

Package ‘cffdrs.core’

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Type Package

Title Canadian Forest Fire Danger Rating System

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Description This project provides a group of new functions to calculate the outputs of the two main components of the Canadian Forest Fire Danger Rating System (CFFDRS) Van Wagner and Pickett (1985) <<https://cfs.nrcan.gc.ca/publications?id=19973>> at various time scales: the Fire Weather Index (FWI) System Wan Wagner (1985) <<https://cfs.nrcan.gc.ca/publications?id=19927>> and the Fire Behaviour Prediction (FBP) System Forestry Canada Fire Danger Group (1992) <<http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/10068.pdf>>.

License GPL-2

URL <https://r-forge.r-project.org/projects/cffdrs/>

BugReports

https://r-forge.r-project.org/tracker/?func=browse&group_id=1970&atid=5372

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R topics documented:

cffdrs.core-package	2
BackRateOfSpread	4
BuildupEffect	5
BuildupIndex	5
CriticalSurfaceIntensity	6
CriticalSurfaceRateOfSpread	7
CrownFractionBurned	7
CrownFuelConsumption	8

CrownRateOfSpreadC6	9
DistanceAtTime	9
DroughtCode	10
DuffMoistureCode	11
FineFuelMoistureCode	12
FireBehaviourPrediction	12
FireIntensity	13
FireSeason	13
FireWeatherIndex	16
FlankRateOfSpread	17
FoliarMoistureContent	17
gfmc	18
hffmc	21
InitialSpreadIndex	24
IntermediateSurfaceRateOfSpreadC6	25
LengthToBreadthRatio	25
LengthToBreadthRatioAtTime	26
OverwinterDroughtCode	27
RateOfSpread	29
RateOfSpreadAtTheta	30
RateOfSpreadAtTime	30
RateOfSpreadC6	31
sdmc	32
ShelteredDuffMoistureCode	34
SimardRateOfSpreadLine	35
SimardRateOfSpreadPoint	37
SlopeAdjust	39
SurfaceFuelConsumption	41
SurfaceRateOfSpreadC6	41
TotalFuelConsumption	42
Index	43

Description

The cffdrs.core package allows R users to calculate the outputs of the two main components of the Canadian Forest Fire Danger Rating System (CFFDRS; <http://cwffis.cfs.nrcan.gc.ca/background/summary/fdr>): the Fire Weather Index (FWI) System (<http://cwffis.cfs.nrcan.gc.ca/background/summary/fwi>) and the Fire Behaviour Prediction (FBP) System (<http://cwffis.cfs.nrcan.gc.ca/background/summary/fbp>) along with additional methods created and used Canadian fire modelling. These systems are widely used internationally to assess fire danger (FWI System) and quantify fire behavior (FBP System).

Details

The FWI System (Van Wagner 1987) is based on the moisture content and the effect of wind of three classes of forest fuels on fire behavior. It consists of six components: three fuel moisture codes (Fire Fuel Moisture Code, Duff Moisture Code, Drought Code), and three fire behavior indexes representing rate of spread (Initial Spread Index), fuel consumption (Buildup Index), and fire intensity (Fire Weather Index). The FWI System outputs are determined from daily noon weather observations: temperature, relative humidity, wind speed, and 24-hour rainfall.

The FBP System (Forestry Canada Fire Danger Group 1992; Hirsch 1996) provides a set of primary and secondary measures of fire behavior. The primary outputs consist of estimates of fire spread rate, fuel consumption, fire intensity, and fire description (i.e., surface, intermittent, or crown fire). The secondary outputs, which are not used nearly as often, give estimates of fire area, perimeter, perimeter growth rate, and flank and back fire behavior based on a simple elliptical fire growth model. Unlike the FWI System, which is weather based, the FBP System also requires information on vegetation (hereafter, fuel types) and slope (if any) to calculate its outputs. Sixteen fuel types are included in the FBP System, covering mainly major vegetation types in Canada.

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Author(s)

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References

1. Van Wagner, C.E. and T.L. Pickett. 1985. Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. Can. For. Serv., Ottawa, Ont. For. Tech. Rep. 33. 18 p.
2. Van Wagner, C.E. 1987. Development and structure of the Canadian forest fire weather index system. Forest Technology Report 35. (Canadian Forestry Service: Ottawa).
3. Lawson, B.D. and O.B. Armitage. 2008. Weather guide for the Canadian Forest Fire Danger Rating System. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.
4. Hirsch K.G. 1996. Canadian Forest Fire Behavior Prediction (FBP) System: user's guide. Nat. Resour. Can., Can. For. Serv., Northwest Reg., North. For. Cent., Edmonton, Alberta. Spec. Rep. 7. 122p.
5. Forestry Canada Fire Danger Group. 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Forestry Canada, Ottawa, Ontario Information Report ST-X-3. 63 p. <http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/10068.pdf>
6. Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p. http://publications.gc.ca/collections/collection_2010/nrcan/Fo123-2-10-2009-eng.pdf
7. Tymstra, C., Bryce, R.W., Wotton, B.M., Armitage, O.B. 2009. Development and structure of Prometheus: the Canadian wildland fire growth simulation Model. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-417.

See Also

[fbp](#), [fireSeason](#), [fwi](#), [gfmc](#), [hffmc](#), [ShelteredDuffMoistureCode](#), [wDC](#)

BackRateOfSpread

Back Fire Rate of Spread Calculator

Description

Calculate the Back Fire Spread Rate. All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992).

Usage

```
BackRateOfSpread(FUELTYPE, FPMC, BUI, WSV, FMC, SFC, PC, PDF, CC, CBH)
```

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
FPMC	Fine Fuel Moisture Code
BUI	Buildup Index
WSV	Wind Speed Vector
FMC	Foliar Moisture Content
SFC	Surface Fuel Consumption
PC	Percent Conifer
PDF	Percent Dead Balsam Fir
CC	Degree of Curing (just "C" in FCFDG 1992)
CBH	Crown Base Height

Value

BROS: Back Fire Rate of Spread

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

BuildupEffect	<i>Build Up Effect Calculator</i>
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Description

Computes the Buildup Effect on Fire Spread Rate. All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992).

Usage

```
BuildupEffect(FUELTYPE, BUI)
```

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
BUI	The Buildup Index value

Value

BE: Build up effect

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

BuildupIndex	<i>Build Up Index Calculator</i>
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Description

Buildup Index Calculation. All code is based on a C code library that was written by Canadian Forest Service Employees, which was originally based on the Fortran code listed in the reference below. All equations in this code refer to that document. Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. 1985. Van Wagner, C.E.; Pickett, T.L. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Forestry Technical Report 33. 18 p.

Usage

```
BuildupIndex(dmc, dc)
```

Arguments

dmc	Duff Moisture Code
dc	Drought Code

Value

A single Build Up Index value

References

<http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/19927.pdf> Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

CriticalSurfaceIntensity

Critical Surface Intensity Calculator

Description

Calculate Critical surface intensity (CSI).

Usage

CriticalSurfaceIntensity(FUELTYPE, FMC, CBH)

Arguments

FMC	Foliar Moisture Content
CBH	Crown Base Height

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

CSI

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

`CriticalSurfaceRateOfSpread`*Critical Surface Rate of Spread Calculator*

Description

Calculate Critical Surface fire rate of spread (RSO). The value of each of these equations can be returned to the calling function without unnecessary additional calculations.

Usage`CriticalSurfaceRateOfSpread(CSI, SFC)`**Arguments**

CSI	Critical Surface Intensity
SFC	Surface Fuel Consumption

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

RSO

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

`CrownFractionBurned`*Crown Fraction Burned Calculator*

Description

Calculate Calculate Crown Fraction Burned.

