Study on Eco-health Evaluation of \textit{Ledum-Larixgmelinii} Forest in Cold Temperate Zone

YeGu\textsuperscript{1}, PenglinShen\textsuperscript{1}, GuoliRen\textsuperscript{1}, WuZhang\textsuperscript{1}, YuehuaZhang\textsuperscript{1}, JinqiuGuan\textsuperscript{1*}, LanLi\textsuperscript{2*}

\textsuperscript{1}School of Science, Jiamusi University, Jiamusi City, Heilongjiang Province, 154007, China
\textsuperscript{2}School of Data Science and Software Engineering, Wuzhou University, Wuzhou City, Guangxi Province, 543000, China
\textsuperscript{*}Co-Corresponding author’s e-mail: jmsdx8888@sohu.com; lljmsu@163.com

**Abstract.** Field surveys set standard measurement indicators, use principal component analysis to screen indicators, determine weights, construct evaluation models, and use cluster analysis to classify Durian larch forest health grades. Three types of \textit{Ledum-Larixgmelinii} forest in the clearcut forest were studied for health evaluation. The results of the study show that: forest stand productivity, soil nutrients, organizational structure, resistance, and resilience have identified 19 indicators that are more important for the health of Duxiang-Xing'an larch forest. A forest health assessment index system of \textit{Ledum-Larixgmelinii} forest was established. The principal component analysis method was used to select comprehensive indexes such as comprehensiveness, resilience, plant diseases, and insect pests, plant species diversity, fire disturbance degree, structural rationality, soil nutrients and natural disturbance, as the evaluation indicators of \textit{Ledum-Larixgmelinii} larch forest. Although the overall health status of the \textit{Ledum-Larixgmelinii} forest is generally good, there are still areas of forest with health problems. Through analysis, the primary forest has the highest health index and the best health status. It can be seen that the forest grown in the original state has a stable structure, high vitality, strong resistance, and strong sustainability. The health level of the declining forest is second only to that of the primary forest. In clearing forests, there are two kinds of clearing forests in the study area. Among them, 2/3 of the forest are poor, and 1/3 of the forest are in the middle, but the health of the clear cutting forest is the lowest overall.

1. Introduction

Forests are the largest ecosystem on land and the important ecological environment for human survival. They are the most complete biological functions, genetic structures, carbon reservoirs and green reservoirs on the planet with the most complete functions, the most complex structures and the largest biological yields [1]. As an indispensable natural resource and material wealth for the sustainable development of society and economy, it has extremely important strategic significance for maintaining the global ecological balance and biodiversity and maintaining the stability and development of human society [2]. The study area is a region with strong development of cold and wet margins in the northern part of the Greater Xing'an Mountains. The main erosion forces are frost weathering, frost heave erosion and snow erosion. The main glacial landform types include Shihai, peat mound ice hills, and snow eroded depressions [3]. The climate is a cold temperate humid climate zone. Due to the control of cold Siberian air and Mongolian high pressure, the winter is long and severely cold, the
spring and autumn are cool and short, the summer is shorter, and the temperature difference varies greatly. The Xing'an larch forest, and grass-Xing'an larch forest, Beulah platyphylla - Xing'an larch forest, and true moss-Xing'an larch forest, all of which are natural forests, of which Ledum-Larixgmelinii forest has the widest distribution area and is the most typical type of forest. The regular assessment of the forest management status in the area is aimed at monitoring and diagnosing the forest growth status, possible potential problems, and its ecological, economic, and social benefits in a certain area [4]. Forest health assessment is the research basis for the prediction or early warning of ecosystem status. It can provide objective information and a reliable basis for forest health management.

