Study on Water-holding Properties of Litters in Different Types of Forests of Yuntaishan Mountain Area in Shibing County, Guizhou Province

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Abstract. Taking the coniferous forest, the hard leaf forest at mountain ridge and the evergreen broad-leaved forest as research objects, using field observations and indoor immersion test methods, analyzing the water holding capacity and water holding characteristics of litters. Through experimental monitoring and data analysis, compared the difference between the accumulation amount of litter, maximum water holding amount, maximum water holding rate and effective interception amount, and study on the relationship between water holding amount, water holding rate and soaking time, The results show: (1) Accumulation amount of litter: the coniferous forest 10.15t/hm\textsuperscript{2} > the hard leaf forest at mountain ridge 8.73t/hm\textsuperscript{2} > the evergreen broad-leaved forest 5.82t/hm\textsuperscript{2}; maximum water-holding capacity: the hard leaf forest at mountain ridge 21.6t/hm\textsuperscript{2} > the coniferous forest 21.4t/hm\textsuperscript{2} > the evergreen broad-leaved forest 5.82t/hm\textsuperscript{2}; maximum water holding rate: the evergreen broad-leaved forest 316.39% > the hard leaf forest at mountain ridge 247.73% > the coniferous forest 202.71%. (2)Effective interception amount: the coniferous forest 7.96t/hm\textsuperscript{2} > the evergreen broad-leaved forest 6.41t/hm\textsuperscript{2} > the hard leaf forest at mountain ridge 6.36t/hm\textsuperscript{2}. (3)Litter soaking experiments show that the overall changing trend of water holding capacity, water holding rate and soaking time of the three kinds of litters are basically the same (logarithmic curve relationships); and the overall changing trend of water absorption rate and soaking time are basically the same, and it’s monomial relationship.

1. Introduction
In the ecosystem, the component of the ground plants produce and return to the ground surface, forming litter accumulation. Then, litter provide material base and energy sources for disintegrator. They are the general term for all organic matters that maintain the stability of the ecosystem. The litter layer plays an important role in forest ecosystem, which can play an important role in water
conservation and soil conservation, and its water holding performance is an important index to reflect the forest ecological effect [1]. Litter layer of forest vegetation play an important role in water-holding capacity and the water and energy transfer between atmosphere and soil [2]. Domestic and foreign scholars started in the 1970s on the research of the litter. Most of them are the stoichiometric characteristics of forest litter, the effect of the nutrient of litter on woodland productivity of woodland [3] [4], the effect of decomposition of litter on the forest habitat, the effect on the physical and chemical properties of the soil, and the study of soil and water conservation [5] [6]. In the karst area, the study on litter was also for the above aspects, and there was less research on the water-holding capacity of forest litter. The ecological environment in karst area is fragile, which carbonate rocks are widely distributed, the rock is bare, the soil layer is shallow, the dissolution is obvious [7]. The withered objects have the function of retaining water, water conservation and have an indirect effect on the dissolution of carbonate rocks. The research provides theoretical basis for the transformation of forest and retaining soil in karst area through the study on the water holding of three kinds of forest in the dolomite area of Shibing.

2. The overview of research area
The research area is located in the world natural heritage site Shibing Yuntaishan Mountain in the east of Guizhou, located in the mountainous region of central Guizhou to the hilly slope of west Hunan, and located in the middle reaches of wuyang river of yuanjiang river basin, east longitude 108°06'00"-108°07'12", north latitude 27°12'00"-27°10'12". The research area is in central Guizhou, which is a subtropical karst plateau that is heavily cut by rivers. The soil is mainly a thin layer of limestone weathered by dolomite. It is the evergreen broad-leaved forest region of central Asia of the subtropical evergreen broad-leaved forest area. There are rich in vegetation types, including evergreen broad-leaved forest, coniferous forest, and broad-leaved mixed forest, deciduous broad-leaved forest, evergreen hard leaf forest, Pinus massoniana Lamb, Quercus Linn, Carpinus rupestris and other plants. The vegetation types in the valley and valley are more abundant, which are mainly Castanopsis carlesii (Hemsl.) Hay, Ostrya multinervis, Cyclobalanopsis glauca (Thunb.) Oerst, Phoebe shearer (Hemsl.) Gamble, Manglietia fordiana Oliv, Sloanea sinensis, Light sticks and many kinds of cold water flowers. The study area belongs to subtropical monsoon climate zone, in which the light and rainwater is enough, the annual average temperature is 16 ℃, the annual average precipitation is 1220mm, the annual sunshine time is 1195.4h, and the annual total solar radiation is 9.26 ×106kw/m².

