Study on Nutrient Characteristics of Aspen Woody Debris in Saihanwula National Nature Reserve, Inner Mongolia

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Abstract

In this paper, the secondary forest of Populus in Saihanwula National Nature Reserve in Inner Mongolia is the research area,a large area of aspen forests that have died abnormally in recent years in the study area, three types of sample plots, namely Fallen wood plots, Dead standing wood plots and Control plots, were set up in the poplar forest for post-death update investigation.The study found that the Carbon(C) content of Woody Debris in Saihanwula Reserve decreased first and then increased with the increase of decomposition level; There is no obvious change rule of Nitrogen(N) element;Phosphorus(P) elements in Saihanwula Reserve decreased with the increase of decomposition grade.The P content leveled off to III decomposition level; The reserves of Kalium (K), Calcium (Ca), Natrium (Na), Magnesium (Mg), and Ferrum (Fe) in the Woody Debris in the study area are small, and there is no obvious release pattern.

Keywords

Natural Secondary Forest; Woody Debris; Nutrient Release; Nutrient Function.

1. Background

After the trees die, they remain in the forest land in the form of Woody Debris (including Dead standing trees, Fallen trees, and Dead branches) [1-2],Woody Debris decompose slowly over time, and the amount of nutrients released during different decomposition periods is also different [3].In 1974, Kaarik et al. began to study the role of Woody Debris and their decomposition in nutrient dynamics, and found that their decomposition can increase soil nutrients to a certain extent [4],Since then, the research on the decomposition of Woody Debris has been in-depth. In 1977, Fogel et al. proposed a five-level system for classifying fallen wood rot based on the appearance characteristics of Douglas fir dead wood, and carried out research on the nutrient element content of fallen wood [5].In 1978, Grie et al., through the decomposition study of *Tsuga heterophylla,* learned that its decomposition model was a single exponential decay model, and also found that the changes of nutrients such as N, P, Ca, Mg, K, and Na during the decomposition of fallen wood were affected. Dynamic Trends [6]. At this stage, people gradually paid attention to the important role of Woody Debris in the material cycle and energy flow of the ecosystem [7].Later, Laiho et al. found that the content of nutrient elements in Woody Debris was much less than that in forest litter[8], However, due to the reserves of Woody Debris in forest stands are much larger than those of litter, Woody Debris are extremely important nutrient reservoirs in forest ecosystems[9], and play a huge role in maintaining forest productivity[10]. Laura G. et al. studied wet eucalyptus forests in Tasmania, Australia and found that the carbon content of Woody Debris in mature forests accounted for

10-20% of the total aboveground biomass carbon content [11].In 1983, Cheng Borong et al. conducted a decomposition experiment on the stumps of larch and Korean pine in Changbai Mountain and found that the nutrients of the Woody Debris were slowly released along with the decomposition [12].In addition, some scholars have studied the decomposition mechanism, nutrient release, organic chemical composition and other characteristics of Woody Debris [13]. Through nutrient release in different periods, Woody Debris are an important nutrient pool in forest ecosystems [14]. In 2014, Scott A et al. found that Woody Debris with high decomposing grades significantly increased soil carbon and nitrogen pools in forest ecosystems [15]. In 2018, Steffen et al. studied the decomposition of Woody Debris of three important Central European tree species and found that nutrients can be utilized and recycled by microorganisms in Woody Debris, But with the exception of P in beech, Mg in pine, and K in two tree species, the net nutrient output appears to be very small, until the decomposition to two-thirds of the weight of the Woody Debris itself, the net release of P begins. [16]. After the tree dies, it is decomposed into fallen wood after a long time in the external environment. When it comes into contact with the soil, a large amount of organic matter will accumulate in the soil. These organic matter will decompose and erode the wood residue under the action of soil, animals, microorganisms and other factors. Some organic matter It will participate in the carbon and nitrogen cycle of the atmosphere in the form of gas [17]. at the beginning of this century, the research on Woody Debris has entered a stage of rapid development. Researchers have carried out in-depth studies on the nutrient content and decomposition dynamics of Woody Debris in different regions, tree species, and forest ages, etc. [18].

