STUDY OF COMMUNITY STRUCTURE AND DISTRIBUTION OF MIXED FOREST NEAR NANWAN LAKE

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The community structure distribution of a forest that grows in the coastal zone is an important index for the diversity and sustainable development of riparian ecosystem and is also an important basis for the production of forest land management. In order to understand the ecological function of the riparian zone of Nanwan Lake (Xinyang City, Henan Province, China), the growth status of the forest in the downstream of the reservoir was investigated. The results of the study indicate that Pinus massoniana Lamb and Pistacia chinensis Bunge are the predominant species in the coastal zone. There is a gradual decrease in the representation of Pinus massoniana Lamb in this community. Lower story of Quercus dentate Thunb. and Pistacia chinensis Bunge demonstrates significant potential to replace the upper story. The tree structure characteristics (DBH - diameter of a tree trunk at breast high (1,3 m), tree height and crown width) were recorded at each experimental plot. The tree structure characteristics conform the inverted "J" distribution and the linear relationship between the DBH and tree height in the foreststand (can be well described by using Richard model equation), the model equation is $H=1.3+20.095\left(1-\frac{1}{e^{0.0809(1.765)}}\right)$. In the absence of anthropogenic accidents or natural extremes, the forest lands near Nanwan Lake could effectively use environmental benefits for a long time. In order to improve the level of forest management in mixed forests in these areas, it is suggested to closely monitor the growth status of trees, cut dead or poor growing Pinus massoniana Lamb, and prevent the occurrence of forest fires.

Key words: Nanwan Lake riparian zone; mixed forest; community structure characteristics.

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Introduction. Forestland growing in the riparian zone has an important ecological value and functional benefits in water conservation, non-point source pollution interception, litter decomposition, carbon storage, nitrogen deposition and other aspects. It is a momentous ecological buffer area for water area and terrestrial ecosystems (González et al., 2016; Dybala et al., 2019; Ran et al., 2020). Riparian forest land provides a substrate of litter and other organic matter for aquatic organisms, which control water temperature and light through shade, maintain riparian vegetation stability, and reduce soil erosion (Naiman & Decamps, 1997).

The main driving force of vegetation community structure characteristics in riparian zone is the adjacent hydrologic condition. The riparian forest adjacent to the water area is disturbed by the unpredictable and rhythmless reservoir stream which often leads to the decrease of soil dissolved
oxygen, the decrease of hydraulic conductivity, the restricted respiration of trees and other factors, which greatly affect the community structure of riparian forest (Kuglerová et al., 2014; Myster, 2018). Besides being directly affected by the flow of the reservoir, riparian forests are also indirectly affected by the microclimate brought by the river (González et al., 2016).

In the riparian zone (typical small climate habitat) the growth strategies of plants and animals, propagation of propagules, migration of groundwater and flow of material and energy have their own unique modes of operation (Naiman & Decamps, 1997).

Compared with the riparian zones formed by large river basins and alluvial plains, reservoir riparian zone shows more obvious ecological vulnerability in spatial heterogeneity, landscape pattern, plant community structure and other aspects, and has more frequent groundwater activities and stronger dependence on stable habitat. However, in practice, the ecological importance of such a small watershed is often ignored by experts and forestry managers (Hagan et al., 2006).

It has been agreed that riparian forests play an important role in buffer. In many European countries, buffer zones are left to protect the ecological environment of rivers when conducting forest management (Oldén et al., 2019). Many researchers have discussed the relationship between the width of buffer zone and the ecological benefit (Ali, 2019; Kuglerová et al., 2014; Ring et al., 2017).

In the management activities of riparian forest, we generally try not to disturb its ecological cycle as much as possible, in order to obtain the maximum ecological benefits (Tolkkinen et al., 2015). Such conservative management measures often lead to problems such as overmaturating of forest land, unreasonable structure of forest canopy and gradually unbalance of tree species in the management of riparian forestland.

Studies have shown that moderate disturbance can improve the functional heterogeneity of forest communities, promote the succession of ecological communities, and improve biodiversity (Kreutzweiser et al., 2012; Kuglerová et al., 2014; Sibley et al., 2012). Proper management measures can promote the ecological benefits of riparian forestland.