2. Materials and methods

2.1. Research plot
To study the health of Ledum-Larixgmelinii larch forest from the stand scale, based on the data, on-site investigation and analysis, determine the main research content of Ledum-Larixgmelinii forest health evaluation index system suitable for this study: Ledum-Larixgmelinii forest health evaluation index selection and determination; preliminary construction of Ledum-Larixgmelinii forest health evaluation index system suitable for cold temperate zone; determination of Ledum-Larixgmelinii forest health grade standard, and judging the degree of health; the indicators selected by the principal component analysis method are used to evaluate the health indicators of Ledum-Larixgmelinii forest, and the health indexes of the primary forest, deforestation forest and clear forest in the study area are ranked, and their health status perform comparative analysis (in Tab1).

| Plot | Altitude | Slope | Aspect | Species | Standard abbreviation | Cutting strength (%) |
|------|----------|-------|--------|---------|------------------------|----------------------|
| 1    | 825      | 3     | east   | 10      | Interval               | 60                   |
| 2    | 810      | 42    | east   | 8       | All cut                | 90                   |
| 3    | 689      | 5     | north  | 5       | original               | 5                    |
| 4    | 653      | 5     | north  | 10      | original               | 4                    |
| 5    | 866      | 4     | southwest | 10 | Interval               | 50                   |
| 6    | 675      | 6     | northwest | 9  | Interval               | 50                   |
| 7    | 738      | 2     | south  | 8+2     | All cut                | 90                   |
| 8    | 465      | 7     | north  | 6+3     | original               | 3                    |
| 9    | 754      | 7     | northwest | 9  | original               | 4                    |
| 10   | 657      | 8     | south  | 7+2     | All cut                | 95                   |

2.2. Research methods

2.2.1. Basic data collection. Field survey this study adopted the method of setting a standard site to collect data, and conducted a field survey from Sep-2017 to Aug-2019. Set up standard plots in the typical sections of three forest types in the primary forest, gradually felled forest and clear-cut forest in the Ledum-Larixgmelinii forest in the study area. Set 6 repetitions for each forest type, for a total of 18 standard plots. They are 50m × 40m and 50m × 40m respectively. Collect data to analyze and summarize the current status of relevant theories and methods, clarify the research content, determine the evaluation index system construction principles, evaluation indicators, construct the principal component analysis of the Ledum-Larixgmelinii forest health evaluation index system, determine the Ledum-Larixgmelinii forest health level Standard evaluation.

2.2.2. Ledum-Larixgmelinii Larch Forest Health Survey. Set five 1.0m×1.0m herb plots in each standard area uniformly, and investigate and record the types, quantity, and coverage of herbs in detail;
one 1m×1m shall be arranged in the four corners and the centre of each standard area. The litter collection baskets are put in the basket from the beginning of August 2008, the collection time is: early October, early April, early June, early August, weigh the collected litter every time, weigh it after drying dry weight; forest age structure survey: within each standard area, use the growth cone to take the core of the standard wood of each diameter step to investigate the proportion of near, mature and over mature forests; soil layer and humus survey: within each standard area measure and record the thickness of the humus and the thickness of the soil layer on the four sides (in Tab. 1).

2.2.3. Standardization methods of indicators. The dimensionless method of quantitative indicators is the standardization and normalization of data. It is a method to eliminate the dimensional influence between the original variables through mathematical transformation. The quantification of indicators includes the quantification of positive indicators and the quantification of reverse indicators. A positive indicator indicates that the increase in the value of the indicator will have a positive effect on the evaluation calculation result; a reverse indicator indicates that the increase in the value of the indicator will reverse the evaluation result effect [5]. A commonly used quantization formula for forward and reverse indicators is as follows:

\[
\text{Calculation formula of positive index: } X_{sv} = \frac{X_i}{X_{\text{max}}} \\
\text{Reverse index of calculation formula: } X_{sv} = \frac{X_i}{X_{\text{max}}}
\]

Note: \(X_{sv}\) is the normalized index value, \(X_i\) is the selected index value, and \(X_{\text{max}}\) is the maximum value among similar indicators.