2. Methods and Materials

2.1. Research Area Survey

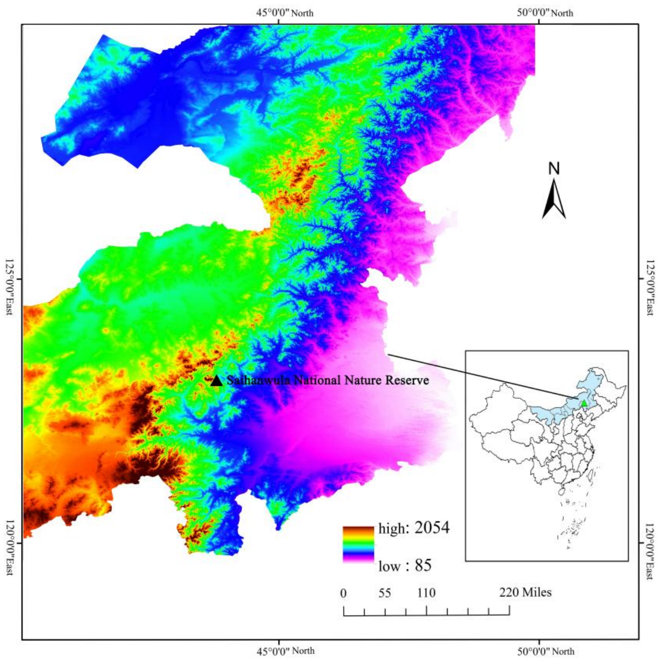

Fig 1. Distribution map of the study area

The study area is in Saihanwula National Nature Reserve, Balinyou Banner, Chifeng City, Inner Mongolia. The landform type in the study area belongs to the Zhongshan Mountains, with the mountains trending from northeast to southwest [19].The mountain is relatively high, with an average altitude above 1000 m, and the highest peak, Wulanba, is 1997 m above sea level [20].The mid-temperate semi-arid and semi-humid warm-cold climate[21]; the average annual sunshine hours is 3000 h; the annual average temperature is about 2°C, the annual extreme maximum temperature is 33°C, and the annual extreme minimum temperature is -36 ℃ [22]; the annual average precipitation is about 400 mm, and the annual evaporation is 2050 mm [23].There are gray forest soil, mountain black soil, brown loam soil and aeolian sandy soil in the study area [21]. The water system is relatively developed. The study area is one of the important sources of water in the upper reaches of the West Liaohe River. There are 10 rivers such as Wulanba River, Baiqi River and Huitong River, which flow through Chaganmulu River and Xitong River. The Lamulun River eventually merges into the Xiliao River, becoming one of the important water sources of the Xiliao River, with an annual runoff of $0.5\times10^8 m^3$. Plant communities are divided into 5 vegetation groups and 6 vegetation types [22]. There are large areas of *Ostryopsis davidiana* thickets that gradually transition upward to forest vegetation [22]. The trees include *Betula platyphylla* forest, *Populus davidiana* forest, and *Betula davurica* forest. Currently, there are only a small area of *Picea meyeri* forest, *Larix principis-rupprechtii* forest and *Quercus mongolica* forest et al [22].

2.2. Research Methods

2.2.1. Sampling Setting

The study area set up *Populus* Control plots (selected aspen in the plot were basically growing normally, with a small number of fallen and dead trees. referred to as "C") [21], Dead standing wood plots (Most of the selected plots are withered, dying or dead standing *Populus*. referred to as "D") and the Fallen wood plots (selected sample plots where most of the *Populus* died and formed mostly fallen woods, referred to as "F"), the plot area was 20 m×20 m, and three replicates were set for each type of plot, for a total of 9 plots. selected aspen in the plot were basically growing normally, with a small number of fallen and dead trees.

