LANDIS-II Social-Climate-Fire (v4.0) User Guide

Robert M. Scheller[1]

Alec Kretchun

Zachary Robbins[1,2]

[1]North Carolina State University

[2]Los Alamos National Laboratory

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1. Introduction

This document describes the Social-Climate Fire ('SCF') extension for the LANDIS-II model. For information about the LANDIS-II model and its core concepts, see the *LANDIS-II Conceptual Model Description.*

1.1. Fire Simulation

We included three types of fires in the model: Lightning, Human Unintentional ('Accidental'), and Prescribed Fire ('RxFire'). Each has its own ignition and suppression and severity patterns. All fires behave similarly in regards to spread and mortality. Our model consists of four primary algorithms: Ignition, Spread, and Fire Severity, described below.

1.1.1. Ignition

Our ignitions follow a "supply and allocation" model whereby the supply of ignitions are generated from a zero-inflated Poisson model and then ignitions are allocated across the landscape with an ignition surface.

For Accidental and Lightning fires, the number of ignitions per day is determined from empirical data relating the number of ignitions (by each of three types) to FWI. Two separate equations can be fit to available ignition and FWI data. The first is a zero inflated Poisson distribution, where the probability of an excess zero is given as

zero(p) = $\frac{1}{(1+p)}$, (Equation 1)

where

p= $e^{b_{z0} + b_{z1} * FWI}$. (Equation 2)

Given that an ignition can occur on a day (not an excess zero) the number of fires is given as a random draw from a Poisson Distribution in which

Number of fires =Pois(Lambda=$e^{b0 + b1 * FWI}$). (Equation 3)

This requires fitting four-parameters to the model by ignition type. The second distribution type is the Poisson, in which only Equation 3 is fit to the data. This requires fitting only two-parameters. For both modes, Fire Weather Index (FWI) follows the calculations from the Canadian Fire Prediction System (1992) and is a smoothed averaged that integrates long- and short-term variation in precipitation and temperature. FWI was calculated for each day-of-the-year and the appropriate number of ignitions were generated for each day. The location of each ignition is determined below.

Please see https://github.com/LANDIS-II-Foundation/Extension-Social-

Climate-Fire/tree/master/Supporting%20R%20Code/Ignition_FWI for an example of this calculation.

For RxFire, a set number of fires are generated per year, based on expert input and/or scenario design. For each day of the year, a single RxFire is attempted, given that FWI is within a specified range and that the wind speed is below an allowable maximum. RxFires are attempted sequentially (by day of year) until the expected number of fires is successfully ignited. Conditions are placed on RxFire ignitions based on a minimum FWI (necessary to maintain fire spread, below), a maximum FWI (conditions under which prescribed fire would be avoided), and a maximum wind speed (again, conditions under which prescribed fire would be avoided).

A continuous weighted surface of historic ignitions occurrences is provided for each of the three ignition types and used to allocate ignitions. For regions where ignitions have no spatial pattern, this surface would be a constant value or a smoothed average of ignition rates. For other regions, the spatial pattern of ignitions could be projected based on climate change estimates. All available sites are then randomly shuffled, with an algorithm that biases selection by the weights (constant, historic, or projected) provided; ignition locations begin at the top of the shuffled list. The list of ignitions sites is re-shuffled at the beginning of each year.

In combination, the three ignition sources generate the total number of fires per year per fire type and is dependent upon FWI.

1.1.1.1. Fire Spread: Lightning and Accidental

From the point of ignition, fire spreads. Fire can spread to each adjacent cell dependent upon a probability of spread to adjacent neighbor (out of four nearest neighbors). Fire spread is from cell-to-cell and determines fire size. A fire will continue burning until no more cells are selected for spread.

Fire spread was built from a general equation relating event probability to FWI (Beverly and Wotton 2007):

Probability of Fire Spread = $\frac{\exp(Bx)}{1+\exp(Bx)}$ Equation 4

here βx is the probability of spread into a site given condition on that site:

$\beta x = \beta 0 + \beta 1(FWI) + \beta 2(FineFuels) + \beta 3(EffectiveWindSpeed)$ Equation 5

Where EffectiveWindSpeed is an adjusted wind speed (**kilometers/hour**) whereby reported wind speed and direction for the region (from meteorological stations) is downscaled to individual sites by accounting for slope angle and the slope azimuth relative to the wind direction (see Nelson 2002 for complete information). EffectiveWindSpeed also incorporates the severity of the source fire. A high severity fire burning upslope generates a greater EffectiveWindSpeed than a moderate or light fire. This in turn feeds back into the estimate of fire severity (see below), creating self-sustaining high-severity fires under certain conditions.