Usage`CrownFractionBurned(FUELTYPE, ROS, RSO)`**Arguments**

ROS	Rate of Spread
RSO	Critical Surface Rate of Spread

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

CFB

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

CrownFuelConsumption *Crown Fuel Consumption calculation*

Description

Computes the Crown Fuel Consumption by Fuel Type. All variables names are laid out in the same manner as FCFDG (1992) or Wotton et. al (2009)

Usage

CrownFuelConsumption(FUELTYPE, CFL, CFB, PC, PDF)

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
CFL	Crown Fuel Load (kg/m ²)
CFB	Crown Fraction Burned (0-1)
PC	Percent Conifer (%)
PDF	Percent Dead Balsam Fir (%)

Details

Forestry Canada Fire Danger Group (FCFDG) (1992). "Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

CFC Crown Fuel Consumption (kg/m²)

CrownRateOfSpreadC6	<i>C-6 Crown Fire Spread Calculator</i>
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Description

Calculate crown rate of spread (RSC).

Usage

CrownRateOfSpreadC6(ISI, FMC)

Arguments

ISI	Initial Spread Index
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Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

RSC

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

DistanceAtTime	<i>Distance at time t calculator</i>
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Description

Calculate the Head fire spread distance at time t. In the documentation this variable is just "D".

Usage

DistanceAtTime(FUELTYPE, ROSeq, HR, CFB)

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
ROSeq	The predicted equilibrium rate of spread (m/min)
HR	The elapsed time (min)
CFB	Crown Fraction Burned

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

DISTt - Head fire spread distance at time t

DroughtCode

Drought Code Calculator

Description

Drought Code Calculation. All code is based on a C code library that was written by Canadian Forest Service Employees, which was originally based on the Fortran code listed in the reference below. All equations in this code refer to that document. Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. 1985. Van Wagner, C.E.; Pickett, T.L. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Forestry Technical Report 33. 18 p. Additional reference on FWI system Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

Usage

DroughtCode(dc_yda, temp, rh, prec, lat, mon, lat.adjust = TRUE)

Arguments

dc_yda	The Drought Code from previous iteration
temp	Temperature (centigrade)
rh	Relative Humidity (%)
prec	Precipitation(mm)
lat	Latitude (decimal degrees)
mon	Month (1-12)
lat.adjust	Latitude adjustment (TRUE, FALSE, default=TRUE)

Value

A single drought code value

References

<http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/19927.pdf> Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

DuffMoistureCode*Duff Moisture Code Calculator*

Description

Duff Moisture Code Calculation. All code is based on a C code library that was written by Canadian Forest Service Employees, which was originally based on the Fortran code listed in the reference below. All equations in this code refer to that document.

Usage

```
DuffMoistureCode(dmc_yda, temp, rh, prec, lat, mon, lat.adjust = TRUE)
```

Arguments

dmc_yda	The Duff Moisture Code from previous iteration
temp	Temperature (centigrade)
rh	Relative Humidity (%)
prec	Precipitation(mm)
lat	Latitude (decimal degrees)
mon	Month (1-12)
lat.adjust	Latitude adjustment (TRUE, FALSE, default=TRUE)

Details

Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. 1985. Van Wagner, C.E.; Pickett, T.L. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Forestry Technical Report 33. 18 p.

Additional reference on FWI system

Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

Value

A single duff moisture code value

References

<http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/19927.pdf> Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

FineFuelMoistureCode *Fine Fuel Moisture Code Calculation*

Description

Fine Fuel Moisture Code Calculation. All code is based on a C code library that was written by Canadian Forest Service Employees, which was originally based on the Fortran code listed in the reference below. All equations in this code refer to that document.

Usage

```
FineFuelMoistureCode(ffmc_yda, temp, rh, ws, prec)
```

Arguments

ffmc_yda	The Fine Fuel Moisture Code from previous iteration
temp	Temperature (centigrade)
rh	Relative Humidity (%)
ws	Wind speed (km/h)
prec	Precipitation (mm)

Details

Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. 1985. Van Wagner, C.E.; Pickett, T.L. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Forestry Technical Report 33. 18 p.

Additional reference on FWI system Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

Value

A single fine fuel moisture code value

FireBehaviourPrediction *Fire Behaviour Prediction System Calculation (hidden)*

Description

Fire Behavior Prediction System calculations. This is the primary function for calculating FBP for a single timestep. Not all equations are calculated within this function, but have been broken down further.

Usage

```
FireBehaviourPrediction(input = NULL, output = "Primary")
```

Arguments

input	Data frame of required and optional information needed to calculate FBP function. View the arguments section of the fbp manual (fbp.Rd) under "input" for the full listing of the required and optional inputs.
output	What fbp outputs to return to the user. Options are "Primary", "Secondary" and "All". <code>_Default:_</code> "Primary"

Value

output: Either Primary, Secondary, or all FBP outputs in a data.frame

FireIntensity	<i>Fire Intensity Calculator</i>
---------------	----------------------------------

Description

Calculate the Predicted Fire Intensity

Usage

```
FireIntensity(FC, ROS)
```

Arguments

FC	Fuel Consumption (kg/m ²)
ROS	Rate of Spread (m/min)

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

FI: Fire Intensity (kW/m)

FireSeason	<i>Fire Season Start and End</i>
------------	----------------------------------

Description

[FireSeason](#) calculates the start and end fire season dates for a given weather station. The current method used in the function is based on three consecutive daily maximum temperature thresholds (Wotton and Flannigan 1993, Lawson and Armitage 2008). This function process input from a single weather station.

Usage

```
FireSeason(
  input,
  fs.start = 12,
  fs.end = 5,
  method = "WF93",
  consistent.snow = FALSE,
  multi.year = FALSE
)
```

Arguments

input A data.frame containing input variables of including the date/time and daily maximum temperature. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important either.

<i>yr</i>	(required)	Year of the observations
<i>mon</i>	(required)	Month of the observations
<i>day</i>	(required)	Day of the observations
<i>tmax</i>	(required)	Maximum Daily Temperature (degrees C)
<i>snow_depth</i>	(optional)	Is consistent snow data in the input?

<i>fs.start</i>	Temperature threshold (degrees C) to start the fire season (default=12)
<i>fs.end</i>	Temperature threshold (degrees C) to end the fire season (default=5)
<i>method</i>	Method of fire season calculation. Options are "wf93" or "la08" (default=WF93)
<i>consistent.snow</i>	Is consistent snow data in the input? (default=FALSE)
<i>multi.year</i>	Should the fire season span multiple years? (default=FALSE)

Details

An important aspect to consider when calculating Fire Weather Index (FWI) System variables is a definition of the fire season start and end dates (Lawson and Armitage 2008). If a user starts calculations on a fire season too late in the year, the FWI System variables may take too long to reach equilibrium, thus throwing off the resulting indices. This function presents two method of calculating these start and end dates, adapted from Wotton and Flannigan (1993), and Lawson and Armitage (2008). The approach taken in this function starts the fire season after three days of maximum temperature greater than 12 degrees Celsius. The end of the fire season is determined after three consecutive days of maximum temperature less than 5 degrees Celsius. The two temperature thresholds can be adjusted as parameters in the function call. In regions where temperature thresholds will not end a fire season, it is possible for the fire season to span multiple years, in this case setting the multi.year parameter to TRUE will allow these calculations to proceed.

This fire season length definition can also feed in to the overwinter DC calculations ([wDC](#)). View the cffdrs package help files for an example of using the FireSeason, [wDC](#), and [fwi](#) functions in conjunction.

Value

FireSeason returns a data frame of season and start and end dates. Columns in data frame are described below.