Table 1. Information of sample points

Study area	Plot	Longitude	Latitude	Altitude (m)	Aspect	Slope(°)	Canopy	closure Mortality(%)
Saihan Ullah Reserve	C1	118°43′47.19″	44°12′59.36″	1217	WN	12°	0.63	17.39
	C2	118°43′47.39″	44°12′58.30″	1227	WN	10°	0.66	16.65
	C3	118°43′46.27″	44°12′56.90″	1237	WN	13°	0.62	15.55
	D1	118°43′46.33″	44°13′00.37″	1212	WN	16°	0.69	46.54
	D2	118°43′48.10″	44°12′57.74″	1231	WN	19°	0.71	48.76
	D3	118°43′47.38″	44°12′57.20″	1234	WN	12°	0.78	45.25
	F1	118°44′08.53″	44°12′56.46″	1227	WN	18°	0.55	43.93
	F2	118°44′10.55″	44°12′56.65″	1232	WN	17°	0.56	45.17
	F3	118°44′07.52″	44°12′55.62″	1239	WN	23°	0.61	42.83

2.2.2. Plot Investigation

This study mainly focused on Woody Debris with a diameter of ≥2.5 cm. Combined with Harmon's classification standard, make the Woody Debris with diameters > 2.5 cm and < 10 cm were regarded as Fine Woody Debris, and the diameters of ≥10 cm were regarded as Coarse Woody Debris. On this basis, according to the state and length of Woody Debris in the forest ecosystem, they are further divided into Fallen log, Snag, Slump and Large branch [86]. In order to distinguish it from fallen wood, dead standing wood refers to Woody Debris with an inclination of no more than 45, a diameter of large head ≥ 10 cm, and a length of > 1 m; like other characteristics of Dead standing wood, a height of < 1 m is defined as a root pile.

Investigate Fallen trees, Dead standing trees, and Dead branches in the plots, During the investigation, record the altitude, slope, slope aspect, slope position, and basic information of each sample plot. After that, check the Dead standing trees record their tree species, DBH, tree height, and the decomposition grade of dead standing trees were recorded (Table 2). The decomposition levels of Woody Debris are classified according to the internationally unified "five-level classification system" [23]. Investigation of Fallen trees and Dead branches: record the tree species, diameter, length, and location of large and small heads, and investigate the existence mode of fallen trees (Root uprooting, Stem base breaking, and Stem breaking) and Decomposition grades [21].

2.2.3. Sample Collection

Take the upper, middle and lower parts of the fallen wood. For the Woody Debris of grades, I, II, and III, take the discs and mark them and bring them back to the laboratory. The Woody Debris of grades IV and V are directly sampled with a sealed bag. 15 samples were collected from each plot, for a total of 135 samples.

Table 2. Classification system of Woody Debries decomposition grades

Type	Feature	Decomposition Level				
		I	II	III	IV	V
Fallen Wood	Leaves	Present	None	None	None	None
	Branches	All small branches exist	Large branches exist	Large thick branches exist	Branch shedding nodes exist	None
	Bark	Present	Present	Mostly present	Mostly exfoliated	None
	Trunk shape	Round	Round	Round	round to oval	oval to flat
	Invaded by roots	None	None	Sapwood area	Invaded all	Invaded all
	Plant growth	None	Few plant	growth Few young shrubs	Seedlings and moss Moss large area	Growing shrub moss and young tree
Dead Standing Wood	Bark	Tight Partially	Exfoliated Partially	Present	None	Form fallen wood
	branch	complete	only large branches present	None	None	
	Body	Freshly dead	standing, sturdy	standing, rotting	badly decayed	

2.3. Indoor Analysis Scheme

The collected samples were mechanically crushed and then smashed through a 1 mm aperture mesh sieve for elemental analysis.

2.3.1. Determination of Organic C, N, O Elements in Woody Debris

(1) Packing sample: Weigh about 10 mg (± ≤ 0.1 mg) of the prepared wood residue powder with a one-millionth balance, put it into the tin foil specially used for the elemental analyzer, and press the tin foil into a button shape. spare.

(2) Debug the elemental analyzer, put the packaged sample into the instrument, and measure.

2.3.2. Determination of P Element in Woody Debris

(1) Digest: Weigh 0.3 g of wood residue powder, put nitric acid and hydrochloric acid in a ratio of 1:3 to digest the Woody Debris.

(2) Constant volume: Pour the digested solution into a 50 ml volumetric flask to constant volume.