Note here and elsewhere: The climate library converts all wind speed units into kilometers / hour. *Be sure to convert your wind data into the correct units when inputting into the climate library.*

During model execution, fine fuels are estimated from endogenous (internal to the model framework) litter estimates. Notably, during model execution, fine fuels are dynamic over time to reflect reductions from fuel treatments or prescribed fire and additions from overstory mortality, e.g., from insect outbreaks.

A fire will spread (if it does not fail to or is not suppressed) until it has reached a maximum area for the day. Spread area is defined as the increase in day-to-day area of total fire perimeter. Maximum area (in hectares) is determined empirically:

Maximum daily spread area (ha) = $\beta 0 + \beta 1 * \text{FWI} + \beta 2 * \text{EffectiveWindSpeed}$ Equation 6

Note that the FWI and Effective wind speed parameters ($\beta 1 + \beta 2$) used to determine maximum daily spread are entirely separate from and derived differently from the parameters fit to determine successful cell-to-cell fire spread (Equation 5). In simulations, cell-to-cell and maximum daily fire spread are updated separately with daily FWI estimates until the fire can no longer spread (e.g. disconnected fuels), FWI levels reduces spread rates, or suppression is applied.

To estimate the fire spread parameters, spatial data are needed for daily FWI, daily wind speed, daily wind direction, and fine fuel loading for a set of reference fires. Daily fire perimeters are then overlain on each of the datasets to extract successful and unsuccessful spread areas. Our approach allows unburned islands within fire perimeters.

Please see https://github.com/LANDIS-II-Foundation/Extension-Social-Climate-Fire/tree/master/Supporting%20R%20Code/Spread/ for an example.

1.1.1.2. Fire Spread: Prescribed Fires

If it is a prescribed fire, default fire spread probability will be 1.0 although this can be reduced via suppression. Prescribed fires spread up until they reach their target size or are constricted by suppression or non-active cells. Prescribed fires occur entirely within a single day.

1.1.1.3. Fire Severity

A note on fire *severity* vs. *intensity*: Early versions of SCF emphasized fire *intensity*, the amount of energy released during a fire. This was implemented as three categories of flame length that subsequently caused mortality. Beginning with v3, SCF uses fire *severity* – the amount of change induced by a fire – as a determinant of mortality. All references to intensity within this document have therefore been changed to severity.

Fire severity is the mortality caused by fire at each site and varies depending on the tree species and ages present. Severity is represented in two stages to align with available data on severity and the understanding of mortality within a fire. The first is site level mortality, which is built to align with gridded observation of fire severity (such as those available in the dNBR style maps). This represents the cells experience of mortality without regard individual species presence. Site level severity is calculated as with an inverse link as

Site Level Severity =

$$\frac{1}{b_0+b_1(\text{Clay }\%)+b_2(\text{ET})+b_3(Eff.Windspeed)+b_4(\text{CWD})+b_5(\text{Fuels})} \text{ . Equation (7)}$$

Where Clay % is the percentage of soil that is clay based, ET is the previous years evapotranspiration by calculated with the model, Eff. Windspeed is the effective windspeed as described in above in fire spread, CWD is the climatic water deficit (potential evapotranspiration – evapotranspiration) calculated within the model, and Fuels is the fine fuels calculated within the model and described above in fire spread. This requires calculation of each of the variables b_x for the relative contribution of each variable. These variables were chosen for a flexibility of user definition to site severity, representing endogenous and exogenous site conditions. The maximum site level mortality is 2000. Site level mortality is then translated to a probability of mortality for each cohort based on its species and age. This is calculated as

P(mort)= $\frac{P}{1+P}$, Equation (8)

where,

P = $e^{(b_0+b_1 Bark+b_2 Site\ Level\ Mortality)}$. Equation (9)

This requires calculating 3 parameters. The site level mortality is given by the equation above and bark is calculated as

Bark = $\frac{Max\ Bark\ Thickness_s * Age}{Age+AgeDBH_s}$ Equation (10)

where Max Bark Thickness_s and AgeDBH_s are parameters estimated for each species, and Age is the cohort's age within the model. MaxBarkThickness is the bark thickness of the largest DBH observed within the species, and AgeDBH is a general relationship between Age and DBH for each species.