Primary FBP output includes the following 8 variables:

yr	Year of the fire season start/end date
mon	Month of the fire season start/end date
day	Day of the fire season start/end date
fsdatetype	Fire season date type (values are either "start" or "end")
date	Full date value

Author(s)

Alan Cantin, Xianli Wang, Mike Wotton, and Mike Flannigan

References

Wotton, B.M. and Flannigan, M.D. (1993). Length of the fire season in a changing climate. *Forestry Chronicle*, 69, 187-192.

http://www.ualberta.ca/~flanniga/publications/1993_Wotton_Flannigan.pdf

Lawson, B.D. and O.B. Armitage. 2008. Weather guide for the Canadian Forest Fire Danger Rating System. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB <http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/29152.pdf>

See Also

[fwi](#), [wDC](#)

Examples

```
library(cffdrs)
#The standard test data:
data("test_wDC")
print(head(test_wDC))
## Sort the data:
input <- with(test_wDC, test_wDC[order(id,yr,mon,day),])

#Using the default fire season start and end temperature
#thresholds:
a_fs <- FireSeason(input[input$id==1,])

#Check the result:
a_fs

#   yr mon day fsdatetype
#1 1999  5  4      start
#2 1999  5 12       end
#3 1999  5 18      start
#4 1999  5 25       end
#5 1999  5 30      start
#6 1999 10  6       end
#7 2000  6 27      start
#8 2000 10  7       end
```

```
#In the resulting data frame, the fire season starts
#and ends multiple times in the first year. It is up to the user #for how to interpret this.

#modified fire season start and end temperature thresholds
a_fs <- FireSeason (input[input$id==1,],fs.start=10, fs.end=3)
a_fs
#   yr mon day fsdatatype
#1 1999   5   2      start
#2 1999  10  20       end
#3 2000   6  16      start
#4 2000  10   7       end
#select another id value, specify method explicitly
b_fs <- FireSeason(input[input$id==2,],method="WF93")
#print the calculated fire season
b_fs
#   yr mon day fsdatatype
#1 1980   4  21      start
#2 1980   9  19       end
#3 1980  10   6      start
#4 1980  10  16       end
#5 1981   5  21      start
#6 1981  10  13       end
```

FireWeatherIndex	<i>Fire Weather Index Calculation.</i>
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Description

All code is based on a C code library that was written by Canadian Forest Service Employees, which was originally based on the Fortran code listed in the reference below. All equations in this code refer to that document.

Usage

```
FireWeatherIndex(isi, bui)
```

Arguments

isi	Initial Spread Index
bui	Buildup Index

Details

Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. 1985. Van Wagner, C.E.; Pickett, T.L. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Forestry Technical Report 33. 18 p.

Additional reference on FWI system

Development and structure of the Canadian Forest Fire Weather Index System. 1987. Van Wagner, C.E. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

Value

A single fwi value

FlankRateOfSpread	<i>Flank Fire Rate of Spread Calculator</i>
-------------------	---

Description

Calculate the Flank Fire Spread Rate.

Usage

FlankRateOfSpread(ROS, BROS, LB)

Arguments

ROS	Fire Rate of Spread (m/min)
BROS	Back Fire Rate of Spread (m/min)
LB	Length to breadth ratio

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

FROS Flank Fire Spread Rate (m/min) value

FoliarMoistureContent	<i>Foliar Moisture Content Calculator</i>
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Description

Calculate Foliar Moisture Content on a specified day. All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Usage

FoliarMoistureContent(LAT, LONG, ELV, DJ, D0)

Arguments

LAT	Latitude (decimal degrees)
LONG	Longitude (decimal degrees)
ELV	Elevation (metres)
DJ	Day of year (offeren referred to as julian date)
D0	Date of minimum foliar moisture content. _If D0, date of min FMC, is not known then D0 = NULL._

Value

FMC: Foliar Moisture Content value

gfmfc	<i>Grass Fuel Moisture Code</i>
-------	---------------------------------

Description

gfmfc calculates both the moisture content of the surface of a fully cured matted grass layer and also an equivalent Grass Fuel Moisture Code (gfmfc) (Wotton, 2009) to create a parallel with the hourly ffmc (see the [fwi](#) and [hffmc](#) functions). The calculation is based on hourly (or sub-hourly) weather observations of temperature, relative humidity, wind speed, rainfall, and solar radiation. The user must also estimate an initial value of the gfmfc for the layer. This function could be used for either one weather station or multiple weather stations.

Usage

```
gfmfc(
  input,
  GFMCold = 85,
  batch = TRUE,
  time.step = 1,
  roFL = 0.3,
  out = "GFMCanMC"
)
```

Arguments

input A dataframe containing input variables of daily noon weather observations. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important.

<i>temp</i>	(required)	Temperature (centigrade)
<i>rh</i>	(required)	Relative humidity (%)
<i>ws</i>	(required)	10-m height wind speed (km/h)
<i>prec</i>	(required)	1-hour rainfall (mm)
<i>isol</i>	(required)	Solar radiation (kW/m ²)
<i>mon</i>	(recommended)	Month of the year (integer' 1-12)
<i>day</i>	(optional)	Day of the month (integer)

GFMCoId	Previous value of GFMC (i.e. value calculated at the previous time step)[default is 85 (which corresponds to a moisture content of about 16%)]. On the first calculation this is the estimate of the GFMC value at the start of the time step. The GFMCoId argument can accept a single initial value for multiple weather stations, and also accept a vector of initial values for multiple weather stations. NOTE: this input represents the CODE value, not a direct moisture content value. The CODE values in the Canadian FWI System increase within decreasing moisture content. To roughly convert a moisture content value to a CODE value on the FF-scale (used in the FWI Systems FFMCC) use $\text{GFMCoId} = 101 - \text{gmc}$ (where gmc is moisture content in %)
batch	Whether the computation is iterative or single step, default is TRUE. When batch=TRUE, the function will calculate hourly or sub-hourly GFMC for one weather station over a period of time iteratively. If multiple weather stations are processed, an additional "id" column is required in the input to label different stations, and the data needs to be sorted by time sequence and "id". If batch=FALSE, the function calculates only one time step (1 hour) base on either the previous hourly GFMC or the initial start value.
time.step	Time step (hour) [default 1 hour]
roFL	The nominal fuel load of the fine fuel layer, default is 0.3 kg/m^2
out	Output format, default is "GFMCandMC", which contains both GFMC and moisture content (MC) in a data.frame format. Other choices include: "GFMC", "MC", and "ALL", which include both the input and GFMC and MC.

Details

The Canadian Forest Fire Danger Rating System (CFFDRS) is used throughout Canada, and in a number of countries throughout the world, for estimating fire potential in wildland fuels. This new Grass Fuel Moisture Code (GFMC) is an addition (Wotton 2009) to the CFFDRS and retains the structure of that System's hourly Fine Fuel Moisture Code (HFFMC) (Van Wagner 1977). It tracks moisture content in the top 5 cm of a fully-cured and fully-matted layer of grass and thus is representative of typical after winter conditions in areas that receive snowfall. This new moisture calculation method outputs both the actual moisture content of the layer and also the transformed moisture Code value using the FFMCC's FF-scale. In the CFFDRS the moisture codes are in fact relatively simple transformations of actual moisture content such that decreasing moisture content (increasing dryness) is indicated by an increasing Code value. This moisture calculation uses the same input weather observations as the hourly FFMCC, but also requires an estimate of solar radiation incident on the fuel.

Value

gfmcc returns GFMC and moisture content (MC) values collectively (default) or separately.

Author(s)

Xianli Wang, Mike Wotton, Alan Cantin, and Mike Flannigan

References

Wotton, B.M. 2009. A grass moisture model for the Canadian Forest Fire Danger Rating System. In: Proceedings 8th Fire and Forest Meteorology Symposium, Kalispell, MT Oct 13-15, 2009. Paper 3-2. <https://ams.confex.com/ams/pdfpapers/155930.pdf>

Van Wagner, C.E. 1977. A method of computing fine fuel moisture content throughout the diurnal cycle. Environment Canada, Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario. Information Report PS-X-69. <http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/25591.pdf>

See Also

[fwi](#), [hffmc](#)