(3) Acid adjustment: After 30 min, 5 ml of solution was taken out for acid adjustment. Dissolve 0.25 g of 2,4-dinitrophenol in 100 mL of water. The discoloration point of this indicator is about pH_3, it is colorless when it is acidic, and it is yellow when it is alkaline. Dissolve 16 g of NaOH in 100 mL of water to prepare a 4 $mol \cdot L^{-1}$ sodium hydroxide solution. Draw 6 mL of concentrated sulfuric acid solution, slowly add it to 80 mL of water, stir while adding, add water to 100 mL after cooling, and prepare 2 $mol \cdot L^{-1}$ H_2SO_4 solution.

(4) Molybdenum-antimony anti-reagent: A. 5$g \cdot L^{-1}$ potassium antimony tartrate solution: Dissolve 0.5 g of potassium antimony tartrate $[K(SbO)C_4H_4O_6]$ in 100 mL of water, and configure potassium antimony tartrate as 0.5 $g \cdot L^{-1}$.

B. Ammonium molybdate-sulfuric acid solution: Weigh 10 g of ammonium molybdate $[(NH_4)_6Mo_7O_{24}H_2O]$, dissolve it in 450 mL of water, prepare 10 g L^{-1} of ammonium molybdate, and slowly add 153 mL of concentrated H_2SO_4 (5.5 $mol \cdot L^{-1}$), stirring while adding. Add the above solution A to the solution B, and finally add water to 1 L. Shake well and store in a brown bottle. This is the molybdenum-antimony mixture. Before use (on the same day), weigh 1.5 g of L-ascorbic acid ($C_6H_8O_5$, chemically pure), dissolve it in 100 mL of molybdenum-antimony mixture, prepare 15 $g \cdot L^{-1}$ of ascorbic acid, mix well, this is the molybdenum-antimony anti-reagent. Valid for 24 hours, longer if stored in the refrigerator.

(5) Phosphorus standard solution: Accurately weigh 0.2195 g of KH_2PO_4 (analytical grade) dried in an oven at 105°C, dissolve it in 400 mL of water, add 5 mL of concentrated H_2SO_4 solution (add H_2SO_4 to prevent mold growth, and the solution can be stored for a long time)), transfer to a 1 L volumetric flask, add water to the constant volume mark. This solution is a P standard solution of 50 $g \cdot mL^{-1}$, and a standard curve is drawn.

(6) Take an appropriate amount of the acid-adjusted solution and put it into a flow analyzer for measurement.

2.3.3. Determination of Total K, Na, Fe, Ca, Mg Elements in Woody Debris

(1) Digest: Weigh 0.3 g of Woody Debris powder, put nitric acid and hydrochloric acid in a ratio of 1:3 to digest the Woody Debris.

(2) Constant volume: Pour the digested solution into a 50 ml volumetric flask to constant volume.

(3) Acid adjustment: After 30 minutes of constant volume, take out 5 ml of solution for acid adjustment. Dissolve 0.25 g of 2,4-dinitrophenol in 100 mL of water. The discoloration point of this indicator is about pH_3, it is colorless when it is acidic, and it is yellow when it is alkaline. Dissolve 16 g of NaOH in 100 mL of water to prepare a 4 $mol \cdot L^{-1}$ sodium hydroxide solution. Draw 6 mL of concentrated sulfuric acid solution, slowly add 80 mL of water, stir while adding, add water to 100 mL after cooling, and prepare 2 $mol \cdot L^{-1}$ H_2SO_4) solution.

(4) Put an appropriate amount of the acid-adjusted solution into an atomic absorption spectrometer for measurement.

In this study, Microsoft Excel 2010 software was used to organize, calculate and plot the survey data. IBM SPSS 25.0 was used for statistical analysis, and SigmaPlot 12.5 software was used for graphing.

3. Results

3.1. Characteristics of Organic Carbon Content and Nutrient Element Content in Aspen Woody Debris of Different Decomposition Grades

Organic carbon is an indispensable element in the growth of aspen. When the tree dies, these elements still exist in the body for slow release. Studies have shown that the content of Woody

Debris released by different levels of decomposition is different, and the content of organic carbon in the Woody Debris of aspen is relatively higher than that of other elements. The organic carbon content of the five decomposition grades in Saihanwula Nature Reserve is the largest in the I decomposition grade, with a content of 496.6 g/kg, and the smallest in the III decomposition grade, 443.91 g/kg, and the change trend is I>II>V>IV >III decomposition level.