For further about site and cohort mortality, see Robbins et al. 2022.

See https://github.com/LANDIS-II-Foundation/Extension-Social-Climate-Fire/tree/master/Supporting%20R%20Code/Mortality for an example of how to calculate this.

1.2. References

Beverly, J. L., and B. M. Wotton. 2007. Modelling the probability of sustained flaming: predictive value of fire weather index components compared with observations of site weather and fuel moisture conditions. International Journal of Wildland Fire 16:161-173.

Nelson, R.M. 2002. An effective wind speed for models of fire spread. International Journal of Wildland Fire 11: 153–161.

Robbins, Z.J., E.L. Loudermilk, M.J. Reilly, J.J. O'Brien, K. Jones, C.T. Gerstle, R.M. Scheller. 2022. Delayed fire mortality has long-term ecological effects across the Southern Appalachian landscape. Ecosphere 13: e4153.

Scheller, R.M., A. Kretchun, T.J. Hawbaker, P.D. Henne. 2019. A landscape model of variable social-ecological fire regimes. Ecological Modelling 401: 85-93.

1.3. Acknowledgments

Funding for this extension was provided by USFS Southwest Region.

1.4. Major Versions

1.4.1. Version 4.0 (August 2024)

Update to Core v8.0.

1.4.2. Version 3.2 (October 2021)

The climate library was updated to v4.2. Also added a dNBR output map. Minor fixes to documentation and fine fuels.

1.4.3. Version 3.1 (March 2021)

The climate library was updated to v4.2. The event log file was expanded to include additional entries. Ladder fuel max age was fixed.

1.4.4. Version 3.0 (February 2021)

Major revisions to site mortality (aka ‘fire severity’) and to cohort mortality with new inputs and retirements of prior inputs. Included new ignition options (Poisson versus Zero-inflated Poisson). Adjustment to how ignition algorithm is executed. Included change to spread based lower probability to diagonally adjacent cells, to account for increased distance.

1.4.5. Version 2.4 (August 2020)

Updated to latest version of the climate library (v4.1). Also added dynamic lightning ignition maps and dynamic accidental ignition maps.

1.4.6. Version 2.3 (May 2019)

Added additional input parameters for prescribed fires: Maximum temperature, minimum relative humidity, last day of prescribed fire, and number of prescribed fires per day.

1.4.7. Version 2.2 (April 2019)

Update to climate library v4. Other small improvements.

1.4.8. Version 2.1 (November 2018)

Now includes dynamic ignition maps for prescribed fire and prescribed fire zones map.

1.4.9. Version 2.0 (September 2018)

Compatible with Core v7.

1.4.10. Version 1.1 (June 2018)

If it is a prescribed fire, default fire spread probability will be 1.0 although this can be reduced via suppression. Prescribed fires spread up until they reach their target size or are constricted by suppression or non-active cells. Prescribed fires occur entirely within a single day.

1.4.11. Version 1.0 (April 2018)

First release.

1.5. Minor Versions (this major release)

2. Parameter Input File

Most of the input parameters for this extension are specified in one input file. This text file must comply with the general format requirements described in section 3.1 *Text Input Files* in the *LANDIS-II Model User Guide*.

2.1. LandisData

This parameter's value must be `"Social Climate Fire"`.

2.2. Timestep (Not functional)

Note: This parameter is not functional. Because SCF requires daily data, it cannot produce an average fire regime for longer than annual time steps. Therefore, the default is 1. Future versions will remove this parameter.

2.3. TimeZeroPET (optional double)

The Potential Evapotranspiration (PET) for time zero. Because there is no preceding weather data at time one, it is sometimes necessary to give time zero a PET value to prevent too much fire initially.

2.4. TimeZeroCWD (optional double)

The Climate Water Deficit (CWD) for time zero. Because there is no preceding weather data at time one, it is sometimes necessary to give time zero a CWD value to prevent too much fire initially.

2.5. Species_CSV_File

The parameter specifies the location of a .csv file containing the columns "SpeciesCode", "AgeDBH","MaximumBarkThickness". Each row should be a species code (from the list of model species) followed by the parameters described in Equation 10. These are empirical relationships derived from empirical data.

2.6. AccidentalIgnitionsMap

This parameter specifies a raster map to represent where accidental ignition occur. The map units are double (allowing for fractions). Units are not specified. The map data weights the location of accidental ignitions occurrence whereby the list of values are sorted with higher values more likely near the top; ignitions are sequentially drawn from this weighted, sorted list. Values of 0.0 will not ignite.