Examples

```
library(cffdrs)
#load the test data
data("test_gfmc")
# show the data format:
head(test_gfmc)
#      yr mon day hr temp  rh  ws prec  isol
# 1 2006   5  17 10 15.8 54.6  5.0   0 0.340
# 2 2006   5  17 11 16.3 52.9  5.0   0 0.380
# 3 2006   5  17 12 18.8 45.1  5.0   0 0.626
# 4 2006   5  17 13 20.4 40.8  9.5   0 0.656
# 5 2006   5  17 14 20.1 41.7  8.7   0 0.657
# 6 2006   5  17 15 18.6 45.8 13.5   0 0.629
# (1) gfmc default:
# Re-order the data by year, month, day, and hour:
dat<-test_gfmc[with(test_gfmc,order(yr,mon,day,hr)),]
# Because the test data has 24 hours input variables
# it is possible to calculate the hourly GFMC continuously
# through multiple days(with the default initial GFMCold=85):
dat$gfmc_default<-gfmc(dat)
# two variables will be added to the input, GFMC and MC
head(dat)
# (2) For multiple weather stations:
# One time step (1 hour) with default initial value:
foo<-gfmc(dat,batch=FALSE)
# Chronical hourly GFMC with only one initial
# value (GFMCold=85), but multiple weather stations.
# Note: data is ordered by date/time and the station id. Subset
# the data by keeping only the first 10 hours of observations
# each day:
dat1<-subset(dat,hr%in%c(0:9))
#assuming observations were from the same day but with
#9 different weather stations:
dat1$day<-NULL
dat1<-dat1[with(dat1,order(yr,mon,hr)),]
dat1$id<-rep(1:8,nrow(dat1)/8)
#check the data:
head(dat1)
# Calculate GFMC for multiple stations:
dat1$gfmc01<-gfmc(dat1,batch=TRUE)
# We can provide multiple initial GFMC (GFMCold) as a vector:
dat1$gfmc02<- gfmc(dat1,GFMCold = sample(70:100,8, replace=TRUE),batch=TRUE)
# (3)output argument
## include all inputs and outputs:
dat0<-dat[with(dat,order(yr,mon,day,hr)),]
foo<-gfmc(dat,out="ALL")
## subhourly time step:
```

```
gfmc(dat0,time.step=1.5)
```

hffmc

Hourly Fine Fuel Moisture Code

Description

hffmc is used to calculate hourly Fine Fuel Moisture Code (FFMC) and is based on a calculation routine first described in detail by Van Wagner (1977) and which has been updated in minor ways by the Canadian Forest Service to have it agree with the calculation methodology for the daily FFMC (see [fwi](#)). In its simplest typical use this current routine calculates a value of FFMC based on a series of uninterrupted hourly weather observations of screen level (~1.4 m) temperature, relative humidity, 10 m wind speed, and 1-hour rainfall. This implementation of the function includes an optional time.step input which is defaulted to one hour, but can be reduced if sub-hourly calculation of the code is needed. The FFMC is in essence a bookkeeping system for moisture content and thus it needs to use the last time.step's value of FFMC in its calculation as well. This function could be used for either one weather station or for multiple weather stations.

Usage

```
hffmc(
  weatherstream,
  ffmc_old = 85,
  time.step = 1,
  calc.step = FALSE,
  batch = TRUE,
  hourlyFWI = FALSE
)
```

Arguments

weatherstream		A dataframe containing input variables of hourly weather observations. It is important that variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important.
temp	(required)	Temperature (centigrade)
rh	(required)	Relative humidity (%)
ws	(required)	10-m height wind speed (km/h)
prec	(required)	1-hour rainfall (mm)
hr	(optional)	Hourly value to calculate sub-hourly ffmc
bui	(optional)	Daily BUI value for the computation of hourly FWI. It is required when hourlyFWI=TRUE.

Typically this dataframe also contains date and hour fields so outputs can be associated with a specific day and time, however these fields are not used in the calculations. If multiple weather stations are being used, a weather station ID field is typically included as well, though this is simply for bookkeeping purposes and does not affect the calculation.

ffmc_old	Initial FFMC. At the start of calculations at a particular station there is a need to provide an estimate of the FFMC in the previous timestep; this is because the FFMC is, in essence, a bookkeeping system for moisture. If no estimate of previous hour's FFMC is available the function will use default value, ffmc_old=85. When using the routine to calculate hourly FFMC at multiple stations the ffmc_old argument can also accept a vector with the same number of weather stations.
time.step	Is the time (in hours) between the previous value of FFMC and the current time at which we want to calculate a new value of the FFMC. When not specified it will take on a default value of time.step=1.
calc.step	Optional for whether time step between two observations is calculated. Default is FALSE, no calculations. This is used when time intervals are not uniform in the input.
batch	Whether the computation is iterative or single step, default is TRUE. When batch=TRUE, the function will calculate hourly or sub-hourly FFMC for one weather station over a period of time iteratively. If multiple weather stations are processed, an additional "id" column is required in the input weatherstream to label different stations, and the data needs to be sorted by date/time and "id". If batch=FALSE, the function calculates only one time step base on either the previous hourly FFMC or the initial start value.
hourlyFWI	Optional for the computation of hourly ISI, FWI, and DSR. Default is FALSE. While hourlyFWI=TRUE, daily BUI is required for the computation of FWI.

Details

The hourly FFMC is very similar in its structure and calculation to the Canadian Forest Fire Weather Index System's daily FFMC ([fwi](#)) but has an altered drying and wetting rate which more realistically reflects the drying and wetting of a pine needle litter layer sitting on a decaying organic layer. This particular implementation of the Canadian Forest Fire Danger Rating System's hourly FFMC provides for a flexible time step; that is, the data need not necessarily be in time increments of one hour. This flexibility has been added for some users who use this method with data sampled more frequently than one hour. We do not recommend using a time step much greater than one hour. An important and implicit assumption in this calculation is that the input weather is constant over the time step of each calculation (e.g., typically over the previous hour). This is a reasonable assumption for an hour; however it can become problematic for longer periods. For brevity we have referred to this routine throughout this description as the hourly FFMC.

Because of the shortened time step, which can lead to more frequent calculations and conversion between moisture content and the code value itself, we have increased the precision of one of the constants in the simple formula that converts litter moisture content to the 'Code' value. This is necessary to avoid a potential bias that gets introduced during extremely dry conditions. This is simply a change in the precision at which this constant is used in the equation and is not a change to the standard FFMC conversion between moisture and code value (which is referred to as the FF-scale).

The calculation requires the previous hour's FFMC as an input to the calculation of the current hour's FFMC; this is because the routine can be thought of as a bookkeeping system and needs to know the amount of moisture being held in the fuel prior to any drying or wetting in the current period. After each hour's calculation that newly calculated FFMC simply becomes the starting FFMC in the next hour's calculation. At the beginning of the calculations at a station this previous hours FFMC must be estimated. It is typical to use a value of 85 when this value cannot be estimated more accurately; this code value corresponds to a moisture content of about 16% in typical pine litter fuels.

Value

hffmc returns a vector of hourly or sub-hourly FFMC values, which may contain 1 or multiple elements. Optionally when hourlyFWI=TRUE, the function also output a data.frame contains input weatherstream as well as the hourly or sub-hourly FFMC, ISI, FWI, and DSR.

Author(s)

Xianli Wang, Mike Wotton, Alan Cantin, Brett Moore, and Mike Flannigan

References

Van Wagner, C.E. 1977. A method of computing fine fuel moisture content throughout the diurnal cycle. Environment Canada, Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario. Information Report PS-X-69. <http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/25591.pdf>

See Also

[fbp](#), [fwi](#), [hffmcRaster](#)