Table 3. Distribution of organic carbon in different regions of Woody Debres

Study area	Decomposition grade	C(g/kg)
Saihan Ullah Reserve	I	496.6±1.81Aa
	II	486.94±5.81Aa
	III	443.91±2.13Ab
	IV	454.83±2.71Ab
	V	458.61±3.17Ab

N is an indispensable element in plants. The research results show that the N content of Saihanwula Reserve is the I decomposition grade, and the smallest content is the V decomposition grade, the change trend is I>II>IV>III >V decomposition grade, the content is between 3.8 and 7.6 g/kg. With the increase of decomposition grade, the average content of N shows a downward trend, and tends to be flat when it reaches III decomposition grade. The overall performance is that with the increase of decomposition grade, content is decreasing; P can increase the drought resistance of plants. The research results show that the content of P in Saihanwula Reserve is the I decomposition grade with the largest content, and the V decomposition grade with the smallest content. The content is between 0.51 and 1.18 g/kg. The change trend is I>II>IV>III>V decomposition grade. With the increase of decomposition grade, P all show a downward trend, and the P content tends to be stable when the decomposition grade reaches III; K is an activator of various enzymes and plays an important role in the metabolic process. It can not only promote photosynthesis, but also promote nitrogen metabolism and improve the absorption and utilization of nitrogen by plants. The study found that the content of K in Saihanwula Reserve is the III decomposition grade with the largest content, and the IV decomposition grade with the smallest content; Ca is a constituent of the cell wall and prevents extravasation of cells and substances in cells. The study found that the content of Ca element in Saihanwula Reserve is the highest in the V decomposition grade, and the smallest is in the I decomposition grade, ranging from 0.02 to 0.35 g/kg; Na can help plants form chlorophyll. The study found that the Na content in Saihanwula Reserve is between 0.75 and 0.81 g/kg, and there is no obvious change among the five decomposition levels; Mg is a component of chlorophyll. The Mg content of different decomposition grades in Saihanwula Reserve is between 0.82 and 0.94 g/kg. With the increase of decomposition grade, the content of Mg has no obvious change trend; Fe element is the element with the lowest content. The Fe content in Saihanwula Reserve is between 0.001 and 0.004 g/kg.

The elements of K, Ga, Na, Mg and Fe in the Woody Debris were analyzed, and the content of metal elements was less than that of matrix elements. The content of metal elements in the Woody Debris of Saihanwula Reserve is generally Mg>Na>K>Ca>Fe.