Tree species diversity, diameter class diversity and height of tree diversity all affect the attribute of forestland, and further affect the ecological benefit. Thus, stand structural complexity is defined as differences in the diameter and height of individual trees, as well as the heterogeneity of tree size (diameter and/or height) within the stand. In summary, stand structural diversity, complexity, and other related variables (such as average tree size, stand density, and stand basal area) are characterized as stand structural attributes.

The DBH diversity describes the degree of difference in tree size within the stand. The greater the difference, the stronger the spatial heterogeneity of the stand is, and the more species it can accommodate. Changes in the size (diameter and/or height) of individual trees, for example, between and within species, are critical to species diversity and the maintenance of forest function (Clark, 2010; Yuan et al., 2018).

The greater capacity to provide ecological niches or food diversity for a variety of animals, plants, and microorganisms in the forest is improved if the variation of stand diameter class and stand structure became more complex (Rolstad et al., 2001). The relationship between tree species structure, species diversity and aboveground productivity in 300,000 sample plots were studied and found that tree structure characteristics were the main driving force of aboveground productivity (Bohn & Huth, 2017). According to the research in the African tropical rain forest region (Poulsen et al., 2017), the availability of forest structure and the availability of large trees, compared with environmental variables and disturbances, are important predictors of abundance and distribution of large liana plants.

Canopy structure is also an important structural feature affecting forest land in riparian zone. Canopy intercepts rainfall to change surface runoff, thus affecting decomposition rate of litter and soil structure, and improving water circulation characteristics of riparian zone (Livesley et al., 2014; Sun et al., 2018).

It was found that the correlation between stand structure and forest species diversity was positive, negative and insignificant, and the determinants of these three relationships mainly lie in the competitive relationship between individual trees, light conditions and selection effect, while the relationship between stand structure characteristics and forest function is more directly determined by the environmental effect in which the stand is located (Ali, 2019).

In recent years, the implementation of China’s ecological civilization strategy has played a positive role in the promotion of forestry development. In this context it should be noted that China’s forest coverage rate has been continuously increased and the area of artificial forests has been continuously expanded. Undesirable consequences for maintaining the ecological benefits of forests in the coastal zone are observed in the case of abandonment of felling and no other measures for the well-being of all riparian ecosystems.

Nanwan Lake Reservoir is a 4A tourist attraction in Xinyang City, Henan Province, China. It has provided important ecological benefits for the local community in tourism, domestic water, irrigation, regional climate characteristics and other aspects. With the adjustment of forest management measures in recent years, the forest land around the reservoir has obviously degraded in landscape pattern and ecological benefit. In order to find out the growth and development status of the forest land near Nanwan Lake reservoir, the community distribution structure of the forest land in Nanwan Lake reservoir was investigated, so as to provide the production basis for the rational management of the forestland.

Materials and Methods. Overview of test site. The test site is located around Nanwan Lake Reservoir in Xinyang City, Henan Province, China (E 114° 08’, N 32° 13’). Xinyang city, situated in the south of Henan Province, located at the Qinling mountain and Huai River boundary, is a transitional region from subtropical zone to warm temperate zone. The terrain is high in the south and low
in the north, with an altitude of 75–300 m. Xinyang has plenty of solar radiation, the average annual sunshine hours are 1900–2100 ones. The average annual temperature is 15.3–15.8°C, and the average annual rainfall is 993–1294 mm. The relative humidity averages is 74–78 %. The average annual rainfall is 177–255 mm. There are many rivers in this region, which are part of Yangtze River and Huai River basins. Huai River basin occupies 98.2 % of the city’s area and is located in the upper reaches of the Huai River, which traverses the whole city from west to east. Under the influence of special geographical location and climate, the spatial and temporal distribution of rainfall is uneven, and the annual and inter-annual precipitation greatly varies. The precipitation is mainly concentrated in June to August in the main flood season, and the annual difference between high and low rainfall can be up to 2–3 times. The main forest trees species in this area are Pinus massoniana Lamb, Cunninghamia lanceolata (Lamb.) Hook, Quercus acutissima Carruth., Quercus dentate Thunb. and Pistacia chinensis Bunge etc. These tree species are distributed in pure forest or Mosaic and form the main forest community.

