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A GIS-based cellular automata model to simulate field-scale flaming and smouldering wildfires on peatlands

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Abstract

Peatland wildfires are the largest fires on Earth and comprise both flaming and smouldering types of combustion. Smouldering is flameless, slow, has relatively low temperature but is more persistent and releases more pollutants than flaming. The smouldering behaviour is strongly determined by fuel moisture content. The fuel of smouldering in peatland wildfires is mainly the organic soil (peat) underneath surface vegetation. In natural peatlands, the peat moisture content changes significantly over time because of seasonal variations that can be strengthened by anthropogenic activities. Research on smouldering wildfires is limited, especially at the field-scale, and have not explored the effect of the temporal variation of peat moisture content. This lack of research is mainly due to the complexity, spatial extent, data availability, and computational cost of wildfire models. For the first time, we developed a cellular automata model that includes transient peat moisture content information to simulate peatland wildfires. Cellular automata are discrete models that use simple and flexible rules to simulate complex phenomena while remaining computationally light. We consider both flaming and smouldering in our model to simulate a peatland wildfire in Borneo. Model input parameters were derived from GIS data of vegetation type and density, and temporal variation of peat moisture content was simulated using a peat-specific land surface model. Once validated with the data of burn scar caused by flaming wildfire (79% accuracy), the model is used to simulate the smouldering peat and estimated that in 90 days, the smouldering could burn 54.5 ha of peat. The smouldering burnt area grows exponentially with time in the regime of smouldering hotspot creation, followed by a quadratic increase in the subsequent spread regime. Simulations with a constant peat moisture content strongly underestimate the total smouldering burnt area (12.1 ha), emphasizing the importance of temporal variation of peat moisture content. Despite being four times shorter than spread regime, the creation regime is critical in determining the overall severity of smouldering wildfires. Additional model simulations over our study area, within and across years with contrasting Oceanic Niño Indices, showed that the peat smouldering burnt area ranges from 1.3 ha to 210 ha, depending on peat moisture content variations. The novel model improves understanding of the wildfire spread in peatlands and can contribute to efforts in mitigating carbon emissions and adversities of haze from smoldering peatlands through an improved management of fire regimes in the inhabited peat-rich landscapes.

Keywords: Peatland wildfires, smouldering, flaming, cellular automata, GIS

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