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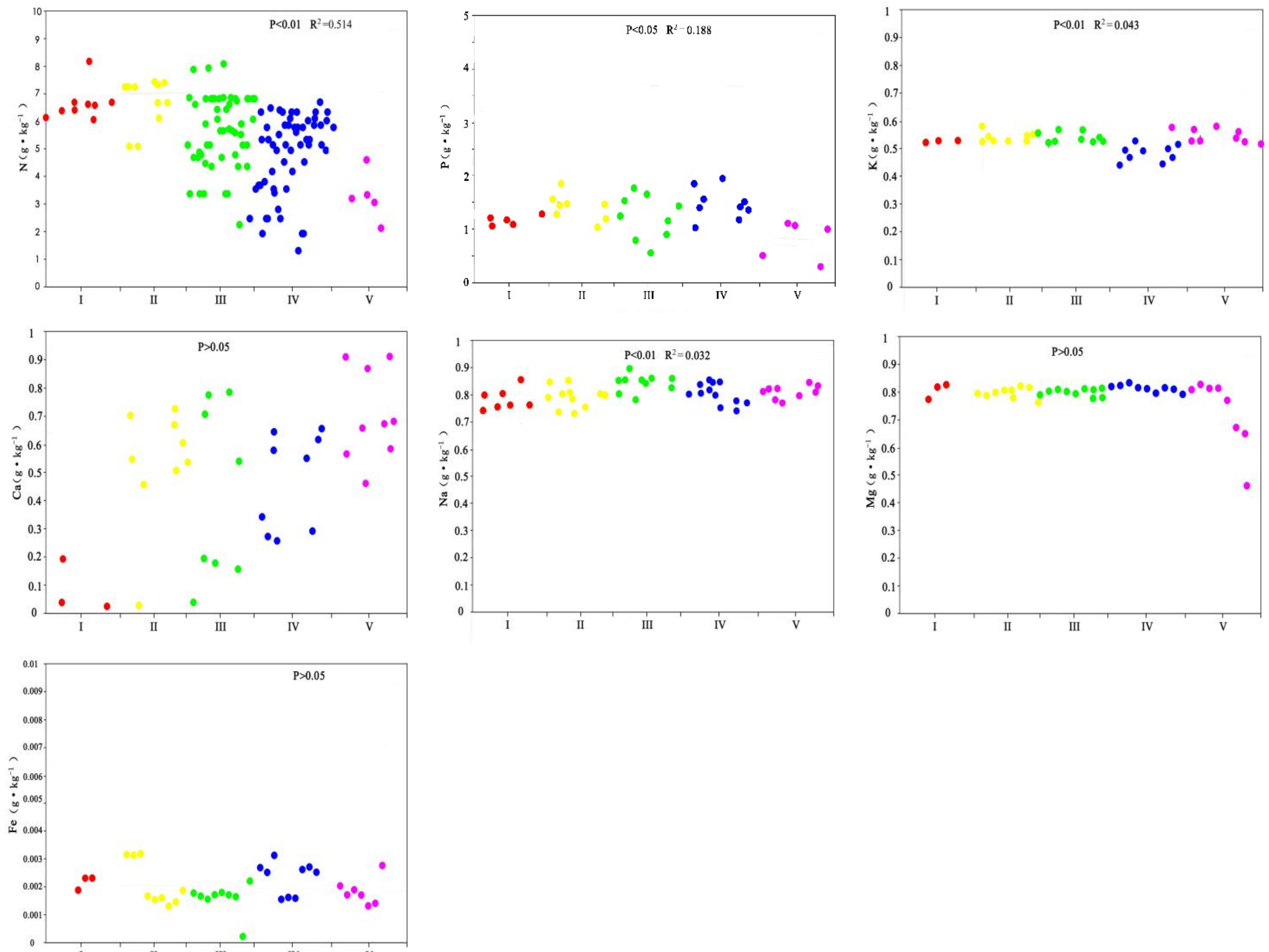

Fig 2. Elemental Analysis of K, Ga, Na, Mg and Fe in Wood Chips

3.2. Analysis of the Relationship between the Nutrients and Influencing Factors of the Woody Debris of Aspen with Different Decomposition Grades

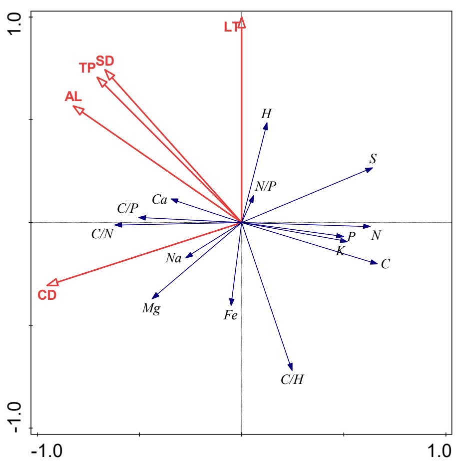

Fig 3. Redundancy analysis of nutrient elements and environmental factors in Woody Debris

Note: canopy density (CD), litter thickness (LT), stand density (SD), regeneration density (TP), average annual precipitation (AP), temperature (TD), altitude (AL), carbon (C), nitrogen (N), phosphorus (P), Kalium (K), calcium (Ga), Natrium (Na), magnesium (Mg), Ferrum (Fe).

Through the RDA study on the relationship between nutrient elements and environmental factors in the secondary forest area of Saihanwula Reserve, it was found that the nutrient element concentrations were related to Altitude (AL), Regeneration density (TP), Stand density (SD), and Litter thickness (LT). had no correlation with Canopy density (CD) ($P>0.05$), the C/N value of Saihanwula Reserve was negatively correlated with Litter Thickness (LT) ($P<0.05$), and other elements had little correlation.

