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Response of Pine Wilt Disease Spread Rate to Human Activities in the Three Gorges Reservoir Area (Postprint)

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Abstract

Pine wilt disease is a significant quarantine disease in China's forests. Beyond natural vector beetle transmission, human-mediated transmission plays a crucial role in its spread and proliferation. This study selected the Three Gorges Reservoir area, a key region for pine wilt disease occurrence in China, to investigate the landscape patterns of masson pine forests and the diffusion dynamics of pine wilt disease with human activity intensity as the primary factor, aiming to elucidate the disease's diffusion mechanism. Results indicated an increasing trend in the number of epidemic points in the Three Gorges Reservoir area in recent years, while incidence rates in various regions have been brought under certain control. In both epidemic and non-epidemic areas, the highest aggregation index of masson pine forest patches was observed in Dadukou (a non-epidemic area) at 98.6406, while the highest patch isolation index was in Zigui (a non-epidemic area) at 0.9318. Analysis of variance revealed no significant correlation between masson pine forest landscape patterns and pine wilt disease. Further investigation into the relationship between pine wilt disease and human activity intensity demonstrated that disease incidence exhibits strong correlations with regional road network density and total population, but weak correlations with regional GDP and freight turnover. In Yichang, the correlation coefficients between pine wilt disease incidence and road network density and total population were 0.985 and 0.866, respectively; in Chongqing, these values were 0.924 and 0.999, respectively. Additionally, based on road network density and total population, we projected the pine wilt disease epidemic in the Three Gorges Reservoir area over the next decade. The projections indicated that with expanding road network density and growing population, pine wilt disease incidence in Yichang will exhibit a gradual upward trend, with R^2 values of 0.919 and 0.637, respectively; Chongqing demonstrated a consistent pattern, with R^2 values of 0.976 and 0.992, respectively.

Full Text

Response of Pine Wood Nematode Disease Expansion Rate to Human Activities in the Three Gorges Reservoir Area

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Abstract: Pine wood nematode disease represents a major quarantine pest in China's forests. While natural transmission occurs through vector beetles (*Monochamus alternatus*), human-mediated dispersal plays a crucial role in the proliferation and spread of this disease. This study focused on the Three Gorges Reservoir Area, a key region for pine wood nematode outbreaks in China, to investigate the landscape patterns of *Pinus massoniana* forests and the diffusion dynamics of pine wood nematode disease, with human activity intensity as the primary factor, in an attempt to elucidate the underlying dispersal mechanisms.

The results revealed an increasing trend in the number of epidemic sites in the Three Gorges Reservoir Area in recent years, though incidence rates in various regions have been brought under control. The highest patch aggregation index (98.6406) for *P. massoniana* forests occurred in Dadukou, a non-epidemic area, while the highest division index (0.9318) was found in Zigui, also a non-epidemic area. Analysis of variance demonstrated no significant correlation between *P. massoniana* landscape patterns and pine wood nematode disease. Further investigation of the relationship between pine wood nematode disease and human activity intensity showed significant positive correlations between disease incidence and road network density (correlation coefficient: 0.985) and total population (correlation coefficient: 0.866) in Yichang. In Chongqing, the correlation coefficients were 0.924 for road network density and 0.999 for total population, while correlations with GDP and freight turnover were weak.

Based on these relationships, we predicted the disease trend for the next decade using road network density and population data. The results indicated that as road network density and population continue to expand, pine wood nematode disease in Yichang will show a gradually increasing trend, with R^2 values of 0.919 and 0.637 respectively. The trend is more pronounced in Chongqing, with R^2 values of 0.976 and 0.992 respectively, suggesting a steady increase in disease incidence.