Experiment design. In the downstream of the reservoir, 9 forest land samples close to the water area were selected (Fig. 1), with an area of 20 m × 15 m. We carried out each wood gauging in the samples. The main records included the tree species and growth status of each tree, DBH (≥ 5cm), tree height (H), height under the branches of alive trees, canopy width and other factors.

Data analysis. Tree species composition. The composition coefficient of tree species was used to represent the proportion of each tree species in mixed forest, and the proportion of different tree species’ basal area in total basal area was used to calculate the composition coefficient of tree species.

Importance value. Importance Value (IV) is an important indicator in the calculation and evaluation of species diversity, which represents the relative importance of plant species in the community with comprehensive values. The more the IV, the more important they are in the stand. The calculation formula as follows (Curtis & McIntosh, 1951):

\[ IV(\%) = \left( \frac{\text{relative density} + \text{relative frequency} + \text{relative significance}}{3} \right) \times 100, \]

where:
- relative density = the number of individuals of a certain species/the number of individuals of all species × 100 %;
- relative frequency = the frequency value of a certain species/the frequency value of all species × 100 %;
- relative significance = basal area of a certain species/basal area of all species × 100 %.

Diameter distribution. The DBH of trees was taken as the index to measure the size of trees, the trees were graded according to the DBH, and the DBH of trees was statistically analyzed with 2cm as the diameter step length, and the starting DBH was 5 cm.

Forest story division. According to the International Union of Forest Research Organization standard, the vertical stratification of the stand is divided into three vertical stratifications based on the average dominant tree height of the stand. In the upper canopy, the height of the tree is more than or equal to 2/3 of the average height of the dominant tree. In the middle canopy, the height of the trees is more than 1/3 and less than 2/3 of the average height of the dominant tree. Lower canopy, tree height is less or equal to 1/3 of the average height of the dominant trees.

Tree height distribution. The tree height structure was analyzed with 1 m as the height step size.

Tree size diversity index. In order to quantify the distribution characteristics of individual diameter class of trees in a stand, the species diversity evaluation index applied to the ecosystem has been widely used for tree diameter class diversity evaluation, and thus the distance-independent diversity index and the distance-related diversity index have been proposed. The diversity index is independent of the distance, it can be applied easily. DBH data are needed to effectively characterize the diameter class distribution characteristics in the stand (Peder & Ljusk, 2000; Pommerening, 2002; Schulte & Buongiorno, 1998).

Four size diversity indexes independent of distance were selected, Simpson size diversity index \( (D_N) \) and Shannon index \( (H'_S) \) were used to evaluate the diameter class distribution richness of forest land along the riparian zone of Nanwan Lake reservoir. Gini coefficient of basal area \( (GC) \) and diameter variation coefficient \( (CV_d) \) were used to evaluate the DBH size variation degree of forest land along the riparian zone of Nanwan Lake reservoir, with the diameter class of 2 cm. The specific expression is as follows:

Simpson size diversity index (Valbuena et al., 2012)

\[ D_N = 1 - \sum_{j=1}^{s} P_j^2 \]
Shannon size diversity index [3] (Buongiorno, 2001)
\[ H_N = -\sum_{i=1}^{n} P_i \ln(P_i) \]

\[ GC = \frac{\sum_{i=1}^{n} (2i - n - 1)BA_i}{\sum_{i=1}^{n} BA_i(n - 1)} \]

Diameter coefficient of variation index is:
\[ CV_d = \frac{\sqrt{\sum_{i=1}^{n} (d_i - \bar{d})^2}}{n - 1} \]

S represents number of diameter classes, \( P_i \) - proportion of tree numbers in size class \( j \), \( BA_i \) - basal area for tree with rank \( i \) (m²), \( n \) - total number of trees, \( d_i \) - mean diameter (cm).

Relationship between tree height and DBH
- Richard model, Weibull model, logistic model, Korf model and compertz model were used to simulate the relationship between tree height and diameter at breast height (DBH) and calculate the parameter values of the equations.
- To ensure a tree height of 1.3 m at DBH 0; constant 1.3 was added to all models (Tab. 1), where: \( a, b, c \) - parameters,
- \( a \) - total height limit (means upper bound of total height), \( b \) - related to growing speed, \( c \) - shape parameter.
- SPSS19.0 software was used to simulate each expression parameter.