Examples

```
library(cffdrs)
data("test_hffmc")
# show the data format:
head(test_hffmc)
# (1)hffmc default:
# Re-order the data by year, month, day, and hour:
test_hffmc<-test_hffmc[with(test_hffmc, order(yr,mon,day,hr)),]
# Because the test data has 24 hours input variables
# it is possible to calculate the hourly FFMC chronically
# through multiple days(with the default initial ffmc_old=85):
test_hffmc$ffmc_default<-hffmc(test_hffmc)
# (2) Calculate FFMC for multiple stations:
# Calculate hourly FFMC with only one initial
# value (ffmc_old=85), but multiple weather stations.
# Sort the input by date/time and the station id:
test_hffmc<-test_hffmc[with(test_hffmc,order(yr,mon,hr)),]
# Add weather station id:
test_hffmc$id<-rep(1:10,nrow(test_hffmc)/10)
#check the data:
head(test_hffmc)
test_hffmc$ffmc01<-hffmc(test_hffmc,batch=TRUE)
# With multiple initial FFMC (ffmc_old) as a vector:
test_hffmc$ffmc02<- hffmc(test_hffmc,ffmc_old = sample(70:100,10, replace=TRUE),batch=TRUE)
# One time step assuming all records are from different
# weather stations:
foo<-hffmc(test_hffmc,batch=FALSE)
# (3) output all hourly FWI System variables:
test_hffmc$id<-NULL
test_hffmc<-test_hffmc[with(test_hffmc, order(yr,mon,day,hr)),]
foo<-hffmc(test_hffmc,hourlyFWI=TRUE)
# this will not run: warning message requesting for daily BUI
test_hffmc$bui<-100
foo<-hffmc(test_hffmc,hourlyFWI=TRUE)
# (4) Calculate time steps in case the time intervals are
```

```
# not uniform:
dat0<-test_hffmc[sample(1:30,20),]
dat0<-dat0[with(dat0,order(yr,mon,day,hr)),]
# with or without calc.step, hffmc is going to generate
# different FFMC values.
# without calculating time step (default):
hffmc(dat0,time.step=1)
# with calc.step=TRUE, time.step=1 is applied to
# only the first record, the rests would be calculated:
hffmc(dat0,time.step=1,calc.step=TRUE)
```

InitialSpreadIndex *Initial Spread Index Calculator*

Description

Computes the Initial Spread Index From the FWI System. Equations are from Van Wagner (1985) as listed below, except for the modification for fbp taken from FCFDG (1992).

Usage

```
InitialSpreadIndex(ffmc, ws, fbpMod = FALSE)
```

Arguments

ffmc	Fine Fuel Moisture Code
ws	Wind Speed (km/h)
fbpMod	TRUE/FALSE if using the fbp modification at the extreme end

Details

Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. 1985. Van Wagner, C.E.; Pickett, T.L. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ontario. Forestry Technical Report 33. 18 p.

Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

ISI - Initial Spread Index

IntermediateSurfaceRateOfSpreadC6

C-6 Conifer Plantation Intermediate Surface Fire Spread Rate Calculator

Description

Calculate intermediate surface fire rate of spread, before BUI effect is applied (RSI).

Usage

IntermediateSurfaceRateOfSpreadC6(ISI, FMC)

Arguments

ISI	Initial Spread Index
FMC	Foliar Moisture Content

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

RSI

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

LengthToBreadthRatio *Length-to-Breadth ratio*

Description

Computes the Length to Breadth ratio of an elliptically shaped fire. Equations are from listed FCFDG (1992) except for errata 80 from Wotton et. al. (2009).

Usage

LengthToBreadthRatio(FUELTYPE, WSV)

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

@param FUELTYPE The Fire Behaviour Prediction FuelType @param WSV The Wind Speed (km/h)

Value

Length to Breadth ratio value

LengthToBreadthRatioAtTime

Length-to-Breadth ratio at time t

Description

Computes the Length to Breadth ratio of an elliptically shaped fire at elapsed time since ignition. Equations are from listed FCFDG (1992) and Wotton et. al. (2009), and are marked as such.

Usage

LengthToBreadthRatioAtTime(FUELTYPE, LB, HR, CFB)

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
LB:	Length to Breadth ratio
HR:	Time since ignition (hours)
CFB:	Crown Fraction Burned

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

Length to Breadth ratio at time since ignition

OverwinterDroughtCode *Overwintering Drought Code*

Description

OverwinterDroughtCode calculates an initial or season starting Drought Code (DC) value based on a standard method of overwintering the Drought Code (Lawson and Armitage 2008). This method uses the final DC value from previous year, over winter precipitation and estimates of how much over-winter precipitation 'refills' the moisture in this fuel layer. This function could be used for either one weather station or for multiple weather stations.

Usage

```
OverwinterDroughtCode(DCf = 100, rw = 200, a = 0.75, b = 0.75)
```

Arguments

DCf	Final fall DC value from previous year
rw	Winter precipitation (mm)
a	User selected values accounting for carry-over fraction (view table below)
b	User selected values accountain for wetting efficiency fraction (view table below)

Details

Of the three fuel moisture codes (i.e. FFMC, DMC and DC) making up the FWI System, only the DC needs to be considered in terms of its values carrying over from one fire season to the next. In Canada both the FFMC and the DMC are assumed to reach moisture saturation from overwinter precipitation at or before spring melt; this is a reasonable assumption and any error in these assumed starting conditions quickly disappears. If snowfall (or other overwinter precipitation) is not large enough however, the fuel layer tracked by the Drought Code may not fully reach saturation after spring snow melt; because of the long response time in this fuel layer (53 days in standard conditions) a large error in this spring starting condition can affect the DC for a significant portion of the fire season. In areas where overwinter precipitation is 200 mm or more, full moisture recharge occurs and DC overwintering is usually unnecessary. More discussion of overwintering and fuel drying time lag can be found in Lawson and Armitage (2008) and Van Wagner (1985).

Value

OverwinterDroughtCode returns either a single value or a vector of wDC values.

Author(s)

Xianli Wang, Mike Wotton, Alan Cantin, and Mike Flannigan

References

Lawson B.D. and Armitage O.B. 2008. Weather Guide for the Canadian Forest Fire Danger Rating System. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. 84 p. <http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/29152.pdf>

Van Wagner, C.E. 1985. Drought, timelag and fire danger rating. Pages 178-185 in L.R. Donoghue and R.E. Martin, eds. Proc. 8th Conf. Fire For. Meteorol., 29 Apr.-3 May 1985, Detroit, MI. Soc. Am. For., Bethesda, MD. <http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/23550.pdf>

See Also

[fwi](#), [fireSeason](#)

Examples

```
library(cffdrs)
# The standard test data:
data("test_wDC")
# (1) Simple case previous fall's DC was 300, overwinter
# rain 110mm
winter_DC <- wDC(DCf=300,rw=110)
winter_DC
#(2) modified a and b parameters. Find table values in listed
# reference for Lawson and Armitage, 2008.
winter_DC <- wDC(DCf=300,rw=110,a=1.0,b=0.9)
winter_DC
#(3)with multiple inputs:
winter_DC <- wDC(DCf=c(400,300,250), rw=c(99,110,200),
                 a=c(0.75,1.0,0.75), b=c(0.75,0.9,0.75))
winter_DC
#(4) A realistic example:
#precipitation accumulation and date boundaries
input <- test_wDC
#order data by ID and date
input <- with(input,input[order(id,yr,mon,day),])
input$date <- as.Date(as.POSIXlt(paste(input$yr,"-",input$mon,"-",input$day,sep="")))
#select id value 1
input.2 <- input[input$id==2,]
#Explicitly defined fire start and end dates.
data("test_wDC_fs")
print(test_wDC_fs)
#Set date field
test_wDC_fs$date <- as.Date(as.POSIXlt(paste(test_wDC_fs$yr,"-",test_wDC_fs$mon,"-",
                                             test_wDC_fs$day,sep="")))
#match to current id value
input.2.fs <- test_wDC_fs[test_wDC_fs$id==2,]
#assign start of winter date (or end of fire season date)
winterStartDate <- input.2.fs[2,"date"]
#assign end of winter date (or start of new fire season date)
winterEndDate <- input.2.fs[3,"date"]
#Accumulate overwinter precip based on chosen dates
curYr.prec <- sum(input.2[(input.2$date>winterStartDate & input.2$date < winterEndDate),]$prec)
#Assign a fall DC value
fallDC <- 500
#calculate winter DC
winter_DC <- wDC(DCf=fallDC,rw=curYr.prec)
winter_DC
```

```
#Assign a different fall DC value
fallDC <- 250
#calculate winter DC
winter_DC <- wDC(DCf=fallDC,rw=curYr.prec,a=1.0)
winter_DC
```

RateOfSpread

*Rate of Spread Calculation***Description**

Computes the Rate of Spread prediction based on fuel type and FWI conditions. Equations are from listed FCFDG (1992) and Wotton et. al. (2009), and are marked as such.