User Tip: If empirical ignition data exist, these can be used to create a continuous surface of probability of ignition per year. If no such data exist, the map can have a single value and will therefore random locations will be selected.

2.7. DynamicAccidentalIgnitionMaps (Optional)

This **optional table** allows you to change accidental fire ignition maps for any given year. The table contains **simulation year** and **map name**, each pair on a separate line.

```
DynamicAccidentalIgnitionMaps << Optional
3       AccIgnitions3.img
5       AccIgnitions5.img
13      AccIgnitions13.img
```

2.8. LightningIgnitionsMap

This parameter specifies a raster map to represent where lightning ignitions occur. The map units are double (allowing for fractions). Units are not specified. The map data weights the location of accidental ignitions occurrence whereby the list of values are sorted with higher values more likely near the top; ignitions are sequentially drawn from this weighted, sorted list. Values of 0.0 will not ignite.

2.9. DynamicLightningIgnitionMaps (Optional)

This **optional table** allows you to change lightning fire ignition maps for any given year. The table contains **simulation year** and **map name**, each pair on a separate line.

```
DynamicLightningIgnitionMaps << Optional
3       LtIgnitions3.img
5       LtIgnitions5.img
13      LtIgnitions13.img
```

2.10. RxIgnitionsMap

This parameter specifies a raster map to represent where prescribed fire occur. The map units are double (allowing for fractions). Units are not specified. The map data weights the location of accidental ignitions occurrence whereby the list of values are sorted with higher values more likely near the top; ignitions are sequentially drawn from this weighted, sorted list. Values of 0.0 will not ignite.

2.11. DynamicRxIgnitionMaps (Optional)

This **optional table** allows you to change prescribed fire ignition maps for any given year. The table contains **simulation year** and **map name**, each pair on a separate line.

```
DynamicRxIgnitionMaps << Optional
3       RxIgnitions3.img
5       RxIgnitions5.img
```

```
13       RxIgnitions13.img
```

2.12. AccidentalSuppressionMap

This parameter specifies a raster map to represent where and how accidental fires are suppressed. The map units are integers and should only include: 0, 1, 2, 3, indicating no suppression, light, moderate, and maximal suppression is possible. This relates to the possible suppression probabilities listed in 2.55 SuppresionTable.

2.13. LightningSuppressionMap

This parameter specifies a raster map to represent where and how lightning fires are suppressed. The map units are integers and should only include: 0, 1, 2, 3, indicating no suppression, light, moderate, and maximal suppression is possible. This relates to the possible suppression probabilities listed in 2.55 SuppresionTable.

2.14. RxSuppressionMap

This parameter specifies a raster map to represent where and how prescribed fires are suppressed. The map units are integers and should only include: 0, 1, 2, 3, indicating no suppression, light, moderate, and maximal suppression is possible. This relates to the possible suppression probabilities listed in 2.55 SuppresionTable.

2.15. DynamicAccidentalSuppressionMaps (Optional)

This **optional table** allows you to change accidental suppression maps for any given year. The table contains **simulation year** and **map name**, each pair on a separate line.

```
DynamicAccidentalSuppressionMaps << Optional
3        AccSupp3.img
5        AccSupp5.img
13       AccSupp13.img
```

2.16. GroundSlopeFile

This parameter specifies a raster map to represent ground slope ***in degrees***. The map should have integer values representing degrees on the ground.

2.17. UphillSlopeAzimuthMap

This parameter specifies a raster map to represent the direction of uphill slope. Values in this map should be integers ranging from 0 to 360 degrees, specifying the direction upslope. Note: this is the opposite of the way aspect is commonly defined.

2.18. Clay Map

This parameter specifies a raster map to represent the percent clay. Values in this map should range for 0 to 1.

2.19. LightningIgnitionsB0

The B0 parameter from equation 1 (Scheller et al. 2019). This value is empirically derived for lightning ignitions.

2.20. LightningIgnitionsB1

The B1 parameter from equation 1 (Scheller et al. 2019). This value is empirically derived for lightning ignitions.

2.21. AccidentalIgnitionsB0

The B0 parameter from equation 1 (Scheller et al. 2019). This value is empirically derived for accidental ignitions.

2.22. AccidentalIgnitionsB1

The B1 parameter from equation 1 (Scheller et al. 2019). This value is empirically derived for accidental ignitions.