<table>
<thead>
<tr>
<th>No.</th>
<th>model</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Richard</td>
<td>( H = 1.3 + a(1 - e^{bDH}) )</td>
</tr>
<tr>
<td>2</td>
<td>Weibull</td>
<td>( H = 1.3 + a(1 - e^{bDH}) )</td>
</tr>
<tr>
<td>3</td>
<td>Logistic</td>
<td>( H = 1.3 + \frac{a}{1 + be^{cDH}} )</td>
</tr>
<tr>
<td>4</td>
<td>Korf</td>
<td>( H = 1.3 + a(e^{bDH}) )</td>
</tr>
<tr>
<td>5</td>
<td>Compertz</td>
<td>( H = 1.3 + a(e^{bDH}) )</td>
</tr>
</tbody>
</table>

**Results. 1. Composition of tree species.** By surveying each samples, the stand density is 1220 plants / ha², and there are 12 arbor species (Tab. 2).

The top four species in terms of important value are *Q. dentata*, *P. massoniana*, *Q. acutissima*, *P. chinensis*. The coniferous forest species mainly is *P. massoniana*,

### Table 2
General situation of tree species in the sample plots

<table>
<thead>
<tr>
<th>species</th>
<th>Number</th>
<th>%</th>
<th>Sum</th>
<th>Average</th>
<th>DBH/cm</th>
<th>H/m</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Quercus dentata</em> Thunb.</td>
<td>156</td>
<td>54.6</td>
<td>1.639</td>
<td>0.008</td>
<td>25.5</td>
<td>31.0</td>
<td>4.6</td>
</tr>
<tr>
<td><em>Quercus dentata</em> (dead) Thunb.</td>
<td>4</td>
<td>13.2</td>
<td>5.3</td>
<td>10.2</td>
<td>2.8</td>
<td>19.96</td>
<td>14.41</td>
</tr>
<tr>
<td><em>Pinus massoniana</em> Lamb</td>
<td>31</td>
<td>14.4</td>
<td>1.648</td>
<td>0.034</td>
<td>25.6</td>
<td>21.0</td>
<td>11.7</td>
</tr>
<tr>
<td><em>Pinus massoniana</em> Lamb (dead)</td>
<td>11</td>
<td>10.6</td>
<td>0.252</td>
<td>0.008</td>
<td>3.9</td>
<td>20.2</td>
<td>5.4</td>
</tr>
<tr>
<td><em>Quercus acutissima</em> Carruth.</td>
<td>32</td>
<td>10.9</td>
<td>2.570</td>
<td>0.080</td>
<td>39.9</td>
<td>44.2</td>
<td>6.2</td>
</tr>
<tr>
<td><em>Pistacia chinensis</em> Bunge</td>
<td>31</td>
<td>10.6</td>
<td>0.252</td>
<td>0.008</td>
<td>3.9</td>
<td>20.2</td>
<td>5.4</td>
</tr>
<tr>
<td><em>Platycarya strobilacea</em> Sieb. et Zucc.</td>
<td>11</td>
<td>3.8</td>
<td>0.095</td>
<td>0.009</td>
<td>1.5</td>
<td>23.0</td>
<td>5.9</td>
</tr>
<tr>
<td><em>Symplocos paniculata</em> (Thunb.) Miq.</td>
<td>5</td>
<td>1.7</td>
<td>0.034</td>
<td>0.007</td>
<td>0.5</td>
<td>13.1</td>
<td>5.4</td>
</tr>
<tr>
<td><em>Acer ginnala</em> Maxim.</td>
<td>4</td>
<td>1.4</td>
<td>0.022</td>
<td>0.006</td>
<td>0.3</td>
<td>9</td>
<td>7.8</td>
</tr>
<tr>
<td><em>Broussonetia papyrifera</em></td>
<td>3</td>
<td>1.0</td>
<td>0.023</td>
<td>0.008</td>
<td>0.4</td>
<td>14.3</td>
<td>6.0</td>
</tr>
<tr>
<td><em>Ulmus parvifolia</em> Jacq.</td>
<td>2</td>
<td>0.7</td>
<td>0.141</td>
<td>0.071</td>
<td>2.2</td>
<td>42.0</td>
<td>5.9</td>
</tr>
<tr>
<td><em>Cerasus dieula</em> (Schneid.) Yu et Li</td>
<td>1</td>
<td>0.3</td>
<td>0.007</td>
<td>0.007</td>
<td>0.1</td>
<td>9.3</td>
<td>9.3</td>
</tr>
<tr>
<td><em>Armeniaca vulgaris</em> Lam.</td>
<td>1</td>
<td>0.3</td>
<td>0.003</td>
<td>0.003</td>
<td>0.05</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td><em>Cotinus coggyria</em> Scop.</td>
<td>1</td>
<td>0.3</td>
<td>0.004</td>
<td>0.004</td>
<td>0.05</td>
<td>7.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Total 293 100 6.439 0.022 100
the relative density of it is 14.4 %, the conifer-broad leaf mixed ratio is 1:6, and the breast-height basal area ratio is 1 : 4. *Q. dentata* accounted for 54.6 % of the total number of plants, followed by *P. massoniana* and *Q. acutissima*.