Keywords: pine wood nematode; *Pinus massoniana* landscape pattern; human activities; road network density; total population; occurrence trend

Introduction

The gradual diffusion and invasion of pine wood nematode disease has become an undeniable reality in China's forests. The disease is transmitted through the vector beetle *Monochamus alternatus* during its feeding process, introducing the nematode into host trees and causing wilting and death within months. Currently designated as a major forest biological disaster in China, the disease has reached epidemic proportions with increasingly severe scope and impact. While numerous studies have focused on the disease and its vector insect, control efforts have proven ineffective, with the affected area expanding annually. Human-mediated indirect transmission is considered a critical mechanism for long-distance dispersal, as infected wood products move through human activity corridors. Economic development levels significantly influence disease diffusion, making the study of human activity factors essential for effective control.

Landscape-level research on forest pest invasion and diffusion, and its relationship with landscape patterns, has gained increasing attention from scholars as a means to reveal causal mechanisms and develop new control strategies. Corridors and matrix are important landscape components, with corridors serving as the only elements that connect and facilitate dispersal in landscapes, playing significant ecological roles. With rapid urbanization intensifying conflicts between ecological resources and environmental problems, land use pattern transformations have become frequent, drawing growing attention to corridor functions. Corridors have dual functions: they can act as ecological barriers that block biological and energy flows between sides, while also connecting patches and promoting energy and biological flows between them. The ecological functions of corridors are closely related to their scale, structure, and pattern. Corridors can be categorized as natural (e.g., rivers) or artificial (e.g., roads and hedgerows). Given that pine wood nematode disease spread is heavily influenced by human activities, studying corridor spatial patterns is crucial for understanding transmission dynamics and developing control measures. This research takes the Three Gorges Reservoir Area as a case study to examine the relationship between corridor spatial patterns and pine wood nematode disease, providing theoretical support for landscape-scale research and control.

1. Study Area Overview

The Three Gorges Reservoir Area extends from Yichang in Hubei Province in the east to Jiangjin in Sichuan Province in the west, covering approximately 2 million hectares between 106°-110°50 E and 29°16'-31°25' N. The region includes Badong, Zigui, and Yubei, Changshou, Wuxi in Chongqing, characterized as an intraplate uplift erosion middle-low mountain landform zone. Situated on China's second topographic step, the area has high terrain in the west and low

in the east, with the Yangtze River as the main waterway. Valley plains account for 4.3% of the total area. The reservoir area lies on the northern edge of the subtropical zone, with an average annual temperature of 17-19°C and annual precipitation of 1000-1250 mm. The current vegetation is dominated by coniferous forests (21.7%), coniferous-broadleaf mixed forests, deciduous broadleaf forests, shrubs, and grassland degradation ecosystems. The primary coniferous species is *Pinus massoniana*, commonly mixed with *P. massoniana* in coniferous-broadleaf forests.

2. Data Sources and Methods

2.1 Data Sources

Pine wood nematode disease damage data were obtained from the Hubei Provincial Forest Pest Control and Quarantine Station and Chongqing Academy of Forestry. Since Yichang City confirmed its first epidemic site in 2003, the study period spans 2003-2015. As the disease specifically damages *P. massoniana* forests, all statistics and analyses reflect disease conditions through damage to these forests, including damaged area and tree numbers. Vector data were sourced from the Hubei Provincial Forestry Survey and Planning Institute and the Chinese Academy of Sciences Resource and Environmental Science Data Center, including national *P. massoniana* forest distribution data. National economic data and road mileage statistics were obtained from Yichang and Chongqing Statistical Yearbooks for 2006-2015.

2.2 Analysis Methods

Based on historical epidemic site distribution in the Three Gorges Reservoir Area, the region was divided into eastern (Yichang section) and western (Chongqing section) segments. Badong County, with minimal disease occurrence, was excluded from this study. Statistics were compiled at the county/district level. Using ArcGIS software, epidemic site distributions were mapped at large scales for 2006, 2010, and 2015, with township-level mapping providing finer-scale description of disease conditions. The incidence rate was calculated as the ratio of actual damaged area to total pine forest area within each unit. The study area was divided into epidemic and non-epidemic regions based on 2015 announcements from the State Forestry Administration. Epidemic areas included Xiaoting, Wanzhou, and Fuling, while non-epidemic areas included Wujia, Yichang City proper, and others.