2.23. IgnitionDistribution

This parameter indicates to the model which ignition sub-model you are using either, ZeroInflatedPoisson or Poisson

2.24. LightningIgnitionsBinomialB0

The b_{z0} parameter from equation 2. This value is empirically derived for lightning ignitions.

2.25. LightningIgnitionsBinomialB1

The b_{z1} parameter from equation 2. This value is empirically derived for lightning ignitions.

2.26. AccidentalIgnitionsBinomialB0

The b_{z0} parameter from equation 2. This value is empirically derived for accidental ignitions.

2.27. AccidentalIgnitionsBinomialB1

The b_{z1} parameter from equation 2. This value is empirically derived for accidental ignitions.

2.28. MaximumFineFuels

This is the maximum amount of fine fuels (g m^{-2}), above which more fuels do not increase fire spread. The value rescales the fine fuel parameter in equations 5 and 7 (above. See also Scheller et al. 2019). The parameter is often estimated from landscape average fine fuels excluding any recent disturbances.

2.29. MaximumRxWindSpeed

The maximum wind speed under which prescribed fires will be ignited on the landscape.

2.30. MaximumRxFireWeatherIndex (Optional)

The maximum Fire Weather Index under which prescribed fires will be put on the landscape.

2.31. MinimumRxFireWeatherIndex (Optional)

The minimum Fire Weather Index under which prescribed fires will be put on the landscape. Typically prescribed fires will *not* be attempted if fuels are too moist.

2.32. MaximumRxTemperture (Optional)

The maximum temperature (Celsius) under which prescribed fires will occur.

2.33. MinimumRxRelativeHumidity (Optional)

The minimum relative humidity necessary for prescribed fires. If the relative humidity is too low, prescribed fires are often avoided as it indicates very dry conditions.

2.34. MaximumRXFireIntensity

The maximum allowable fire *severity* for prescribed fires. Prescribed fires will not exceed this intensity level. **Note**: Although the meaning has changed to fire severity, the keyword remains the same.

2.35. NumberRxAnnualFires

The number of prescribed fires attempted per year.

2.36. NumberRxDailyFires

The number of prescribed fires attempted per day.

2.37. FirstDayRxFires

The first Julian day in which a prescribed fire can begin. This is important if fall burning is preferred over spring burning.

2.38. LastDayRxFires

The last Julian day in which a prescribed fire can begin.

2.39. TargetRxSize

The maximum size for a prescribed fire in hectares.

2.40. RxZonesMap (Optional)

This **optional map** creates stands for prescribed fires. A prescribed fire will burn only within the zone (stand) within which it starts. It will NOT burn into other zones. The size remains limited by **TargetRxSize**.

This parameter specifies a raster map to represent stands. The map units are integers.

2.41. MaximumSpreadAreaB0

The B0 (intercept) parameter from equation 4 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

Note: Though empirically derived, this parameter can be used to match fire regime calibration targets.

Note: Equation #4 calculates area in hectares.

2.42. MaximumSpreadAreaB1

The B1 parameter (*FWI) from equation 4 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

2.43. MaximumSpreadAreaB2

The B2 parameter (*Effective wind speed) from equation 4 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

Note: The climate library converts all wind speed units into **kilometers / hour**.

2.44. SpreadProbabilityB0

The B0 (intercept) parameter from equation 3 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

Note: Though empirically derived, this parameter can be used to match fire regime calibration targets.

2.45. SpreadProbabilityB1

The B1 (*FWI) parameter from equation 3 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

2.46. SpreadProbabilityB2

The B2 (*Fine fuels) parameter from equation 3 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

2.47. SpreadProbabilityB3

The B3 (*Effective wind speed) parameter from equation 3 (Scheller et al. 2019). This value is empirically derived from all fires in the landscape or region.

Note: The climate library converts all wind speed units into **kilometers / hour**.

2.48. SiteMortalityB0

The b0 parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape.

2.49. SiteMortalityB1

The b1 (*Clay %) parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape in combination with maps of soil composition.

2.50. SiteMortalityB2

The b2 (*previous years ET) parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape and estimates of annual ET or products such as MODIS 16.

2.51. SiteMortalityB3

The b3 (*Effective Windspeed) parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape and estimates of daily windspeed calculated with respect to slope and aspect.

Note: The climate library converts all wind speed units into **kilometers / hour**.

2.52. SiteMortalityB4

The b4 (*previous years CWD) parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape and estimates of annual PET and ET or products such as MODIS 16.