As for average DBH and tree height, the average DBH of *Q. acutissima* is 30.66 cm, and the average tree height is 18.28 m. Followed by *Ulmus parvifolia* Jacq., which the average DBH was 23.95 cm, the average tree height was 14.41 m. Although there were many *Q. dentata*, the average DBH was 9.10 cm and the average tree height was only 7.33 m. The number of *P. chinensis* was close to *Q. acutissima*: with the average DBH of 9.32 cm and average tree height of 8.64 m.

Based on comprehensive analysis, *P. massoniana* and *Q. acutissima* had obvious advantages in the community, which are the constructive species of the arbor community. *P. massoniana* had partial death phenomenon and showed the decline trend, while *Q. dentata* and *P. chinensis* have great potential as regeneration species.

**Diameter class distribution.** The individual diameter class distribution of all arbor trees in the riparian zone of Nanwan Lake reservoir showed an inverse "J" distribution, among which the number of trees 5 cm ≥ DBH ≤ 14 cm accounted for 68.6 % of the total, indicating that the diameter class structure of the forest stand is mainly medium-small diameter class (Fig. 2).

The size of *Q. dentata* was mainly distributed between 5 cm to 29.9 cm. The smaller the size the number of plants was more. The diameter class distribution of *P. massoniana* was mainly from 14 cm to 33.9 cm, and the number of plants in each diameter class distribution was more uniform. The diameter class distribution of *Q. acutissima* was commonly from 18 cm to 45.9 cm, among which the number of plants ≥ 34 cm was more distributed, chiefly with large diameter class. The diameter class distribution of *P. chinensis* mainly ranged from 5 cm to 15.9 cm, and it is dominated by small size. In general, the main tree species in the forest land of Nanwan Lake reservoir are *P. massoniana* and *Q. acutissima*, which are mainly distributed in the large-diameter class, while *Q. dentata* and *P. chinensis* are mostly distributed in the small-medium diameter class in large area. It can be predicted that *P. massoniana* and *Q. acutissima* will be gradually replaced with the growth of *Q. dentata* and *P. chinensis*.

Forest story division. According to the height of dominant trees (Tab. 3), the forest story was divided into three vertical structures: upper, middle and lower. The average height of dominant trees in the forest story was 22.78 m, with 15.19 and 7.59 m as the boundaries of each forest story. The number of trees in the middle canopy was the largest; accounting for 42.4 %. The number of plants in the upper
The canopy was less, accounting for 23.2%. This indicates that in the whole forest story, the trees in the middle and lower layers occupy the main distribution.

The main tree species in the upper story of forest near Nanwan Lake are *P. massoniana* and *Q. acutissima*, among them a small amount of *Q. dentata* and *P. chinensis* distributed (Tab. 3). The middle story is mainly dominated by *Q. dentata*, and a small amount of *P. massoniana* and *P. chinensis* distributed, about a half among them (*P. massoniana*) are dead and their growth condition is limited. The lower story is dominated by *Q. dentata* with a small amount of *P. chinensis* and *P. strobilacea*.

Tree height distribution. The distribution curve of tree height is asymmetrical shape of mountain and continuous (Fig. 3).