Usage

```
RateOfSpread(FUELTYPE, ISI, BUI, FMC, SFC, PC, PDF, CC, CBH)
```

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
ISI	Intiial Spread Index
BUI	Buildup Index
FMC	Foliar Moisture Content
SFC	Surface Fuel Consumption (kg/m^2)
PC	Percent Conifer (%)
PDF	Percent Dead Balsam Fir (%)
CC	Constant
CBH	Crown to base height(m)

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

ROS - Rate of Spread (m/min) value

RateOfSpreadAtTheta	<i>Rate of spread at a point along the perimeter calculator</i>
---------------------	---

Description

Computes the Rate of Spread at any point along the perimeter of an elliptically shaped fire. Equations are from Wotton et. al. (2009).

Usage

RateOfSpreadAtTheta(ROS, FROS, BROS, THETA)

Arguments

ROS	Rate of Spread (m/min)
FROS	Flank Fire Rate of Spread (m/min)
BROS	Back Fire Rate of Spread (m/min)
THETA	
FUELTYPE	The Fire Behaviour Prediction FuelType

Details

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

ROSTHETA - Rate of spread at point theta(m/min)

RateOfSpreadAtTime	<i>Rate of spread at time t calculation</i>
--------------------	---

Description

Computes the Rate of Spread prediction based on fuel type and FWI conditions at elapsed time since ignition. Equations are from listed FCFDG (1992).

Usage

RateOfSpreadAtTime(FUELTYPE, ROSeq, HR, CFB)

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
ROSeq	Equilibrium Rate of Spread (m/min)
HR	Time since ignition (hours)
CFB	Crown Fraction Burned

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

ROSt - Rate of Spread at time since ignition value

RateOfSpreadC6	<i>C-6 Conifer Plantation Fire Spread Calculator</i>
----------------	--

Description

Calculate rate of spread (ROS).

Usage

RateOfSpreadC6(RSC, RSS, CFB)

Arguments

RSC	Crown Fire Spread Rate (m/min)
RSS	Surface Fire Spread Rate (m/min)
CFB	Crown Fraction Burned

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

ROS

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

sdmc	<i>Sheltered Duff Moisture Code</i>
------	-------------------------------------

Description

sdmc is used to calculate sheltered DMC (sDMC, Wotton et al., 2005) based on daily noon weather observations of temperature, relative humidity, wind speed, 24-hour rainfall, and a previous day's calculated or estimated value of sDMC. This function calculates sDMC for either one weather station or for multiple weather stations over the duration of the daily weather data set, typically over a fire season.

Usage

```
sdmc(input, sdmc_old = NULL, batch = TRUE)
```

Arguments

input	A data.frame containing input variables of daily noon weather observations. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important either.	
	<i>temp</i>	(required) Temperature (centigrade)
	<i>rh</i>	(required) Relative humidity (%)
	<i>ws</i>	(required) 10-m height wind speed (km/h)
	<i>prec</i>	(required) 1-hour rainfall (mm)
	<i>mon</i>	(recommended) Month of the observations (integer 1-12)
	<i>day</i>	(optional) Day of the observations (integer)
sdmc_old	Previous day's value of SDMC. At the start of calculations, when there is no calculated previous day's SDMC value to use, the user must specify an estimate of this value. Where sdmc_old=NULL, the function will calculate the initial SDMC values based on the initial DMC. The sdmc_old argument can accept a single initial value for multiple weather stations, and also accept a vector of initial values for multiple weather stations.	
batch	Whether the computation is iterative or single step, default is TRUE. When batch=TRUE, the function will calculate daily SDMC for one weather station over a period of time iteratively. If multiple weather stations are processed, an additional "id" column is required in the input to label different stations, and the data needs to be sorted by date/time and "id". If batch=FALSE, the function calculates only one time step base on either the previous day's SDMC or the initial start value.	

Details

The Duff Moisture Code (DMC) component of the Canadian Forest Fire Weather Index (FWI) System tracks moisture content of the forest floor away from the sheltering influences of overstory trees. This sheltered Duff Moisture Code (sDMC) was developed to track moisture in the upper 5 cm of the organic layer in the rain sheltered areas near (<0.5 m) the boles of overstory trees (Wotton et al. 2005), an area where lightning strikes usually ignite the forest floor when they run

to ground. The sDMC is very similar in structure (and identical in data requirements) to the DMC. The sDMC, like all the FWI System moisture codes, is a bookkeeping system that tracks gain and loss of moisture from day-to-day; thus an estimate of the previous day's sDMC value is needed to provide a starting point for each day's moisture calculation. Like the other moisture codes in the FWI System the sDMC is converted from a moisture content value to an outputted CODE value which increases in value with decreasing moisture content.

Value

sdmc returns either a single value or a vector of SDMC values.

Author(s)

Xianli Wang, Mike Wotton, Alan Cantin, and Mike Flannigan

References

Wotton, B.M., B.J. Stocks, and D.L. Martell. 2005. An index for tracking sheltered forest floor moisture within the Canadian Forest Fire Weather Index System. *International Journal of Wildland Fire*, 14, 169-182.

See Also

[fwi](#)

Examples

```
library(cffdrs)
data("test_sdmc")
#order the data:
test_sdmc<-test_sdmc[with(test_sdmc,order(yr,mon,day)),]
# (1)Default of sdmc, calculate sdmc for a chronical period
# of time.
# Because sdmc_old is better to be calculated, we normally
# ignore this option:
test_sdmc$SDMC<-sdmc(test_sdmc)
# (2) multiple weather stations:
# Batch process with multiple stations (2 stations) assuming
# they are from the same month:
test_sdmc$mon<-7
test_sdmc$day<-rep(1:24,2)
test_sdmc$id<-rep(1:2,each=24)
# Sort the data by date and weather station id:
test_sdmc<-test_sdmc[with(test_sdmc,order(yr,mon,day,id)),]
# Apply the function
test_sdmc$SDMC_mult_stn<-sdmc(test_sdmc,batch=TRUE)
# Assuming each record is from a different weather station, and
# calculate only one time step:
foo<-sdmc(test_sdmc,batch=FALSE)
```

ShelteredDuffMoistureCode

Sheltered Duff Moisture Code

Description

ShelteredDuffMoistureCode is used to calculate sheltered DMC (sDMC, Wotton et al., 2005) based on daily noon weather observations of temperature, relative humidity, 24-hour rainfall, and a previous day’s calculated or estimated value of sDMC. This function calculates sDMC for either one weather station or for multiple weather stations over the duration of the daily weather data set, typically over a fire season.

Usage

ShelteredDuffMoistureCode(temp, prec, rh, dmc, mon, sdmc_old = NULL)

Arguments

sdmc_old	Previous day’s value of SDMC. At the start of calculations, when there is no calculated previous day’s SDMC value to use, the user must specify an estimate of this value. Where sdmc_old=NULL, the function will calculate the initial SDMC values based on the initial DMC. The sdmc_old argument can accept a single initial value for multiple weather stations, and also accept a vector of initial values for multiple weather stations.	
input	A data.frame containing input variables of daily noon weather observations. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important either.	
	temp	(required) Temperature (centigrade)
	rh	(required) Relative humidity (%)
	prec	(required) 1-hour rainfall (mm)
	mon	(recommended) Month of the observations (integer 1-12)
	day	(optional) Day of the observations (integer)
batch	Whether the computation is iterative or single step, default is TRUE. When batch=TRUE, the function will calculate daily SDMC for one weather station over a period of time iteratively. If multiple weather stations are processed, an additional "id" column is required in the input to label different stations, and the data needs to be sorted by date/time and "id". If batch=FALSE, the function calculates only one time step base on either the previous day’s SDMC or the initial start value.	

