Fire Behavior Estimates

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Install 'firebehavioR' package, load library, and grab fuelMoisture dataset.

```
#install.packages('firebehavioR')
library(firebehavioR)
data(fuelMoisture)
```

Set working directory, then read in fuel models csv set up for the firebehavioR package. Fuel model csv can have any number of fuel models (i.e. plots) and header names are not important (expect the 'heat' column) as long as data is complete and in the correct units and order. See documentation for firebehavioR package for fuel model csv set up. I added plot name, slope, and total fuel load to my csv for use in my ROSIFL() function - order for my added columns is NOT important but should have the headers 'description' for plot name, 'slope' for slope, and 'totalLoad_g_m2' for the total fuel load.

```
plotFuelModels<- read.csv(file = 'plotFuelModels.csv')
```

Canopy fuel parameters to be used for grass fires (i.e. fuel beds without trees). The rothermel() function requires canopy fuels as an input but we use no function outputs dependent on the canopy fuels, so the values here are irrelevant.

```
rangeCrownFuel = data.frame(
  CBD = Inf, FMC = 100,
  CBH = Inf, CFL = Inf
)
```

Extract desired fuel moisture scenarios from firebehavioR 'fuelmoisture' dataset.

```
FM_inputs <- rbind(fuelMoisture['D1L1',], fuelMoisture['D1L2',],
                              fuelMoisture['D1L3',], fuelMoisture['D1L4',])
```

Name your fuel moisture scenarios

```
FM_inputs$name <- rbind('fullcure', 'two3rdcured', 'one3rdcured', 'uncured')
```

Create environmental dataframe. Slope (%) can be set to anything here, it is reset to the slope of the plot later on. [Open] windspeed (km/hr) is the 20-ft windspeed of your choice. A [wind] direction (from up slope) of 0 degrees yields most liberal estimation of fire behavior. Wind adjustment factor (waf) is a value between 0 and 1 and is used to adjust the wind speed measured 20-feet above the vegetation (i.e. 'open windspeed') to midflame windspeed. A WAF of 0.5 is recommended for unsheltered fuels (when surface fuels are not effectively sheltered from the wind, no to sparse overstory).

```r
fbEnviro <- data.frame(
  slope = 3,
  windspeed = 15,
  direction = 0,
  waf = 0.5)
```

Function that returns rate of spread (m/min and km/hr), fireline intensity (kW/m and BTU/ft), and flame length (m).

```r
ROSIFL <-function(FuelMoistures, FuelModels, CrownFuel, Enviro){
  outputs <- data.frame(FuelModels$description)
  inputs <- data.frame(FuelModels$description)
  inputs$heat_BTU_lb <- FuelModels$heat * 0.000947817 * 453.592
  inputs$load_lb_ft2 <- FuelModels$totalLoad_g_m2 / (453.592*10.7639)
  for (i in 1:nrow(FuelMoistures)){
    moisture <- FuelMoistures[i,]
    for (i in 1:nrow(FuelModels)){
      runFuelModel <- FuelModels[i,]
      Enviro$slope <- FuelModels$slope[i]
      outputs[[paste0("ros_", moisture$name)]][i] = rothermel(runFuelModel,
                                                              moisture,
                                                              CrownFuel,
                                                              Enviro)$fireBehavior[,3]
      inputs[[paste0("ros_ft_s_", moisture$name)]][i] <- (
        (outputs[[paste0("ros_", moisture$name)]][i])/60) * 3.28084
      outputs[[paste0("intensity_BTU_ft_", moisture$name)]] <- (
        inputs$heat_BTU_lb * inputs$load_lb_ft2 *(inputs[[paste0("ros_ft_s_", moisture$name)]]))
      inputs[[paste0("fl_ft_", moisture$name)]]<- 0.451 * (
        outputs[[paste0("intensity_BTU_ft_", moisture$name)]])^0.46
      outputs[[paste0("intensity_kW_m_", moisture$name)]] <- (
        (outputs[[paste0("intensity_BTU_ft_",moisture$name)]])*0.000293071)/0.3048
      outputs[[paste0("fl_m_", moisture$name)]] <- inputs[[
        paste0("fl_ft_", moisture$name)]] * 0.3048
      outputs[[paste0("ros_km_hr_", moisture$name)]]<- (
        outputs[[paste0("ros_", moisture$name)]] * 60) / 1000
    }
  }
  return (outputs)
}
```

Run ROSIFL function

```r
firebehavior_outputs <- ROSIFL(FM_inputs, plotFuelModels, rangeCrownFuel, fbEnviro)
```

Write outputs to a csv file

```r
write.csv(firebehavior_outputs, file = 'firebehavior_outputsrmd.csv')
```

NOTES

Rate of spread (ros) in the rothermel() function is computed using equations from Rothermel (1972).

Fireline intensity (J s^-1 m^-1): I = hwr (Byram 1959)

h = heat yield of fuel…

heat yield of grass = 16890 J/g (Trollope 1998)

heat yield of sagebrush = 18610 (Albini 1976), >19000(Qi et al. 2016)

w = weight of available fuel (g m^-2)

r = rate of spread (m s^-1) (Rothermel 1972)

Flame length (ft):

fl (ft) = 4.28(X1) + 0.00151(X2) - 2.92 (Rothermel 1972)

X1 = total fuel loading, lb/ft^2

X2 = average SAV ratio weighted by fuel surface area in each size class, ft^-1

OR

fl (ft) = 0.451 * I^0.46 (Byram 1959)

*** This is the equation used above ***

I = fireline intensity (BTU/ft)

Puckett et al. 1979 suggest wildfire with intensity <50BTU/ft/s & flame length <0.9m is easily attacked and controlled. Wildfire with intensity up to 100BTU/ft/s & flame length up to 1.2m is the limit for eased direct attack. Wildfire with intensity 500-700BTU/ft/s & flame length 2.4-2.7m are when spotting begins to be a problem and the limit of direct attack is reached.

Citations

Albini, F.A., 1976. Computer-based models of wildland fire behavior: a user's manual. Intermountain Forest and Range Experiment Station, Forest Service, US Department of Agriculture.

Byram, G.M., 1959. Combustion of forest fuels. Forest fire: control and use, pp.61-89.

Puckett, J.V., E.M. Johnston, FA. Albini, J.K. Brown, D.L. Bunnell, W.E. Fischer, and JAK. Snell. 1979. User's guide to debris prectiction and hazard appraisal. US Department of Agriculture, Forest Service, Northern Region, Missoula, MT.

Qi, Y., Jolly, W.M., Dennison, P.E. and Kropp, R.C., 2016. Seasonal relationships between foliar moisture content, heat content and biochemistry of lodgepole line and big sagebrush foliage. International Journal of Wildland Fire, 25(5), pp.574-578.

Rothermel, R.C., 1972. A mathematical model for predicting fire spread in wildland fuels (Vol. 115). Intermountain Forest & Range Experiment Station, Forest Service, US Department of Agriculture.

Trollope, W.S.W., 1998. Effect and use of fire in the savanna areas of southern Africa. University of Fort Hare.

Other literature of interest

Brown, J.K., 1982. Fuel and fire behavior prediction in big sagebrush (Vol. 290). US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Cheney, P. and Sullivan, A. eds., 2008. Grassfires: fuel, weather and fire behaviour. Csiro Publishing.