Investigating surface-to-crown fire transition: Impact of wind speed and Crown base height

Natural Hazards Research Australia

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Forest fires pose significant global risks, causing loss of life, property damage, and environmental harm. Predicting the condition necessary to cause transition of fires from surface to crown is critical in developing a clear forest management policy to combat the threats of wildfires. However, the transition depends on various factors like fuel types, terrain, and weather. This study utilizes a physics-based fire model to answer this research query by exploring how the impact of crown base height and wind speed have on the transition from surface fire to crown fire.

Methods

We used Fire Dynamics Simulator (FDS) 6.8 to simulate the fires shown in Figure 1. The surface fuel load was 5.4 kg/m² (pine needles), fixed fuel moisture content of 5%. Crown base height (CBH) took values 1 m, 5 m, and 10 m corresponding to tree heights of 12 m, 17 m, and 25 m, respectively. Wind speeds were varied between 3–10 m/s (10.8–36 km/h).

Results and Discussions

The crown mass loss rate increases with wind speed across all cases with a fixed (CBH). Stronger convective heat transfer and deeper flame penetration into the crown accelerates burning. We assume a sustained crown fire occurs when mass loss exceeds 80%. Losses between 65% and 80% represent intermediate crowning, while values below 65% indicate an incomplete transition.

Table 1. Crown mass loss for all cases

CBH10W3	CBH10W6	CBH10W8	CBH10W10
16.2 %	32.5 %	48.6 %	49.8 %
CBH5W3	CBH5W6	CBH5W8	CBH5W10
58.9 %	66.3 %	72.7 %	68.7 %
CBH1W3	CBH1W6	CBH1W8	CBH1W10
94.4 %	95.1 %	95.8 %	94.5 %

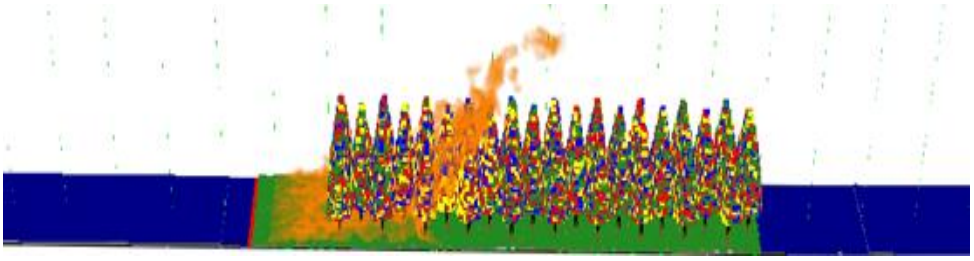
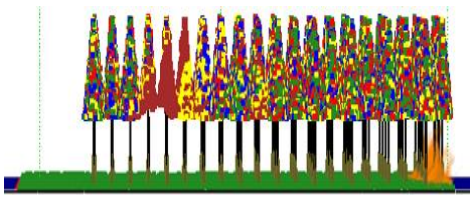
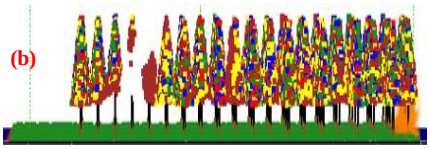


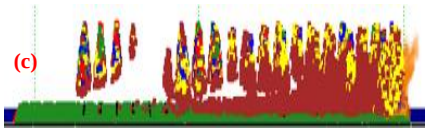
Fig. 1. Smokeview screenshot of the forest



(a)



(b)



(c)

Fig 2. Smokeview screenshots for (a) CHB10W6 (b) CBH5W6 (c) CBH1W6

As shown in Table 3, (CBH) and wind speed significantly affected crown mass loss. At CBH 10 m, crown mass loss increased with wind speed, but crowning was not sustained. Lowering CBH to 5 m led to higher mass loss, suggesting greater crowning potential. At CBH 1 m, crown mass loss exceeded 94% across wind speeds, indicating sustained crowning. Figure 3 presents Smokeview screenshots at the end of the simulation for three cases with 6 m/s wind speed across all simulated CBH values.

Conclusions

CBH strongly influences crowning probability, while wind speed has a greater effect at higher CBH but stabilizes at high speeds due to horizontal heat transfer. Simulations align well with the Cruz model in 9 of 12 cases. However, limitations such as fixed moisture and simplified forest structure highlight the need for future studies with varied moisture and fuel loads.

Further information
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