3. Materials and methods

3.1. Accumulation amount of litters
The vertical bands from the peak to the foothills of the Shibing Yuntaishan Mountain are warm coniferous forest, subtropical mountain evergreen forest, subtropical evergreen broad-leaved forest, and river bank thickets. Therefore, a representative sample of the coniferous forests, the hard leaf forest at mountain ridge, and the evergreen broad-leaved forests were selected as experimental samples. For each of the three vegetation standard sample plot(30×30m²), five quadrants with a size of 50×50 cm² were selected, the quadrants are distributed in the four corners and the center of the standard ground, with 10 points selected for each quadrant. According to the degree of decomposition, the total litter thickness, undecomposed layer thickness, and semi-decomposed layer thickness were determined separately of every quadrants, the fresh weight of undecomposed and semi-decomposed layers were immediately weighed during collection, then dry to weight of balance and weighing weight, and the dry weight is measured and used to calculate the volume and water holding amount of litter in different forest types in per unit area [8].

3.2. The water holding property of litters
Weigh the dried litter samples separately and then put them into cloth bags, then salvaged them after being immersed respectively in water for 0.08, 0.25, 0.5, 1, 2, 4, 6, 8, 10, 24 h, place 5min until not
dripping. quickly weigh the litter weight after the absorption of water at different times, each sample was weighed 3 times and averaged [9].

The following formulas is used to calculate the accumulation amount of litter, water holding amount, water holding rate and interception amount. The actual water holding rate of the litter layers of different vegetation types is all about 85% of the maximum water-holding rate. In order to get closer to the actual interception amount of the undecomposed layer and the semi-decomposition layer of the litter, the effective interception amount of each forest type litter was calculated by using the adjustment coefficient 0.85 [10]. The formulas is as follows:

\[ C_1(\%) = \frac{(m_1 - m_2)}{m_2} \times 100 \]  
\[ S_1(\%) = \frac{(m_3 - m_2)}{m_2} \times 100 \]  
\[ W_{\text{max}} = (R_{\text{max}} - R_1) \times M \]  
\[ W = (0.85R_{\text{max}} - R_1) \times M \]

In the formulas: 
- \( C_1 \) is the natural moisture content, \( \% \);
- \( S_1 \) is the saturated water holdup;
- \( W_{\text{max}} \) is the maximum interception amount of litter, \( \text{t} \cdot \text{hm}^{-2} \);
- \( W \) is the effective interception amount of litter, \( \text{t} \cdot \text{hm}^{-2} \);
- \( m_1 \) is the fresh weight of sample, g;
- \( m_2 \) is sample dry weight of sample, g;
- \( m_3 \) is the weight of sample immersed in water for 24h;
- \( R_{\text{max}} \) is maximum water-holding rate, \( \% \);
- \( R_1 \) is the average natural moisture content for before the rain;
- \( M \) is the accumulation amount of litter, \( \text{t} \cdot \text{hm}^{-2} \)

3.3. Data processing

Excel was used for data processing and analysis.

4. Results and analysis

4.1. The accumulation amount of litters

The input amount, decomposition speed and accumulated age of the litter can affect the reserves of the litter. However, different types of forest vegetation composition, ambient light, heat and water condition have different effects on the reserves of litter. The accumulation amount of litter of litter also affects its water holding amount [11].

As can be seen from table 1, the three types of forest accumulation amount of litter are the coniferous forest 10.15t/hm\(^2\) > the hard leaf forest at mountain ridge 8.73t/hm\(^2\) > the evergreen broad-leaved forest 5.82t/hm\(^2\). The accumulation amount of litter of the coniferous forest is greater than the hard leaf forest at mountain ridge. This is mainly because the production of coniferous forests is large, the texture is hard to decompose, and the accumulation of litter is large. The evergreen broad-leaved forest is relatively easy to decompose, with less accumulation of litter. The proportion of semi-decomposed layers in the reserves of different forest types is larger than that of undecomposed layers. The proportion of each layer of accumulation amount of litter: the coniferous forest has the largest percentage of undecomposed layer, to 68.99%, the second was 63.23% for the hard leaf forest at mountain ridge, the undecomposed layer of the evergreen broad-leaved forest was 61.92%.
Table 1. Accumulation amount of litters in three types of forests.