Tree height ranges from 6 m to 8 m has a large distribution. Maximum tree height is 23 m. The height distribution of *Q. dentata* is mainly concentrated in the range of 3 m to 14 m. The height of *P. massoniana* is mainly distributed in the range of 12 m to 21 m, the height of *Q. acutissima* – in the range of 16 m to 22 m, the height of *P. chinensis* – in the range of 4 m to 8 m. From the perspective of tree height distribution, the tree height distribution of different tree species is clearly stratified. *Q. acutissima* and *P. massoniana* are growing in the middle and upper canopies, while *Q. dentata* and *P. chinensis* are concentrated in the lower and middle canopies. From the perspective of DBH distribution, the tree height distribution and diameter class distribution of each tree species have the same trend.
The whole community, and acutissima was investigated. We found that the downstream of the Nanwan Lake reservoir riparian zone productivity (Naiman & Decamps, 1997; Zhang et al., 2012).

The maintenance of the whole reservoir environment as measures of riparian forest land play a positive role in and microorganisms. The health status and management of the change and formation of the reservoir microclimate, the riverbank of the reservoir plays an important role in

\begin{align*}
    R^2 = 0.656 \quad [0, 1]
\end{align*}

Table 5: Index table of diameter class distribution diversity of arbor forest in Nanwan Lake reservoir riparian zone.

<table>
<thead>
<tr>
<th>Index</th>
<th>Value</th>
<th>Theoretical index value range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simpson size diversity index</td>
<td>0.878</td>
<td>[0,1]</td>
</tr>
<tr>
<td>Shannon size diversity index</td>
<td>2.441</td>
<td>[0, ln(S)]</td>
</tr>
<tr>
<td>Gini coefficient index of basal area</td>
<td>0.600</td>
<td>[0,1]</td>
</tr>
<tr>
<td>Diameter coefficient of variation index</td>
<td>0.656</td>
<td>[0,1]</td>
</tr>
</tbody>
</table>

The Simpson size diversity index of diameter class distribution of arbor forest in Nanwan Lake reservoir riparian zone is 0.878. Shannon size diversity index is 2.441. Gini coefficient index of basal area is 0.600. Diameter coefficient of variation index is 0.656 (Tab. 5). This indicates that the distribution richness of diameter class structure in Nanwan Lake reservoir riparian zone is more abundant, the difference of tree diameter class is obvious, and the forest stand diameter class structure is in a relatively good condition.

Tree height – DBH relationship

Table 6: The tree height – DBH curve was used to fit the parameters.

<table>
<thead>
<tr>
<th>Model</th>
<th>Fitting results</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richard</td>
<td>20.095</td>
<td>0.090</td>
<td>1.765</td>
<td>0.818</td>
<td></td>
</tr>
<tr>
<td>Weibull</td>
<td>19.537</td>
<td>0.020</td>
<td>1.406</td>
<td>0.817</td>
<td></td>
</tr>
<tr>
<td>Logistic</td>
<td>18.527</td>
<td>8.621</td>
<td>0.179</td>
<td>0.810</td>
<td></td>
</tr>
<tr>
<td>Korf</td>
<td>28.488</td>
<td>9.195</td>
<td>0.867</td>
<td>0.818</td>
<td></td>
</tr>
<tr>
<td>Compertz</td>
<td>19.243</td>
<td>3.058</td>
<td>0.122</td>
<td>0.816</td>
<td></td>
</tr>
</tbody>
</table>

Using the main tree species as samples, the parameters \(a\), \(b\) and \(c\) of several commonly used tree height-DBH model equations were fitted to obtain the parameters of each model. Among them, Richard equation and Korf equation have the best fitting effect, with the determination coefficient \((R^2)\) both reaching 0.818. Comparing the residual results obtained by the two methods, Richard's equation is better, which is applicable to describe the relationship between tree height and DBH in the forestland of the Nanwan Lake reservoir riparian zone. The model equation is

\begin{align*}
    H = 1.3 + 20.095 \left(1-e^{-0.090D}\right)^{1.765}.
\end{align*}

**Discussion.** The forest land along the riverbank of the reservoir plays an important role in the change and formation of the reservoir microclimate, and is also an important habitat for various vegetation, birds and microorganisms. The health status and management measures of riparian forest land play a positive role in the maintenance of the whole reservoir environment as well as the development of biodiversity and forest land productivity (Naiman & Decamps, 1997; Zhang et al., 2012).