4. Discussion

4.1. Analysis of the Variation Law of Nutrient Elements in Woody Debris in the Study Area

The slow release of organic carbon in Woody Debris maintains forest nutrients and affects the carbon cycle of microorganisms. The places with more Woody Debris have relatively more nutrient elements, resulting in spatial heterogeneity of soil elements [24]. Studies have shown that the Woody Debris in the study area are rich in a large amount of nutrients, some studies have found that the organic carbon content gradually decreases with the decomposition of Woody Debris, and some is opponent. During the decomposition of Woody Debris in the Saihanwula Reserve, the organic carbon content tends to decrease with the increase of the decomposition level, but it does not gradually decrease, decreases rapidly when the decomposition level reaches III, Which may be due to the fact that the decomposition years of the trees in the experiment was not well controlled, Neglecting the time for the decomposition of Woody Debris ,although the integrity of the Woody Debris structure, the presence of bark, the state and color of the xylem, and the attachment of appendages were directly observed during sampling, The degree of decay of the Woody Debris is determined by the degree of softness and hardness of the wood residue. However, the judgment of the decomposition level is still not very accurate, and there is a possibility of judging the Woody Debris of a certain rot level as the previous or next rot stage, which will affect the experimental results [25]. caused by different contents. the carbon content of Saihanwula Reserve ranges from 443.6 to 496.6%, and the carbon content accounts for 40 to 50% of its own, which is a normal level.

P is the most important limiting nutrient for carbon sequestration in ecosystems [26], and N is an important part of enzymes, both of which are one of the important elements in plants and one of the physiological elements necessary for tree growth and development. Studies have shown that in the Canadian *Picea mariana* forest, the soil around fallen trees is significantly enriched in N, and the concentrations of N and P in the adjacent soil are higher, and the content is 49% higher than that of the open space [27] , it can be seen that Woody Debris play an important role in the soil ecosystem, but some studies have pointed out that although the decomposition of Woody Debris increases the N content in the soil, the materials lost on the Woody Debris also inhibit the N cycle of the soil below. K, Ca, Na, Mg, and Fe are a large number of elements necessary for plant growth and development, and their contents do not show a consistent change in the process of decomposition. During the decomposition of Woody Debris, with the degradation of organic matter, various nutrients are gradually released. Studies have shown that when the release rate of a certain element in the fallen wood is lower than the rate of mass loss of the fallen wood, the content will increase, and vice versa. then the content decreased. The K content gradually decreased with the increase of the decomposition grade. The adsorption strength of heavy metals on Woody Debris of different decomposition grades was different, and with the increase of decomposition grades, nutrients were lost. Elements such as Ca and Mg also showed an increasing trend with the deepening of the decomposition degree of Woody Debris. It may be that the loss rate of elements due to leaching is less than the loss rate of the mass of Woody Debris, resulting in element enrichment.

5. Conclusion and Implications

The C content of the five decomposition grades in Saihanwula Nature Reserve showed a downward trend with the increase of the decomposition grade, and the content was between 458.6 and 496.6 g/kg; The contents of N, P, Na, and Mg elements in Woody Debris of different decomposition grades in the study area increased with the increase of decomposition grades, and nutrients were lost. However, the elements of Ca and Fe tended to increase with the deepening of the decomposition degree of the Woody Debris, which may be because the loss rate of elements due to leaching was less than the rate of loss of the mass of the Woody Debris, resulting in the enrichment of elements. These Woody Debris may play a lot of positive roles in the material cycle, renewal and restoration of the ecosystem, and soil and water conservation in the future. However, the distribution of such high reserves of Woody Debris should also pay attention to the negative impact on forest ecosystem fire prevention and control, pest control, forest health and other aspects of management. Taking appropriate management measures such as clearing and logging is an important means to maintain the health of the forest ecosystem. All the forestry measures we take, such as cultivation, protection, and restoration, are ultimately the pursuit of sustainable development of forestry and sustainable utilization for human beings.

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