| Forest Types                  | Accumulation Amount of Litter (t/hm²) | Semi-decomposed Layer proportion (%) | Undecomposed Layer proportion (%) | Total Accumulation Amount (t/hm²) |
|-------------------------------|---------------------------------------|--------------------------------------|----------------------------------|----------------------------------|
| Evergreen Broad-leaved Forest | 2.22                                  | 38.08                                | 3.61                             | 61.92                            | 5.83 |
| Coniferous Forest             | 3.15                                  | 31.01                                | 7.01                             | 68.99                            | 10.16 |
| Hard Leaf Forest at Mountain Ridge | 3.21                               | 36.77                                | 5.52                             | 63.23                            | 8.73 |

4.2. Water Holding Amount of Litters

It can be seen from Table 2 that the maximum water holding amount of the three kinds of litter is: the hard leaf forest at mountain ridge 21.6t/hm² > the coniferous forest 21.41t/hm² > the evergreen broad-leaved forest 18.19t/hm². The maximum water holding amount of the hard leaf forest at mountain ridge is similar to that of the coniferous forest, which is greater than that of evergreen broad-leaved forest. It is shown that the water holding amount of the different forest types is significantly affected by the reserves of the litter, which is the positive correlation law [12]. The water holding amount of undecomposed layer litters of the hard leaf forest at mountain ridge is the largest, it is larger than evergreen broad-leaved forest and coniferous forest. The maximum water holding amount of semi-decomposed layers litter of coniferous forest is larger than the hard leaf forest at mountain ridge and the evergreen broad-leaved forest. The maximum water holding rate of three types of forest litter is the evergreen broad-leaved forest 316.39% > the hard leaf forest at mountain ridge 247.73% > the coniferous forest 202.71%. Previous studies have shown that the degree of decomposition of litter has great influence on water holding performance, and the water holding amount of the semi-decomposed layers was all higher than the undecomposed layer in different forest types litter[13]. The maximum water-holding rate and water holding amount of the semi-decomposed layers are higher than the undecomposed layers for the three types of forest litter. It can be explained that the water performance capacity of the semi-decomposed layers of different forest types is higher than that of the undecomposed layers.

Table 2. The maximum water holding amount and maximum water holding rate of three types of forest litters

| Forest Types                  | Maximum Water Holding Amount (t/hm²) | Maximum Water Holding Rate (%) |
|-------------------------------|--------------------------------------|--------------------------------|
| Evergreen Broad-leaved Forest | 18.19                                | 316.39                         |
| Coniferous Forest             | 21.41                                | 247.73                         |
| Hard Leaf Forest at Mountain Ridge | 21.6                               | 202.71                         |

4.3. Water Interception Amount

The maximum water holding capacity of litter just reflect the water holding condition under ideal state, it is higher than the actual interception capacity of litter, and it can’t reflect the ability of litter to intercept rain. Therefore, the maximum interception amount of litter and the effective interception amount were calculated. The effective interception amount calculation results will be closer to the actual water holding amount under natural conditions.

As shown in Table 3:
The maximum interception amount of the three types of litter is: the coniferous forest 11.05t/hm$^2$ > the hard leaf forest at mountain ridge 9.61t/hm$^2$ > the evergreen broad-leaved forest 9.17t/hm$^2$, the effective interception amount is: the coniferous forest 7.96t/hm$^2$ > the evergreen broad-leaved forest 6.41t/hm$^2$ > the hard leaf forest at mountain ridge 7.96t/hm$^2$. The natural moisture rate of the coniferous forest is the least, but it has the largest reserves, the natural moisture rate of the evergreen broad-leaved forest and the hard leaf forest at mountain ridge is high, but the reserves are smaller. Therefore, the effective interception amount of the coniferous forest is greater than that of the evergreen broad-leaved forest and the hard leaf forest at mountain ridge.

Table 3. The maximum water interception amount and effective water interception amount of three types of forest litters

| forest types                  | natural moisture rate(%) | Maximum water interception amount(t/hm$^2$) | effective interception amount (t/hm$^2$) |
|-------------------------------|--------------------------|---------------------------------------------|----------------------------------------|
| evergreen broad-leaved forest | 158.75                   | 9.17                                        | 6.41                                   |
| coniferous forest             | 93.85                    | 11.05                                       | 7.96                                   |
| hard leaf forest at mountain ridge | 137.63              | 9.61                                        | 6.36                                   |

4.4. Water holding process of litters

Using Excel, analyze the litter water holding capacity and water holding rate of each forest type and the soaking time, the following logarithmic functional relationships were found between the water holding capacity and the water holding rate and the soaking time:

$$y=a\ln(x)+b$$  \hspace{1cm} (5)