Details

The Duff Moisture Code (DMC) component of the Canadian Forest Fire Weather Index (FWI) System tracks moisture content of the forest floor away from the sheltering influences of overstory trees. This sheltered Duff Moisture Code (sDMC) was developed to track moisture in the upper 5 cm of the organic layer in the rain sheltered areas near (<0.5 m) the boles of overstory trees (Wotton et al. 2005), an area where lightning strikes usually ignite the forest floor when they run

to ground. The sDMC is very similar in structure (and identical in data requirements) to the DMC. The sDMC, like all the FWI System moisture codes, is a bookkeeping system that tracks gain and loss of moisture from day-to-day; thus an estimate of the previous day's sDMC value is needed to provide a starting point for each day's moisture calculation. Like the other moisture codes in the FWI System the sDMC is converted from a moisture content value to an outputted CODE value which increases in value with decreasing moisture content.

Value

ShelteredDuffMoistureCode returns either a single value or a vector of SDMC values.

Author(s)

Xianli Wang, Mike Wotton, Alan Cantin, and Mike Flannigan

References

Wotton, B.M., B.J. Stocks, and D.L. Martell. 2005. An index for tracking sheltered forest floor moisture within the Canadian Forest Fire Weather Index System. International Journal of Wildland Fire, 14, 169-182.

See Also

[fwi](#)

SimardRateOfSpreadLine
<i>Line-based input for Simard Rate of Spread and Direction</i>

Description

SimardRateOfSpreadLine is used to calculate the rate of spread and direction given one set of three point-based observations of fire arrival time. The function requires that the user specify the time that the fire crossed each point, along with the measured lengths between each pair of observational points, and a reference bearing (one specified side of the triangle). This function allows quick input of a dataframe specifying one or many triangles.

Usage

SimardRateOfSpreadLine(input)

Arguments

input	A dataframe containing input variables of time fire front crossed points 1, 2, 3, and latitude/longitude for those same points. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important.		
	<i>T1</i>	(required)	Time that the fire front crossed point 1. Time entered in fractional format. Output ROS will depend on the level of precision entered

		(minute, second, decisecond)
<i>T2</i>	(required)	Time that the fire front crossed point 2. Time entered in fractional format. Output ROS will depend on the level of precision entered
		(minute, second, decisecond)
<i>T3</i>	(required)	Time that the fire front crossed point 3. Time entered in fractional format. Output ROS will depend on the level of precision entered
		(minute, second, decisecond)
<i>LengthT1T2</i>	(required)	Length between each pair of observation points T1 and T2 (subscripts denote time-ordered pairs). (meters)
<i>LengthT2T3</i>	(required)	Length between each pair of observation points T2 and T3 (subscripts denote time-ordered pairs). (meters)
<i>LengthT1T3</i>	(required)	Length between each pair of observation points T1 and T3 (subscripts denote time-ordered pairs). (meters)
<i>BearingT1T2</i>	(required)	Reference bearing. For reference, North = 0, West = -90, East = 90 (degrees)
<i>BearingT1T3</i>	(required)	Reference bearing. For reference, North = 0, West = -90, East = 90 (degrees)

Details

SimardRateOfSpreadLine Allows R users to calculate the rate of spread and direction of a fire across a triangle, given three time measurements and details about the orientation and distance between observational points. The algorithm is based on the description from Simard et al. (1984). See *SimardRateOfSpreadPoint* for more information.

The functions require the user to arrange the input dataframe so that each triangle of interest is identified based on a new row in the dataframe. The input format forces the user to identify the triangles, one triangle per row of input dataframe. Very complex arrangements of field plot layouts are possible, and the current version of these functions do not attempt to determine each triangle of interest automatically.

Value

SimardRateOfSpreadLine returns a dataframe which includes the rate of spread and spread direction. Output units depend on the user's inputs for distance (typically meters) and time (seconds or minutes).

Author(s)

Tom Schiks, Xianli Wang, Alan Cantin

References

1. Simard, A.J., Eenigenburg, J.E., Adams, K.B., Nissen, R.L., Deacon, and Deacon, A.G. 1984. A general procedure for sampling and analyzing wildland fire spread.

2. Byram, G.M. 1959. Combustion of forest fuels. In: Davis, K.P. Forest Fire Control and Use. McGraw-Hill, New York.
3. Curry, J.R., and Fons, W.L. 1938. Rate of spread of surface fires in the Ponderosa Pine Type of California. Journal of Agricultural Research 57(4): 239-267.
4. Simard, A.J., Deacon, A.G., and Adams, K.B. 1982. Nondirectional sampling wildland fire spread. Fire Technology: 221-228.

See Also

[SimardRateOfSpreadPoint](#),

Examples

```
library(cffdrs)
# manual single entry, but converted to a data frame
lros.in1 <- data.frame(t(c(0, 24.5, 50, 22.6, 120, 20.0, 90, 35)))
colnames(lros.in1) <- c("T1", "LengthT1T2", "T2", "LengthT1T3", "T3",
                      "LengthT2T3", "bearingT1T2", "bearingT1T3")
lros.out1 <- SimardRateOfSpreadLine(lros.in1)
lros.out1

# multiple entries using a dataframe
# load the test dataframe for lros
data("test_lros")
SimardRateOfSpreadLine(test_lros)
```

SimardRateOfSpreadPoint

Point-based input for Simard Rate of Spread and Direction

Description

SimardRateOfSpreadPoint is used to calculate the rate of spread and direction given one set of three point-based observations of fire arrival time. The function requires that the user specify the time that the fire crossed each point, along with the latitude and longitude of each observational point. This function allows quick input of a dataframe specifying one or many triangles.

Usage

```
SimardRateOfSpreadPoint(input)
```

Arguments

input	A dataframe containing input variables of Time fire front crossed points 1, 2, 3, and latitude/longitude for those same points. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important.
-------	--

<i>T1</i>	(required) Time that the fire front crossed point 1. Time entered in fractional
-----------	---

		format. Output ROS will depend on the level of precision entered (minute, second, decisecond)
<i>T2</i>	(required)	Time that the fire front crossed point 2. Time entered in fractional format. Output ROS will depend on the level of precision entered (minute, second, decisecond)
<i>T3</i>	(required)	Time that the fire front crossed point 3. Time entered in fractional format. Output ROS will depend on the level of precision entered (minute, second, decisecond)
<i>Long1</i>	(required)	Longitude for datalogger 1. (decimal degrees).
<i>Long2</i>	(required)	Longitude for datalogger 2. (decimal degrees).
<i>Long3</i>	(required)	Longitude for datalogger 3. (decimal degrees).
<i>Lat1</i>	(required)	Latitude for datalogger 1. (decimal degrees).
<i>Lat2</i>	(required)	Latitude for datalogger 2. (decimal degrees).
<i>Lat3</i>	(required)	Latitude for datalogger 3. (decimal degrees).

Details

SimardRateOfSpreadPoint allows R users to calculate the rate of spread and direction of a fire across a triangle, given three time measurements and details about the orientation and distance between observational points. The algorithm is based on the description from Simard et al. (1984).

Rate of spread and direction of spread are primary variables of interest when observing wildfire growth over time. Observations might be recorded during normal fire management operations (e.g., by a Fire Behaviour Analyst), during prescribed fire treatments, and during experimental research burns. Rate of spread is especially important for estimating Byram's fireline intensity, fireline intensity = heat constant of fuel \times weight of fuel consumed \times forward rate of spread (Byram 1959).

Rate of spread is difficult to measure and highly variable in the field. Many techniques were proposed over the years, but most were based on observations collected from a pre-placed reference grid and stopwatch (Curry and Fons 1938; Simard et al. 1982). Early approaches required that observers be in visual contact with the reference grid, but later, thermocouples and dataloggers were employed to measure the onset of the heat pulse at each point.

Simard et al. (1982) proposed calculations for spread based on an equilateral triangle layout. Simard et al. (1984) proposed calculations for spread based on any type of triangle. Both articles also discussed field sampling design and layout, with special attention to the size of the triangles (large enough that the fire traverses the triangle in one to two minutes) and even using triangles of varying size within one field plot (but no triangle larger than one fourth of the site's total area).

