Physics based simulations of grassfire propagation on up-sloped terrain – A parametric study

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How significant is the effect of topographical feature (slope) of terrain on grassland fire behaviour?

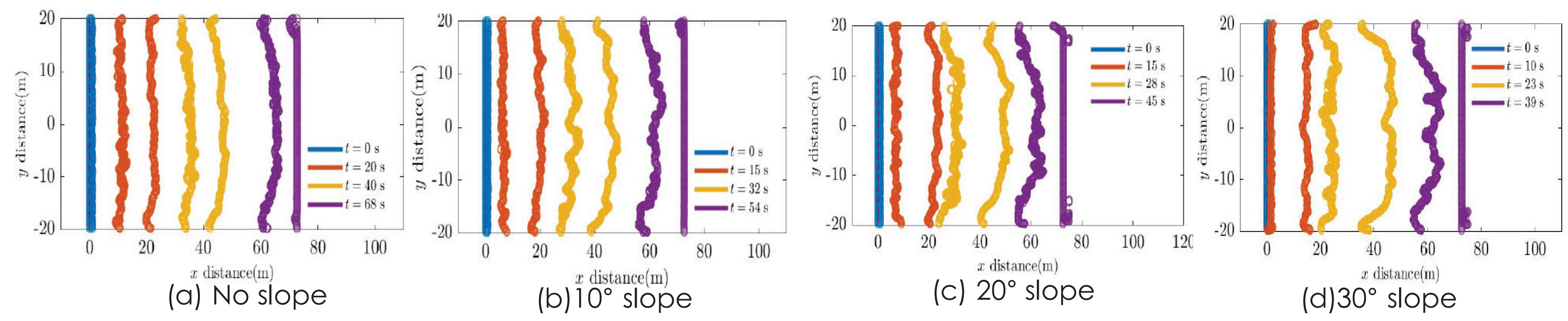
HIGHLIGHTS

- Rate of spread of fire and fire behaviour depends on various topographical, weather and fuel factors. Topographic feature such as slope can increase or decrease the rate of fire spread depending on whether the slope is upward or downward.
- Physics-based Fire Dynamics Simulation(FDS) model is used to conduct a set of simulations with constant wind speed and fuel conditions with varied slope angles.
- Rate of spread (*R*), head fire width, fire intensity, heat flux, flame length and plume attachment behaviour are analyzed and compared with widely used empirical models.
- This study aim to provide insight and improvement to current operational models and thus improve bushfire modelling approaches

MODEL SETUP

The simulation domain size is 360 m long x 120 m wide x60 m high. The burnable plot is 80 m long x 40 m wide x 60m high. Slope is implemented in the simulations by changing the magnitude of components of gravitational force in the x and z directions. Grid resolution (0.25x0.25x0.25m), fuel and thermo-physical parameters are selected following Moinuddin et al [3].

First set of simulations are conducted with slope angles 0°, 5°, 10°, 15°, 20°, 25° and 30° (upslope angles) at driving wind speed U_{10}= 12.5 ms^{-1}. To observe the plume behaviour at lower driving wind velocity, a second set of simulations are conducted with lower U_{10} of 3 ms^{-1}. Further simulations are to be conducted with down slope scenario to understand the effect of downslope on fire spread rate.