2.2.4. Principal component analysis. Create a matrix based on the number of samples \(a\) (that is, quasi-land number) and the number of indicators \(b\) and the value of each index, calculate the correlation matrix through this matrix, and obtain the Eigenvalues of the samples based on the correlation matrix \(\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_p > 0\) and the corresponding unit feature vector \([e_1, e_2, \ldots, e_p]\), then the variable \(F_j\) is called the \(j\)th principal component of the index variable \(X\):

\[
F_j = e_j^T X_{sv} \quad j = 1, 2, 3, \ldots, p
\]

According to the calculated feature roots and feature vectors, the selected indicators and indicator weights are determined and an evaluation model is constructed (in Tab. 2).

| Standard       | Volume (m³/hm²) | Annual accumulation (kg/hm²) | Forest average height(m) |
|----------------|----------------|------------------------------|--------------------------|
| Thinning 1     | 102.3          | 3154.34                      | 11.23                    |
| Thinning 2     | 123.5          | 2344.28                      | 9.42                     |
| Thinning 3     | 156.3          | 3525.86                      | 10.54                    |
| Thinning 4     | 135.6          | 2897.35                      | 9.26                     |
| Thinning 5     | 137.8          | 3280.48                      | 8.78                     |
| Thinning 6     | 129.4          | 2678.27                      | 10.25                    |
| Clear-cut 1    | 49.4           | 2789.53                      | 7.52                     |
| Clear-cut 2    | 48.6           | 2954.32                      | 7.63                     |
| Thinning 3     | 52.1           | 2835.62                      | 7.78                     |
| Clear-cut 4    | 39.4           | 2756.35                      | 8.36                     |
| Clear-cut 5    | 38.7           | 2452.52                      | 9.78                     |
| Clear-cut 6    | 45.0           | 2835.47                      | 7.35                     |
| Original 1     | 209.6          | 3986.73                      | 10.67                    |
| Original 2     | 231.9          | 3875.23                      | 18.34                    |
| Original 3     | 178.4          | 3587.43                      | 16.24                    |
| Original 4     | 167.4          | 3785.76                      | 15.67                    |
| Original 5     | 154.2          | 3578.37                      | 18.36                    |
| Original 6     | 109.6          | 3859.28                      | 20.45                    |

3. Results and discussion

3.1. Forest productivity indicators

Tab. 2 Plant productivity indicators of each standard plot
The productivity index of the forest can reflect its vitality, and vitality is the energy input and nutrient cycling capacity of the ecosystem, it is an important aspect to evaluate the health of the forest ecosystem. Productivity is usually expressed by the amount of organic matter produced by plants per unit area per unit time, and can also be expressed by the amount of carbon or thermal capacity. For a forest stand, the strength of productivity reflects the strength of the forest's ability to grow and is an important indicator of forest health. Three indicators were selected to reflect the level of stand productivity, such as unit volume, annual litter amount, and average stand height. Stock volume measurement unit area stock volume is an important factor that reflects stand productivity. A high unit area stock volume indicates high stand productivity. The calculation method of the total stock volume is: select the standard wood in the plot, the stock volume of the standard wood can be calculated according to the latest international calculation formula:

\[ V = 0.6\pi r^2 h \]  
\[ V = V \times n \]

Note: \( V \) is the accumulation of each tree; 0.6 is the calculation constant of each tree; \( \pi \) is the \( \pi \); \( r \) is the radius of the standard wood; \( h \) is the height of the standard wood; \( n \) is the total number of trees in the standard ground.

Determination of annual litter amount forest litter refers to the general term for all organic substances that are produced by biological components in the forest ecosystem and then returned to the surface of the woodland as the material and energy source of the decompose to maintain the ecosystem function. Forest litter is an important part of the forest ecosystem and plays an important role in nutrient cycling. Studies have shown that the nutrients released annually during the decomposition of plant litter can meet 69% to 87% of the growth of forest organisms. Therefore, the amount of litter means the amount of nutrients produced, which reflects the vitality of the forest ecosystem. During the measurement, the litter collected within one year in each plot is weighed after drying in an oven, and then the dry weight per hectare is calculated; the average height of the forest stands the height of the forest tree is an important indicator that reflects the growth of the forest tree and is also an assessment. An important basis for the quality of forest stand sites. The average stand height refers to the height of the tree corresponding to the average stand diameter.