2.53. SiteMortalityB5

The b5 (*Fine fuels) parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape and estimates of fuels.

2.54. SiteMortalityB6

The b6 (*Ladder Fuels) parameter for equation 7. The value is empirically derived from maps of fire severity for a landscape and estimates of ladder fuels.

2.55. CohortMortalityB0

The b0 parameter for equation 10. The values for equation ten are empirically derived by relating site level measures of severity (such as DNBR, or CBI) and individual cohort mortality as measured from field data.

2.56. CohortMortalityB1

The b1 parameter for equation 10. The values for equation ten are empirically derived by relating site level measures of severity (such as DNBR, or CBI) and individual cohort mortality as measured from field data.

2.57. CohortMortalityB2

The b0 parameter for equation 10. The values for equation ten are empirically derived by relating site level measures of severity (such as DNBR, or CBI) and individual cohort mortality as measured from field data.

2.58. LadderFuelMaxAge

May determine site-level mortality. The maximum age at which a cohort is still considered a ladder fuel, i.e., the cohort is a ladder fuel until reaching this age. The biomass of all cohorts ≥ `LadderFuelMaxAge` listed in `LadderFuelSpeciesList` are summed.

2.59. LadderFuelSpeciesList

A list of species codes for species that are considered ladder fuels. Conifers are typically considered ladder fuels but rhododendrons and other shrubs may also act as ladder fuels.

2.60. SuppressionMaxWindSpeed

The wind speed (m $^{s-1}$) above which no resources would be deployed to suppress a fire. This parameter is intended to capture weather conditions under which fire response is prohibitively dangerous.

2.61. Suppression_CSV_File

The file name of a CSV file with the following column headers:

IgnitionType: Accidental, Lightning, or Rx (text input)

Mapcode: The map code in the corresponding suppression map (integer)

Suppress_Category_0: The suppression effort, given a FWI < FWI_Break_1 (integer). Suppression effort defines how much the probability of spread is reduced by suppression, e.g., 5%, 65%, 95%, and reflects the resources that would be committed to suppression under low fire risk, moderate fire risk, and high fire risk (as defined by the two FWI break points).

FWI_Break_1: The daily FWI that defines the highest FWI for suppression category 0 (integer)

Suppress_Category_1: The suppression effort, given a FWI > FWI_Break_1 and < FWI_Break_2 (integer)

FWI_Break_2: The daily FWI that defines the highest FWI for suppression category 1 (integer)

Suppress_Category_2: The suppression effort, given a FWI > FWI_Break_2 (integer)

Combined, these data create a table that defines suppression effectiveness for each ignition type and across three different FWI ranges. As an example:

2.62. DeadWoodTable

We designed this table to track snags generated by fire. There can be zero or more lines, each corresponding to a species. For each species, there is a minimum age at which a cohort generates snags due to fire. For example:

```
DeadWoodTable

PinuJeff    50
```

IgnitionType	Mapcode	Suppress_Category_0	FWI_Break_1	Suppress_Category_1	FWI_Break_2	Suppress_Category_2
Accidental	1	10	20	20	30	0
Accidental	2	30	20	95	30	10
Accidental	3	95	20	95	30	75
Lightning	1	10	20	20	30	0
Lightning	2	30	20	95	30	10
Lightning	3	95	20	95	30	75
Rx	1	10	20	20	30	0
Rx	2	30	20	95	30	10
Rx	3	95	20	95	30	75

3. Output Files

The extension outputs were designed to assist with model calibration, parameterize, and to analyze fire behavior in the simulation. Full metadata for all outputs is available in the Metadata/social-climate-fire sub-folder after a simulation is run.

3.1. Day of Fire Maps

The map of 'fire days' tracks on which day of the year a cell burned. Map values equal Julian day of time step. Note: map values = 0 indicates an inactive site; 1 = active but unburned; > 1 = Day-of-year for the fire + 1.

3.2. Fire Severity Maps

The map of fire severity reports at which severity (1-10) a cell burned. Map values: 0 = Non-active; 1=Unburned site, 1-10 = Fire severity 1-10.

3.3. Fire Spread Probability Maps

The map of fire spread probability. Map values: 0 = Inactive or unburned site, >0 = A disturbed site with fire spread probability x 100.

3.4. Fire Ignition Type Maps

There are three ignition types with values: 0 = non-active site, 1=active and unburned, 2 = