 50ml of 0.5mol L-1NaHCO3 solution, added activated carbon, and plugged the cork for 30min. And only activated carbon and extract were added in the other bottle as a blank control group. After the shock, immediately filter paper, take the filtrate in 100ml bottle, absorbed 10ml filtrate into 50ml volumetric bottle, then added about 30ml of distilled water, then added Molybdenum 5ml in the pipette, mixed and fixed the volume to 50ml. After placement for 30min, colorization was performed at 880nm or 700nm wavelength.Using this formulas $\frac{\rho\times V\times 10-3\times ts}{m\times k}1000$ we calculated the amount of P present in the soil.

3. Results

We conducted a comprehensive analysis of the means for eight soil variables across the three designated research sites. Our examination revealed significant discrepancies among the three sites for three of the measured variables, as illustrated in Table 1. Specifically, substantial differences were observed in water content (p=0.000009), organic matter (p=0.0003), and Olson-P (p=0.02). These variations indicate contrasting soil characteristics and nutrient availability across the sites, which can have significant implications for plant growth and ecosystem functioning.

A comparative analysis between two specific sites at a given time point was carried out using a t-test, as depicted in Table 2. The results indicated that Site 1 exhibited noteworthy distinctions from Site 3 in terms of two variables, namely water content and organic matter. The higher water content at Site 1 suggests better moisture retention capacity, potentially influencing plant water availability and drought tolerance. Additionally, the higher organic matter content at Site 1 signifies greater soil fertility and nutrient cycling, supporting plant growth and overall ecosystem productivity.

Table 1: Means (+/- Standard deviation) for eight soil variables estimated at three sites on South Campus.

Variable	Site 1	Site 2	Site 3	p-value*
Bulk density (g/cm^3)	1.26 (0.30)	1.23 (0.20)	1.12 (0.30)	0.67
Porosity (%)	52.3 (12.0)	53.9 (8.70)	57.5 (14.1)	0.70
Water content (%)	17.3 (1.40)	12.1 (1.90)	14.2 (1.60)	0.000009
Organic matter (%)	10.0 (1.70)	7.2 (1.00)	5.7 (1.90)	0.0003
NH_4^+ (mg/L)	8.3 (2.10)	11.7 (9.40)	12.7 (6.10)	0.44
NO_3^- (mg/L)	8.7 (3.10)	9.0 (4.80)	5.6 (1.80)	0.16
Olson-P (mg/L)	28.1 (9.50)	15.6 (10.5)	17.0 (3.60)	0.02
pH	8.5 (0.04)	8.4 (0.06)	8.5 (0.07)	0.81

***one way ANOVA**

When comparing Site 1 and Site 2 with respect to Olson-P, it was evident that Site 1 significantly differed from Site 2 in terms of Olson-P levels. This discrepancy can be attributed to the differential fertilization practices and the specific phosphorus requirements of the plant species present at each site. The higher Olson-P content at Site 1 indicates a higher accumulation of phosphorus, likely due to the substantial application of phosphate fertilizers to meet the demands of peonies.

These findings underscore the substantive variations in soil variables across the different research sites, highlighting the nuanced interplay of factors contributing to the diverse chemical and biological composition of soil within these distinct ecological contexts. Understanding these site-specific differences is crucial for effective land management, agronomic practices, and sustainable environmental stewardship.

Table 2: Comparison of sites using a t-test.

Variable	Site comparison	P-value
Bulk density (g/cm^3)	Site 1 VS Site 3	0.45
Porosity (%)	Site 1 VS Site 3	0.47
Water content (%)	Site 1 VS Site 3	0.0001
Organic matter (%)	Site 1 VS Site 3	0.0009
NH_4^+ (mg/L)	Site 1 VS Site 3	0.11
NO_3^- (mg/L)	Site 2 VS Site 3	0.12
Olson-P (mg/L)	Site 1 VS Site 2	0.05
pH	Site 1 VS Site 2	0.51

4. Discussion

Based on our extensive experiments and analysis, significant differences were observed in the humidity content among the three study sites. We believe that these variances can be attributed to the distinctive vegetation characteristics present at each site. Specifically, at site 1 where peony was planted, the leaves may not serve as the primary source for bud and flower development. Peony plants possess well-developed root systems, consisting of deep roots and numerous side roots, which contribute to their ability to absorb ample nutrients and water [3]. Thus, a substantial amount of water is required to sustain their growth and flowering. In contrast, grass and maple/crabapple trees were planted at the other two sites. While these trees also have high water demands during the summer growing season, their water requirements are comparatively lower than those of peony. Consequently, the lack of adequate water supply can easily impede normal flowering and lead to withering of branches and leaves [4]. This discrepancy in water requirements may explain the higher humidity content observed at site 1.