3.2. Soil nutrient indicators

Soil is the most basic resource of the forest ecosystem and the basis on which forest plants grow. It can provide the necessary mineral elements, moisture, air and microorganisms for plant growth, has a mechanical support for the root system, and is also a place for the exchange of substances and energy in the ecosystem. Soil conditions directly affect the growth and development of plants, affect species competition and species richness among plant communities, and then affect the distribution pattern of plant species within communities. It plays an important role in soil fertility and provides rich nutrients for the growth and reproduction of forest plants. In addition, the water absorption rate of humus can reach 500-600%, and it has a good ability to maintain soil moisture. It plays an important role in the nutrient cycling of mountain forest ecosystems, the formation and maintenance of diversity patterns of canopy epiphytes and so on. Therefore, the appropriate thickness of humus is also one of the important conditions for the healthy growth of forest plants. The average thickness of the four sides surveyed in the standard land is the thickness of the humus in the standard land. Soil layer thickness refers to the vertical depth from the soil parent layer to the soil surface. The thickness of the soil layer is the main limiting factor for vegetation growth. Above-ground biomass and vegetation coverage at different thicknesses are different. The thickness of the soil layer limits the depth of the plant root system and affects the plant's absorption of deep soil moisture. The thickness of the soil layer directly determines the soil's water retention and water holding capacity. In a forest, the thickness of the soil layer has a great influence on the forest productivity. The survey data of the soil nutrient index survey data in each standard area is calculated (in Tab.3).
| Standard | Humus thickness (m) | Soil thickness (m) | Standard | Humus thickness (m) | Soil thickness (m) |
|----------|--------------------|-------------------|----------|--------------------|-------------------|
| Thinning 1 | 0.10               | 0.443             | Clear-cut | 0.09               | 0.342             |
| Thinning 2 | 0.12               | 0.356             | Clear-cut | 0.08               | 0.321             |
| Thinning 3 | 0.11               | 0.364             | Clear-cut | 0.09               | 0.238             |
| Thinning 4 | 0.10               | 0.432             | Original  | 0.14               | 0.454             |
| Thinning 5 | 0.13               | 0.362             | Original  | 0.19               | 0.489             |
| Thinning 6 | 0.15               | 0.334             | Original  | 0.16               | 0.501             |
| Clear-cut 1 | 0.07               | 0.345             | Original  | 0.18               | 0.533             |
| Clear-cut 2 | 0.08               | 0.367             | Original  | 0.19               | 0.457             |
| Thinning 3 | 0.06               | 0.352             | Original  | 0.17               | 0.447             |

3.3. Plant diversity
This article uses the Simpson index and richness index to illustrate the level of plant diversity. Species Simpson Index; since Ledum-Larixgmelinii forests are mostly pure forests, this article only investigates the species diversity of shrubs and herbs. Biodiversity is one of the necessary conditions for measuring the integrity, stability and sustainable management and development of forest resources. Forests with poor biodiversity are structurally incomplete and have poor stability, which is extremely vulnerable to external damage. The system is broken or crashed. In this study, simposn index and richness index were selected to represent plant species diversity. The Simpson index is one of the indexes widely used to measure species diversity in the community. It can accurately reflect the distribution of patchy forest vegetation, and it is sensitive to rare species.

4. Conclusions
This study considers the indicators of soil physical properties before the investigation, resulting in insufficient selection of indicators, so that the constructed health evaluation indicator system has certain deficiencies. For example, the indicators of soil nutrients should be more comprehensive and specific, so this study needs to be selected. Comprehensive indicators, establish a perfect indicator system, and conduct further research. Due to the lack of perennial monitoring data, this article fails to evaluate the changes and trends in forest health status on a time scale. Accumulating years of continuous health evaluation data can more accurately reflect the development trend of forest health, and make targeted remedial measures for forest health. In the future, long-term health monitoring and health status prediction will be one of the follow-up studies in this paper. It is recommended to actively carry out forest protection, forest sustainable development propaganda and forest health management practical technology training based on local reality. When cutting forest resources, gradual cutting should not be used and clear cutting should not be used, and human disturbance activities should be controlled and guided to improve forest health and achieve sustainable forest development.

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