In the formula: $y$ is the water holding amount (t/hm$^2$) and water holding rate (%), $x$ is the immersion time (unit: h), $a$ and $b$ are the equation coefficients, the fitting effect is shown in Figure 1 and Figure 2. The litter water holding amount is in logarithmic functional relationships with the soaking time, the correlation coefficient $R^2$ is higher than 0.9498, water holding rate and soaking time are also logarithmic function relationships, the correlation coefficient $R^2$ is higher than 0.9499. As can be seen from Figure 1, the litter water content rose rapidly when the litter was soaked for 0.08h to 1 h, From 1h to 12h, the speed is gradually increased and tends to be gentle, at 24h, the water content is basically no longer rising to reach the saturation state of water absorption. It can be seen from Figure 2 that the relationship between water holding rate and soaking time of three types of forest litter have similarities and differences. As shown in Figure 2, the water-holding rate and soaking time of the three types of forest are in logarithmic curve. They all showed that the water holding rate in the early stage of soaking increased rapidly, the water holding rate slows down after 2h, the water holding rate is basically unchanged after 12h, and the water holding capacity of litters tended to be saturated. There are significant differences in the water holding rates of litter in different forest stands, it appears as the evergreen broad-leaved forest > the hard leaf forest at mountain ridge > the coniferous forest. The main reason is that there is less storage in evergreen broad-leaved forest, so it absorbs less water, but evergreen broad-leaved forest is easy to decompose, with loose texture and good water absorption, therefore, its water absorption rate is higher than that of the hard leaf forest at mountain ridge and coniferous forests. There is more oil content in the coniferous forest, and the decomposition rate of litter is slower, so the water absorption rate is lower [14], however, due to its large reserves, it has a large water content.
4.5. Water absorption rate of litters

The regression analysis of the water absorption rate and water holding time of the litters of the three forest types revealed that they have the following power function relationship:

\[ V = kt^n \]  \hspace{1cm} (6)

In the formula: \( V \) is the water absorption rate of litter (g·kg\(^{-1}\)·min\(^{-1}\)); \( t \) is the soaking time (h), \( n \) is the index, and \( k \) is the coefficient.

As can be seen from Figure 3, the initial water absorption rate of litter in each forest type is very high, and the water absorption rate decreases rapidly after 0.5 h, after that, the water absorption rate of litter decreases slowly with time, and the water absorption tends to be saturated after 10 h. Fully
saturated after 24h. Although the water absorption rates of litters of different forest types are slightly different, the overall change trend of the water absorption rate process line is basically the same.

Figure 3. Change of water absorption rate of three types of forest litters over time

5. Conclusion and discussions
(1) The accumulation amount of litter of the three forest types range from 5.82 t/hm$^2$ to 10.15 t/hm$^2$, the coniferous forest is 10.15 t/hm$^2$ > the hard leaf forest at mountain ridge is 8.73 t/hm$^2$ > the evergreen broad-leaved forest is 5.82 t/hm$^2$, the proportion of undecomposed litter in coniferous forest and the hard leaf forest at mountain ridge is similar in the total accumulation, and the semi-decomposing litter layer volume of coniferous forest is twice as much as that of evergreen broad-leaved forest.

(2) The maximum water holding amount of the litter of three forest types was 21.6 t/hm$^2$ of the hard leaf forest at mountain ridge > 21.41 t/hm$^2$ of coniferous forest > 18.19 t/hm$^2$ of evergreen broad-leaved forest. And the maximum water-holding rate was 316.39% of evergreen broad-leaved forest > 247.73% of the hard leaf forest at mountain ridge > 202.71% of coniferous forest.

(3) The maximum interception volume of the litter of three forest types was 11.05 t/hm$^2$ of the coniferous forest > 9.61 t/hm$^2$ of the hard leaf forest at mountain ridge > 9.17 t/hm$^2$ of the evergreen broad-leaved forest. And the effective interception volume was in the order of 7.96 t/hm$^2$ of the coniferous forest > 6.41 t/hm$^2$ of the evergreen broad-leaved forest > 7.96 t/hm$^2$ of the hard leaf forest at mountain ridge.

(4) The litter water holding amount and the litter water holding rate of the three forest types increased with logarithmic function as the soaking time increased, and the water absorption rate decreased as the soaking time increased as a power function.

The research on the litter of three forest types of Yuntaishan Mountain in Shiping County shows that the litter water holding capacity of different forest types is different. The ecological environment in the karst region is relatively fragile. The accumulation of litter improves the ecological benefit of forest, but also indirectly promotes the dissolution of carbonate rocks. Studying the water-holding characteristics of litter in different forest types is of great significance to the environmental protection and the restoration of forest ecosystem in the karst area.
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