Landscape pattern differences were analyzed at the township scale using Fragstats software. *P. massoniana* forest patches were converted to vector data to calculate area (CA), number of patches (NP), patch density (PD), landscape shape index (LSI), division index (Division), and aggregation index (AI). One-way ANOVA was used to compare differences between epidemic and non-epidemic areas. Human activity intensity was characterized using road network density, population density, and freight volume to reflect changes in

human activity intensity over the past decade. Factor analysis and principal component analysis identified the most influential factors affecting pine wood nematode disease, and prediction models were developed to assess future disease trends.

3. Results

3.1 Expansion Trend of Pine Wood Nematode Disease in the Reservoir Area

The spatial distribution patterns of epidemic sites across three periods (2006, 2010, 2015) are shown in [Figure 1: see original paper]. The maps reveal that Yichang City eradicated epidemic sites in Zigui County, while Chongqing showed no clear county-level invasion. By 2015, Yichang had effectively controlled outbreaks in Dianjun and Xiaoting districts, whereas Chongqing added one new epidemic site. Epidemic sites were primarily distributed along the Yangtze River, posing significant threats to ecological security on both banks. The region's rugged, hilly terrain makes it prone to geological disasters like landslides once forests are damaged.

At the township level, the number of epidemic townships in Yichang increased from 3 in 2006 to 13 in 2015, peaking at 15 in 2010. Chongqing showed greater fluctuation, with epidemic townships increasing from 5 to 11 during the same period. In terms of damage rates, Yichang exhibited a decreasing trend, from a maximum of 0.5450% in 2006 to a minimum of 0.0268% in 2015, excluding the initial discovery year of 2003. Chongqing showed a pattern of initial decrease followed by marked increase, with rates rising from 0.2911% in 2006 to 0.4114% in 2015.

3.2 Landscape Patterns in Epidemic and Non-epidemic Areas

Comparisons of *P. massoniana* forest landscape patterns between epidemic and non-epidemic areas at the same administrative scale are presented in [Figure 2: see original paper], [Figure 3: see original paper], and . The largest forest area was in Dangyang (68,261 ha), while the smallest was in Wujiagang (615 ha). The highest number of patches occurred in Shizhu, and the lowest in Xiling (1 patch). Patch density was highest in Yichang's urban district (1.5515 km/km²) and lowest in Changshou (0.0268 km/km²). The division index was highest in Zigui (0.9318), while the landscape shape index was highest in Shizhu (8.8032). The aggregation index reached its maximum in Dadukou (98.6406).

One-way ANOVA results showed no significant differences between epidemic and non-epidemic areas for any landscape metrics: patch area ($F = 2.38901$, $P = 0.13476$), patch density ($F = 1.23841$, $P = 0.27636$), number of patches ($F = 2.8537$, $P = 0.09616$), landscape shape index ($F = 2.8629$, $P = 0.09865$), division index ($F = 1.5065$, $P = 0.22684$), and aggregation index ($F = 2.38901$, $P = 0.13476$).

3.3 Human Activity Intensity and Principal Component Analysis

Selected indicators of human activity intensity (road network density, total population, and freight volume) for Yichang and Chongqing showed consistent increases from 2006-2015, with more pronounced growth in Chongqing. Road network density increased in both cities, from 1.1845 km/km² to 1.3632 km/km² in Yichang, and from 1.2172 km/km² to 1.5515 km/km² in Chongqing. Population totals remained relatively stable in Yichang but increased in Chongqing. Freight turnover showed substantial growth, particularly in Chongqing (from 51.04 to 2783.04 t/km).

