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Prediction and early Warning of Lightning-induced fire in Dead Standing Trees based on Geovisualisation Analysis: A case Study of Bozhou, Xinjiang, China

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Abstract:

With the intensification of global climate change, the frequency and intensity of forest wildfires continue to rise, posing one of the most significant challenges to the global environment. Current wildfire research primarily focuses on pre-disaster integrated air-ground early warning systems, real-time fire monitoring and command during disasters, and post-disaster damage assessment and ecological restoration. However, in specific localized regions such as the Bozhou Natural Forest Area in Xinjiang, China, Lightning-induced fires in dead standing trees—a major natural fire type—exhibit distinct mechanisms that differ significantly from other wildfires. Lightning strikes are identified as the primary trigger for such fires, highlighting the critical importance of predictive and preventive research on lightning-induced wildfires. By integrating lightning monitoring with surveys of dead standing tree combustibles and other technical approaches, combined with visual analysis, effective early warning, prediction, and prevention of lightning-induced fires can be achieved.

Based on this premise, this study aims to predict and prevent lightning-induced fires in dead standing trees within the Bozhou Natural Forest Area of Xinjiang, China, by employing geographic visual analysis methods to integrate multi-source data, including lightning location data, dead standing tree combustible material data, meteorological data, and forest resources. This approach provides scientific foundations and technical support for wildfire early warning and monitoring. Utilizing geographic visual analysis techniques, we conducted spatial overlay analysis and heatmap modeling to comprehensively assess the interactions among lightning activity, dead standing tree distribution, and meteorological conditions, thereby identifying potential high-risk fire zones. Additionally, historical Lightning-induced fire monitoring data were incorporated to validate the accuracy of lightning-induced fire warnings using machine learning algorithms.

The results demonstrate that visual analysis integrating lightning location data with dead standing tree combustible data can effectively predict high-risk areas for lightning-induced fires, significantly enhancing prediction reliability. We also statistically analyzed and visualized the occurrence of lightning-induced fires in high-frequency fire zones before and after the installation of lightning protection facilities, using lightning monitoring data. By comparing changes in fire frequency, we evaluated whether existing lightning protection infrastructure effectively reduces lightning-induced fire incidents. Our findings indicate that current facilities have mitigated fire occurrences to some extent, though their effectiveness varies due to terrain constraints and coverage limitations.

The multi-source data fusion and geographic visual analysis methodology proposed in this study not only significantly improves the predictive and early warning capabilities for lightning-induced fires in the Bozhou Natural Forest Area but also offers innovative technical solutions with potential applications in wildfire prevention for similar regions. However, the regional specificity of data and implementation constraints limit the method's applicability across diverse environments and its feasibility for large-scale deployment. Future research should explore the integration of additional data sources and optimized analytical techniques to further enhance overall fire prevention effectiveness.

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Figure 1 Data display interface

Figure 2 Cumulative hazard analysis interface

Figure 3 Lightning protection equipment effectiveness analysis system

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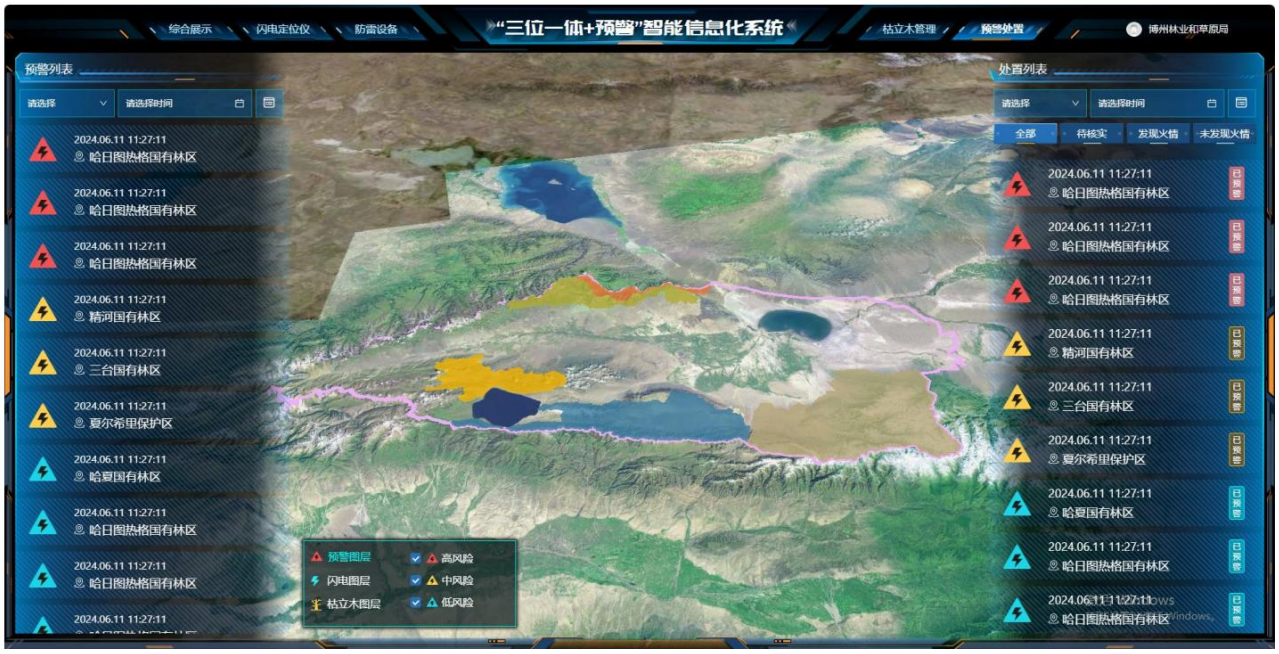

Figure 4 Lightning warning system

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