(a) No slope (b)10° slope (c) 20° slope (d)30° slope

Figure1: Progression of isochrones

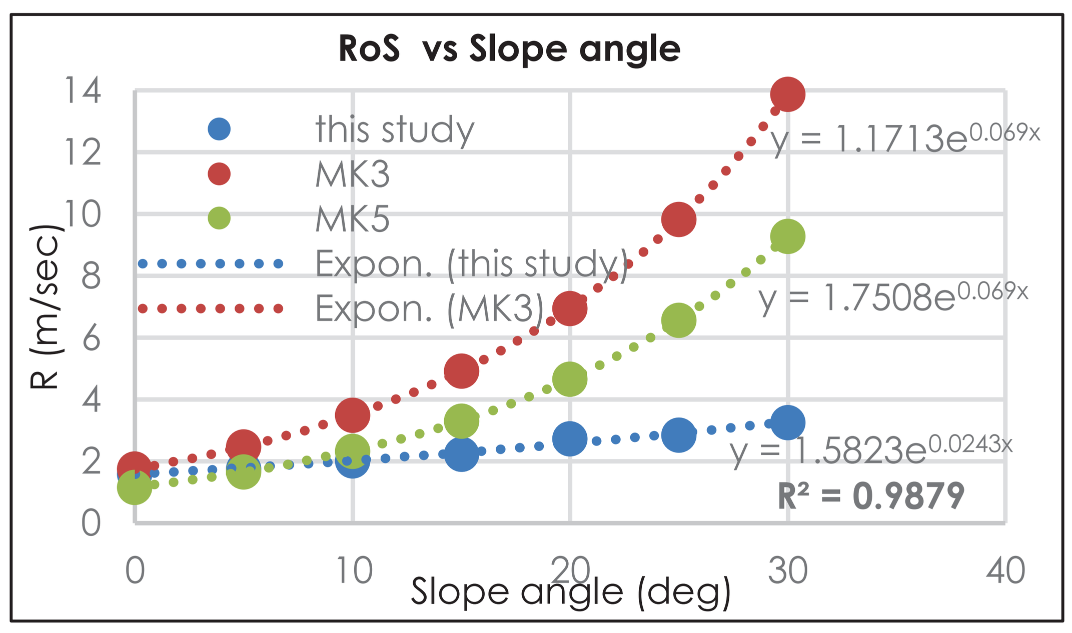


Figure 2: Rate of spread and slope angle correlation

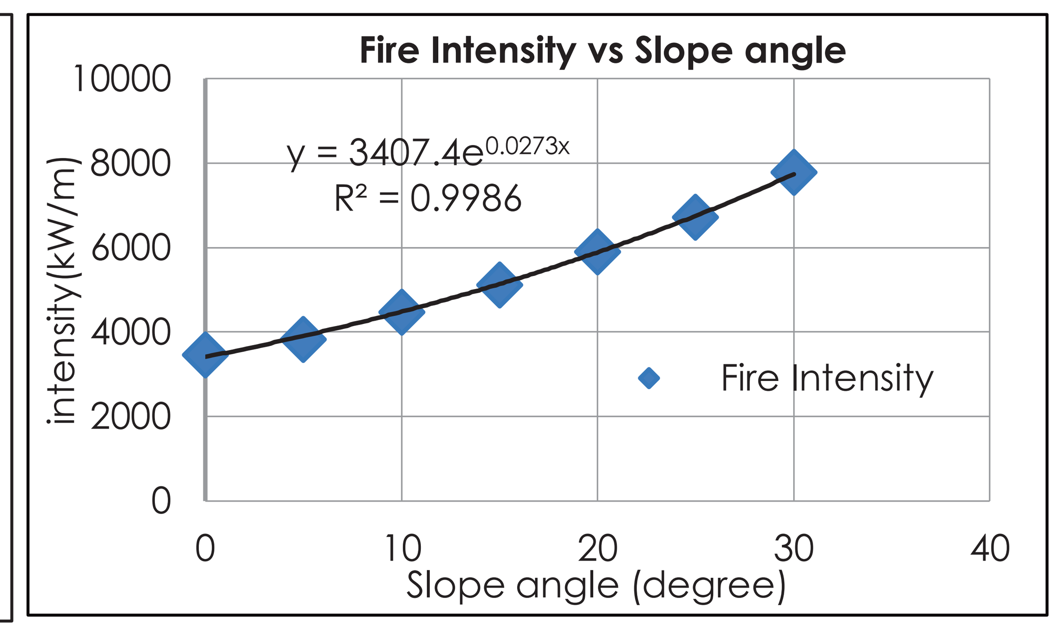


Figure 3: Fire Intensity verses slope angle

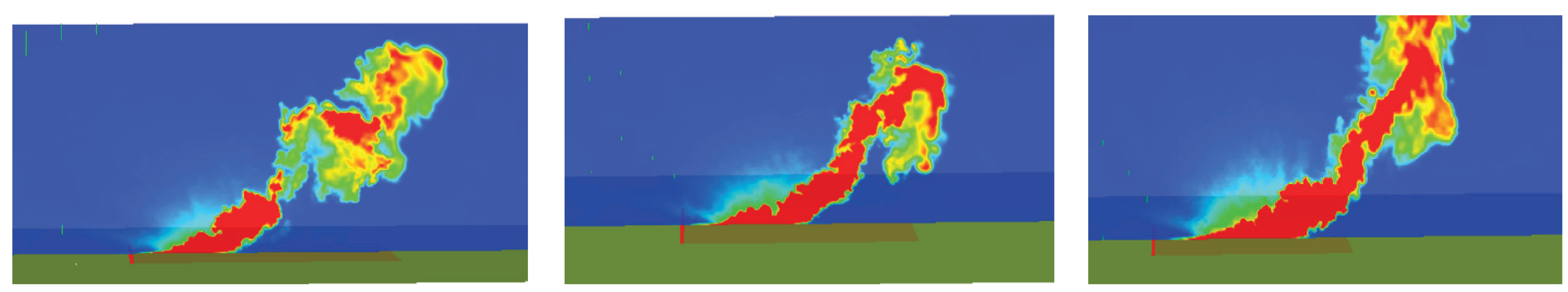


Figure 4: Plumes emanating from grass plot at 10°, 20°and 30° slope -wind velocity 3 ms^{-1}

RESULTS AND CONCLUSION

From the contour plots in figure 1, it is observed that as the slope angle increases firefront becomes wider and reaches the end of burnable grass plot much earlier. Pyrolysis width increases as the firefront progresses from the ignition line, then it plateaus (i.e. reaches a quasi-steady state) and finally decreases.

In figure 2, an exponential relationship between rate of spread (*R*) and slope angle is plotted with r^2 value is ~0.987. A linear fit to the same data results in r^2 value is ~0.97. *R* values obtained from this study are found to be closer to empirically derived MK5 values for slope angle up to 10°. From 15° to 30°, *R* values from this study are higher than MK5 model. The difference widens as the slope angle increases. *R* values with MK3 are found to be significantly higher than those obtained from this study. HRR, fireline intensity (shown in figure 3) and flame length are found to be having exponential-law relationships (r^2~ 0.99) with the slope angle.

From figure 4, results from U_{10} =3ms^{-1} simulations show that as the slope angle increases, the flame and plume becomes more attached to the terrain surface.

References:

[1] McArthur, A.G., *Weather and grassland fire behaviour*. 1966: Forestry and Timber Bureau, Department of national Development, Commonwealth
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[3] Moinuddin, K.A.M., D. Sutherland, and R. Mell, *Simulation study of grass fire using a physics-based model: striving towards numerical rigour and the effect of grass height on the rate-of-spread*. International Journal of Wildland Fire, 2018. 27(12): p. 800-814.

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