Factor analysis revealed strong correlations between disease incidence and both road network density and population. In Yichang, the correlation matrix showed coefficients of 0.985 between incidence and road density, and 0.866 between incidence and population. The Kaiser-Meyer-Olkin measure confirmed sampling adequacy for factor analysis. Principal component analysis extracted two components with eigenvalues >1, explaining 96.748% of variance, with road network density and population as the primary factors.

In Chongqing, correlation coefficients were 0.924 for road density and 0.999 for population. The analysis similarly confirmed these as representative factors, with two components explaining 98.474% of variance.

3.4 Disease Prediction Models

Based on the strong correlations identified, prediction models for the next decade were developed using road network density and population trends. Expert modeler analysis determined that exponential smoothing with linear trends provided the best fit. In Yichang, the model showed increasing disease incidence with R² values of 0.919 for road density and 0.637 for population. In Chongqing, the trend was more severe, with R² values of 0.976 for road density and 0.992 for population, indicating a strong linear increase in disease risk as human activity intensifies [Figure 5: see original paper], [Figure 6: see original paper].

4. Discussion

4.1 Masson Pine Landscape Patterns and Disease Occurrence

Pine wood nematode is an extremely important invasive forest pest in China, causing irreversible damage to pine resources. While landscape ecology theory offers important practical significance for control efforts, and *P. massoniana* is the primary host, this study demonstrates that landscape patterns alone do not directly determine disease epidemics. No significant correlation was found between *P. massoniana* forest spatial patterns and disease occurrence, suggesting that human activity factors or regional landscape characteristics are more influential. However, since the disease depends entirely on host distribution, further research on the relationship between forest component structure and disease at the landscape level is warranted.

4.2 Economic Development and Disease Occurrence

While previous studies have examined relationships between pine wood nematode disease and landscape patterns, few have quantified human activity intensity. This research establishes clear positive correlations between disease incidence and both road network density and population totals. Increased societal demands have driven road network expansion and denser planning, facilitating more frequent inter-regional connections and inadvertently increasing passive disease transmission probabilities. Major infrastructure projects like the Yichang-Xiangyang Expressway and secondary road upgrades in the Three Gorges region will likely intensify environmental and ecological impacts.

Increased road density also reflects heightened habitat patch isolation. According to percolation theory, habitat isolation effects exhibit critical threshold phenomena where ecological impacts suddenly intensify beyond certain levels. However, contrary to expectations that increased isolation might reduce disease spread, pine wood nematode shows no decreasing trend, likely because its vector beetle's dispersal capabilities also respond to isolation thresholds.

4.3 Population Pressure and Disease Occurrence

Both Yichang and Chongqing showed stable or slightly increasing population trends during the study period. Population growth intensifies production and living pressures on resources and environments, leading to more diverse and complex human landscapes. Human landscapes represent fundamental units for studying landscape ecology and human interactions, with population size reflecting dependence on natural resources. Larger populations create greater demand for resources and environmental space, inevitably increasing human-modified landscapes. Studying these landscapes helps clarify relationships between natural resource changes and human society, particularly regarding how spatial heterogeneity of natural resources influences socioeconomic development.

4.4 Conclusions

This study in the Three Gorges Reservoir Area examined relationships between three human activity indicators (road network density, population density, and freight volume) and pine wood nematode disease diffusion. Results show significant positive correlations between disease incidence and both road network density and population totals, with correlation coefficients of 0.985 and 0.866 in Yichang, and 0.924 and 0.999 in Chongqing. Linear trend models based on these factors predict continued disease increase over the next decade, with R^2 values of 0.919 and 0.637 for Yichang, and 0.976 and 0.992 for Chongqing. The findings indicate that pine wood nematode disease will continue its gradual expansion in both regions, with the trend being more severe in Chongqing.

References

- [1] Chinese Forest Insects. China Forestry Publishing House, 1992: 3-91.
- [2] Pine Wood Nematode Disease. China Forestry Publishing House, 2003: 77-80.
- [3] Preliminary study on the mechanism of new epidemic sites of pine wood nematode disease. *Journal of Zhejiang Forestry College*, 1999, 16(4): 425-429.
- [4] National Key Basic Research Program: Mechanisms and control of major disasters in plantation forests—pine wood nematode invasion population formation and expansion mechanisms. *Scientia Silvae Sinicae*, 2009, 39(4): 333-341.
- [5] Robinet C, Roques A, Pan HY, Fang GF, Ye JR, Zhang YZ, Sun JH. Role of human-mediated dispersal in the spread of the pinewood nematode in China. *PLoS One*, 2009, 4(2): e4646.
- [6] Scale and Hierarchy: Landscape Ecology. Higher Education Press, 2001: 219-228.
- [7] Forman RTT, Godron M. Patches and structural components for a landscape ecology. *BioScience*, 1981, 31(10): 733-740.
- [8] Ecological control technologies and measures for forest pests. *Forest Pest and Disease*, 2004, 23(6): 1-8.
- [9] Ecological significance and application of landscape connectivity. *Chinese Journal of Ecology*, 1996, (4): 37-42, 73-73.
- [10] Turner MG. Landscape ecology: The effect of pattern on process. *Annual Review of Ecology, Evolution, and Systematics*, 1989, 20(1): 171-197.
- [11] Road impacts on landscapes and ecological risk assessment: A case study of Lancang River Basin. *Chinese Journal of Ecology*, 2005, 24(8): 897-901.
- [12] Simulation of landscape fragmentation effects on main prey population dynamics of Amur tigers. *Acta Ecologica Sinica*, 2010, 30(1): 15-23.
- [13] Nicholls CI, Parrella M, Altieri MA. The effects of a vegetational corridor on the abundance and dispersal of insect biodiversity within a northern California organic vineyard. *Landscape Ecology*, 2001, 16(2): 133-146.
- [14] Risk assessment and countermeasures for pine wood nematode disease in China. Science Press, 2011: 188-198.
- [15] Analysis of human activity impacts on landscape structure in the Yellow River Delta: A case study of Dongying City, Shandong Province. *Acta Ecologica Sinica*, 1996, 16(4): 337-344.
- [16] Study on degraded ecosystems in China. Yangtze River Press, 2013: 3-10.
- [17] ArcGIS Geographic Information System Spatial Analysis Experimental Tutorial. Science Press, 2012: 16-527.
- [18] Quantitative Methods in Landscape Ecology. Springer-Verlag, 1995: 61-93.
- [19] Kirkpatrick LA, Feeney BC. A Simple Guide to IBM SPSS Statistics for Version 20.0. 13th edition. Cambridge: Wadsworth Publishing, 2012: 5-50.
- [20] Landscape pathology: A new perspective in forest protection. *Scientia Silvae Sinicae*, 2010, 46(3): 139-145.
- [21] Coniferous forest landscape pattern and risk analysis: A case study of *Pinus massoniana* forest in Yidu. *Forestry Science and Technology Development*, 2014, 28(4): 26-29.

- [22] Analysis of green corridor landscape composition and pattern in Jiaozuo City. *Bulletin of Soil and Water Conservation*, 2013, 33(2): 291-295.
- [23] Spatial distribution of human activities and its impact on landscape patterns in Daqing Mountain Nature Reserve. *Chinese Journal of Applied Ecology*, 2014, 25(11): 3247-3254.
- [24] Gardner RH, O' Neill RV. Pattern, process, and predictability: The use of neutral models for landscape analysis. In: Turner MG, Gardner RH, eds. *Quantitative Methods in Landscape Ecology*. New York: Springer-Verlag, 1991: 289-307.
- [25] Wiens JA. Metapopulation dynamics and landscape ecology. In: Hanski IA, Gilpin ME, eds. *Metapopulation Biology: Ecology, Genetics, and Evolution*. San Diego: Academic Press, 1997: 43-62.
- [26] Wu JG. Landscape ecology, cross-disciplinary, and sustainability science. *Landscape Ecology*, 2006, 21(1): 1-4.

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