The organic matter content at site 1 was significantly higher than that at sites 2 and 3. We posit that this disparity can be attributed to the peony's ability to accumulate organic matter. During the flowering process, peony utilizes a substantial amount of carbohydrates stored in its roots, and a significant portion of the soluble sugars and other nutrients required by the flower organs are supplied by the roots [4]. Peony is a shade-tolerant plant that necessitates ample fertilizer and water to promote growth and flowering during its one-year growth cycle. Consequently, site 1, where peony was planted, accumulated a greater amount of organic matter.

The relatively high Olson-P content observed at site 1 can be attributed to the specific fertilization practices employed in this area. It is noteworthy that the peonies planted at site 1 have a pronounced demand for phosphorus (P) due to their unique physiological requirements. Phosphorus plays a vital role in various plant processes, including energy transfer, photosynthesis, and cell division. Peonies require substantial amounts of phosphorus to support their growth and development, particularly during the flowering stage, where phosphorus is crucial for the production of vibrant and abundant blooms. Conversely, the grass and maple/Begonia trees planted at sites 2 and 3 exhibit lower phosphorus requirements. Grass species generally have a more conservative phosphorus utilization strategy, adapted to thrive in low-phosphorus environments.

They have developed efficient root systems that can scavenge and absorb phosphorus from the soil more effectively. Maple and Begonia trees, on the other hand, have moderate phosphorus demands compared to peonies. While they still require phosphorus for essential metabolic processes, their growth and reproduction are not as reliant on high phosphorus levels as peonies. Therefore, the differential fertilization strategy implemented at these sites takes into account the specific phosphorus requirements of each plant community. By adjusting the amount of phosphate fertilizer applied, it ensures that the nutrient needs of each plant species are met without excessive phosphorus accumulation in the soil. This targeted approach optimizes plant growth and minimizes the risk of environmental issues associated with nutrient runoff and pollution.

In conclusion, our experimental analysis of the three study sites highlights the substantial influence of vegetation type, soil organic matter, and fertilization methods on the chemical and biological composition of the soil. These findings provide valuable insights for the better protection and management of land resources. Further investigations into the variations in soil chemical and biological composition under different vegetation and fertilization conditions can enhance our understanding and improve land utilization and ecological benefits.

5. Conclusion

After conducting a series of experiments to explore changes in soil chemical and biological composition under different vegetation and fertilization conditions, we collected and analyzed soil samples to determine the chemical and biological composition characteristics of soil under different factor effects.

The study revealed that vegetation type and fertilization methods play crucial roles in shaping the soil's chemical and biological composition. Different types of vegetation have unique water and nutrient requirements, which directly influence the soil's moisture content and nutrient availability. For example, the site with peony plants exhibited higher humidity content compared to the sites with grass and maple/crabapple trees. This can be attributed to the peony's high water demand due to its well-developed root system and nutrient requirements.

The organic matter content in the soil was found to be significantly influenced by the selected vegetation and fertilization methods. Organic matter is a vital component of healthy soil, as it improves soil structure, enhances nutrient retention, and promotes beneficial microbial activity. The site where peony was planted had a notably higher organic matter content compared to the other sites. This can be attributed to the peony's ability to accumulate organic matter through its growth cycle. The shade-tolerant nature of peony also contributes to the accumulation of organic matter, as it requires ample fertilizer and water to support its growth and flowering.

In terms of soil nutrient composition, the study observed variations in phosphorus levels among the different sites. The site with peony plants had relatively higher Olson-P content, indicating a higher concentration of phosphorus in the soil. This can be attributed to the application of phosphate fertilizers to meet the peony's phosphorus requirements for growth and flowering. In contrast, the grass and maple/crabapple trees at the other sites required less phosphorus, leading to lower Olson-P content.

Understanding the impact of vegetation and fertilization methods on soil chemical and biological composition is essential for sustainable land management and ecosystem health. By selecting appropriate vegetation and implementing suitable fertilization practices, land managers can optimize soil composition, enhance nutrient availability, and improve the stability of ecosystems. This, in turn, can lead to increased productivity and long-term sustainability in agricultural and natural landscapes.

In conclusion, our study provides valuable insights into the influence of vegetation type and fertilization methods on soil chemical and biological composition. The variations observed in humidity content, organic matter content, and phosphorus levels among the different sites highlight the importance of understanding the specific requirements of different vegetation types and implementing tailored fertilization strategies. Further research in this field will contribute to the development of effective land management practices that maximize productivity while preserving soil health and ecological balance.

As we continue to explore the intricate relationships between vegetation, fertilization, and soil composition, it is crucial to prioritize sustainable practices that support long-term land productivity and environmental well-being. By integrating scientific knowledge and innovative approaches, we can ensure the responsible use of land resources and contribute to a more resilient and prosperous future.

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