The underlying algorithms use trigonometry to solve for rate of spread and direction of spread. One important assumption is that the spread rate and direction is uniform across one triangular plot, and that the fire front is spreading as a straight line; Simard et al. (1982, 1984) acknowledge that these assumption are likely broken to some degree during fire spread events.

The functions require the user to arrange the input dataframe so that each triangle of interest is identified based on a new row in the dataframe. The input format forces the user to identify the triangles, one triangle per row of input dataframe. Very complex arrangements of field plot layouts are possible, and the current version of these functions do not attempt to determine each triangle of interest automatically.

Value

SimardRateOfSpreadPoint returns a dataframe which includes the rate of spread and spread direction. Output units depend on the user's inputs for distance (typically meters) and time (seconds or minutes).

Author(s)

Tom Schiks, Xianli Wang, Alan Cantin

References

1. Simard, A.J., Eenigenburg, J.E., Adams, K.B., Nissen, R.L., Deacon, and Deacon, A.G. 1984. A general procedure for sampling and analyzing wildland fire spread.
2. Byram, G.M. 1959. Combustion of forest fuels. In: Davis, K.P. Forest Fire Control and Use. McGraw-Hill, New York.
3. Curry, J.R., and Fons, W.L. 1938. Rate of spread of surface fires in the Ponderosa Pine Type of California. Journal of Agricultural Research 57(4): 239-267.
4. Simard, A.J., Deacon, A.G., and Adams, K.B. 1982. Nondirectional sampling wildland fire spread. Fire Technology: 221-228.

See Also

[SimardRateOfSpreadLine](#),

Examples

```
library(cffdrs)
# manual single entry
pros.in1 <- data.frame(t(c(2, -79.701027, 43.808872, 50, -79.699650, 43.808833
, 120, -79.700387, 43.809816)))
colnames(pros.in1)<-c("T1", "LONG1", "LAT1", "T2", "LONG2", "LAT2", "T3",
"LONG3", "LAT3")
pros.out1 <- SimardRateOfSpreadPoint(pros.in1)
# multiple entries using a dataframe
# load the test dataframe for pros
data("test_pros")
SimardRateOfSpreadPoint(test_pros)
```

SlopeAdjust

Slope Adjusted wind speed or slope direction of spread calculation

Description

Calculate the net effective windspeed (WSV), the net effective wind direction (RAZ) or the wind azimuth (WAZ).

Usage

```
SlopeAdjust(
  FUELTYPE,
  FPMC,
  BUI,
  WS,
  WAZ,
  GS,
  SAZ,
```

```

    FMC,
    SFC,
    PC,
    PDF,
    CC,
    CBH,
    ISI
)

```

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
BUI	The Buildup Index value
WS	Windspeed (km/h)
WAZ	Wind Azimuth
GS	Ground Slope (%)
SAZ	Slope Azimuth
FMC	Foliar Moisture Content
SFC	Surface Fuel Consumption (kg/m ²)
PC	Percent Conifer (%)
PDF	Percent Dead Balsam Fir (%)
CC	Constant
CBH	Crown Base Height (m)
ISI	Initial Spread Index
output	Type of variable to output (RAZ/WSV, default=RAZ)

Details

All variables names are laid out in the same manner as FCFDG (1992) and Wotton (2009).

Forestry Canada Fire Danger Group (FCFDG) (1992). "Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

list(RAZ, WSV) - Rate of spread azimuth (degrees) and Wind Slope speed (km/hr)

SurfaceFuelConsumption

Surface Fuel Consumption Calculator

Description

Computes the Surface Fuel Consumption by Fuel Type. All variables names are laid out in the same manner as FCFDG (1992) or Wotton et. al (2009)

Forestry Canada Fire Danger Group (FCFDG) (1992). "Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Usage

SurfaceFuelConsumption(FUELTYPE, FFMC, BUI, PC, GFL)

Arguments

FUELTYPE	The Fire Behaviour Prediction FuelType
FFMC	Fine Fuel Moisture Code
BUI	Buildup Index
PC	Percent Conifer (%)
GFL	Grass Fuel Load (kg/m ²)

Details

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

SFC Surface Fuel Consumption (kg/m²)

SurfaceRateOfSpreadC6 *C-6 Conifer Plantation Fire Spread Calculator*

Description

Calculate surface fire rate of spread (RSS).

Usage

SurfaceRateOfSpreadC6(RSI, BUI)

Arguments

RSI	Intermediate Surface Fire Rate of Spread
BUI	Buildup Index
FUELTYPE	The Fire Behaviour Prediction FuelType

Details

All variables names are laid out in the same manner as Forestry Canada Fire Danger Group (FCFDG) (1992). Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Value

RSS

References

<https://cfs.nrcan.gc.ca/publications/download-pdf/10068> Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

TotalFuelConsumption *Total Fuel Consumption calculation*

Description

Computes the Total (Surface + Crown) Fuel Consumption by Fuel Type. All variables names are laid out in the same manner as FCFDG (1992) or Wotton et. al (2009)

Forestry Canada Fire Danger Group (FCFDG) (1992). "Development and Structure of the Canadian Forest Fire Behavior Prediction System." Technical Report ST-X-3, Forestry Canada, Ottawa, Ontario.

Usage

```
TotalFuelConsumption(CFC, SFC)
```

Arguments

CFC	Crown Fuel Consumption (kg/m ²)
SFC	Surface Fuel Consumption (kg/m ²)

Details

Wotton, B.M., Alexander, M.E., Taylor, S.W. 2009. Updates and revisions to the 1992 Canadian forest fire behavior prediction system. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario, Canada. Information Report GLC-X-10, 45p.

Value

TFC Total (Surface + Crown) Fuel Consumption (kg/m²)

Index

* methods

- FireSeason, [13](#)
- gfm, [18](#)
- hffm, [21](#)
- OverwinterDroughtCode, [27](#)
- sdm, [32](#)

* package

- cffdrs.core-package, [2](#)

* ros

- SimardRateOfSpreadLine, [35](#)
- SimardRateOfSpreadPoint, [37](#)

BackRateOfSpread, [4](#)

BuildupEffect, [5](#)

BuildupIndex, [5](#)

cffdrs.core (cffdrs.core-package), [2](#)

cffdrs.core-package, [2](#)

CriticalSurfaceIntensity, [6](#)

CriticalSurfaceRateOfSpread, [7](#)

CrownFractionBurned, [7](#)

CrownFuelConsumption, [8](#)

CrownRateOfSpreadC6, [9](#)

DistanceAtTime, [9](#)

DroughtCode, [10](#)

DuffMoistureCode, [11](#)

fbp, [4](#), [23](#)

FineFuelMoistureCode, [12](#)

FireBehaviourPrediction, [12](#)

FireIntensity, [13](#)

FireSeason, [13](#), [13](#), [15](#)

fireSeason, [4](#), [28](#)

FireWeatherIndex, [16](#)

FlankRateOfSpread, [17](#)

FoliarMoistureContent, [17](#)

fwi, [4](#), [14](#), [15](#), [18](#), [20–23](#), [28](#), [33](#), [35](#)

gfm, [4](#), [18](#)

hffm, [4](#), [18](#), [20](#), [21](#)

hffmRaster, [23](#)

InitialSpreadIndex, [24](#)

IntermediateSurfaceRateOfSpreadC6, [25](#)

LengthToBreadthRatio, [25](#)

LengthToBreadthRatioAtTime, [26](#)

OverwinterDroughtCode, [27](#)

RateOfSpread, [29](#)

RateOfSpreadAtTheta, [30](#)

RateOfSpreadAtTime, [30](#)

RateOfSpreadC6, [31](#)

sdm, [32](#)

ShelteredDuffMoistureCode, [4](#), [34](#)

SimardRateOfSpreadLine, [35](#), [39](#)

SimardRateOfSpreadPoint, [37](#), [37](#)

SlopeAdjust, [39](#)

SurfaceFuelConsumption, [41](#)

SurfaceRateOfSpreadC6, [41](#)

TotalFuelConsumption, [42](#)

wDC, [4](#), [14](#), [15](#)