In this study, the growth status of forestland in the downstream of the Nanwan Lake reservoir riparian zone was investigated. We found that \(P.\ massoniana\) and \(Q.\ acutissima\) are the constructive species of the riparian zone, among which \(P.\ massoniana\) is gradually declining in the whole community, and \(Q.\ dentata\) and \(P.\ chinensis\) mainly distributed in the lower canopy showed strong replacement potential, which is consistent with the planting history of the riparian forest of the Nanwan Lake reservoir.

In the 1960s, after the reservoir was built, the local management developed a large area of plantation using \(P.\ massoniana\) and \(Q.\ acutissima\). For a long time, this kind of mixed model has achieved good results. With the succession of forest community structure, local suitable species \(Q.\ dentata\) and \(Q.\ chinensis\) showed strong competitive advantage.

In the investigation process, we also found that many large-diameter \(P.\ massoniana\) appeared dry death phenomenon, which may be due to the rapid growth of newer species in the lower canopy; \(P.\ massoniana\) gradually weakened in the whole niche competition, the root system could not get enough nutrients, and gradually died.

The condition of \(Q.\ acutissima\) is better than \(P.\ massoniana\) in the large size class. The main competitive pressure on \(P.\ massoniana\) is likely to come from \(Q.\ acutissima\). The update status of \(Q.\ acutissima\) in small size class is not ideal, and the distribution range is small. It can be predicted that with the growth of the lower canopy species, \(P.\ massoniana\) and \(Q.\ acutissima\) will be gradually replaced. In the future, the stand will be dominated by the \(Q.\ dentata\), among which the main accompanying species is \(P.\ chinensis\). This is also consistent with the characteristics of the transition region from subtropical zone to warm temperate zone in Xinyang region.

The hierarchical structure of different canopy story in mixed forests affects the primary productivity of forestlands through the distribution of light energy inner forest canopy and the distribution of species communities under the canopy, further affecting the structural characteristics of ecosystem communities (Marks et al., 2020). The relationship between ecosystem diversity and ecosystem function usually has two mechanisms, niche complementary effect and selection effect. The diversity of ecosystem also directly affects the diversity of stand diameter class structure (Naeem, 2002; Tinya et al., 2018). Therefore, the distribution characteristics of individual diameter class structure in stand are also important parameters to evaluate the stability and diversity of the system. From the current status, the forest structure characteristics in the riparian forest land of Nanwan Lake reservoir accord with the inverted "J" pattern distribution, Richard equation can well describe the linear relationship between DBH and tree height in the stand. Indexes such as the diameter class richness and tree size diversity further affecting the structural characteristics of ecosystem and the distribution of species communities under the canopy, through the distribution of light energy inner forest canopy.

In the absence of anthropogenic accidents or natural extremes, the forest lands near Nanwan Lake could effectively use environmental benefits for a long time.

**Conclusions.** Forestland is an important part of riparian ecosystem and the stability of forest land structure is also a prerequisite for the maintenance of biodiversity (Gregory et al., 1991). It is almost impossible to restore the ecological function of riparian zone communities once they are destroyed. Riparian forests play a disproportionate role in maintaining ecosystem diversity and climate stability.
considered its area (González et al., 2016; Tolkkinen et al., 2020). The restoration and reconstruction of riparian forest can effectively improve the efficiency of carbon storage and is an important measure for ecological restoration (Dybala et al., 2019). By investigating the spatial structure characteristics and species in the riparian zone of Nanwan Lake Reservoir forest land, this study evaluated the functional structure characteristics and ecosystem stability, and predicted the management measures of the forest land in the future. From a global perspective, conifer species are gradually declining due to drought, fire, invasion of pests and diseases caused by climate change, and the trend towards broadleaf forest is similar to the results of this research (Kominoski et al., 2013; Mantgem et al., 2009). In order to improve the level of forest management in mixed forests near Nanwan Lake reservoir, it is suggested to closely monitor the growth status of trees, cut dead or poor growing P. massoniana, and prevent the occurrence of forest fires.

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References:


