基于时空精细化及栅格测度的林火蔓延模拟研究

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摘 要:【目的】根据火场参数及自然地理环境条件，精确模拟林火蔓延趋势，为火灾扑救指挥决策提供科基础。【方法】以云南省 2006 年安宁“3.29”火场为对象，分析影响林火蔓延的驱动因子并作 GIS 时空精细化和栅格模拟，基于元胞自动机理论，结合王正非和毛贤敏修正的林火蔓延模型，借助 MATLAB 计算机模拟，实现对林火蔓延时空动态可视化，并比对历史真实火场档案，进行精度评估。【结果】（1）以机理分析风速驱动因子表明风速与海拔成正相关，而与坡度、地形起伏度、地表粗糙度及地表温度呈负相关。构建的 30m 尺度的风速场与 1km 尺度相比，宏观格局一致，但细节更丰富，火灾当日平均最大风速为 1.91 m/s，最小为 0.53 m/s。（2）采用辐射传输模型反演的 30m 尺度地表温度，平均绝对误差 MAE 为 2.91℃，较 MODIS 温度产品小 0.35℃，而均方误 MSE 差值为 4.63℃，较 MODIS 温度产品小 5.24℃。火灾当日平均最高地表温度为 69.87℃，最低为 0.03℃。（3）根据当日最高气温，平均风速及最小湿度，确定初始蔓延速度为 0.64（m/min），结合地理条件、气象因子及可燃物分布模拟火场蔓延态势，火势向上坡方向蔓延速度较快，过火面积为 21.57 km^2，周长为 20.32 km，精度达 84.34%。【结论】综合宏观气象条件及微观地表特征，借助 GIS 空间建模及遥感反演，可进行林火蔓延驱动因子的时空精细化刻划，实现更为精准的林火蔓延模拟。研究对于火灾科学防控，减少林火损失具有重要理论及实践意义。

关键词:林火蔓延，元胞自动机，时空精细化，风速场

Simulation of Forest Fire Spread Based on Spatial and Temporal Refinement and raster metrics

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Abstract:【Objective】Based on the parameters of the fire site and the natural geographical environment conditions, forest fire trend was simulated accurately aimed at providing a scientific basis for fire rescue command decision-making.【Method】Taking the Anning "3.29" fire site in 2006 of Yunnan Province as an example, the driving factors affecting the forest fire spread were analyzed, and GIS spatio-temporal refinement and grid simulation were conducted. Based on the cellular Automata theory, combined with the forest fire spread model revised by Wang Zhengfei and Mao Xianmin, with the assist of MATLAB computer simulation, the spatio-temporal dynamic visualization of forest fire spread was realized, and the accuracy was evaluated by comparing the historical real fire site archives.【Result】(1) Mechanism analysis of wind speed driving factors indicates that wind speed is positively correlated with altitude while negatively correlated with slope, terrain undulation, surface roughness, and surface temperature. The constructed wind speed field in 30m resolution show consistent in macro pattern compared to the 1km scale, but with more detailed features. The average maximum wind speed on the day of the fire was 1.91 m/s, while the minimum was 0.53 m/s. (2) The Mean absolute error (MAE) of the

30m scale surface temperature retrieved by the radiative transfer model is 2.91 ℃, [1]0.35 ℃ less than that of the MODIS temperature product, while the MSE difference is 4.63 ℃, 5.24 ℃ less than that of the MODIS temperature product. The average maximum surface temperature on the day of the fire was 69.87 ℃, with a minimum of 0.03 ℃. (3) Based on the highest temperature, average wind speed, and minimum humidity of the day, the initial spread speed was determined to be 0.64 (m/min). Combined with geographical conditions, meteorological factors, and combustible distribution, the fire spread rapidly uphill, with an area of 21.57 km2 and a circumference of 20.32 km, with an accuracy of 84.34%.【Conclusion】 By integrating macro meteorological conditions and micro surface features, and using GIS spatial modeling and remote sensing inversion, the spatio-temporal refinement of the driving factors of forest fire spread can be delineated, achieving more accurate simulation of forest fire spread. Research show theoretical and practical significance for scientific fire prevention and control, as well as reducing forest fire losses.

Key words: Forest fire spread, Cellular automata, Spatio-temporal refinement, Velocity field

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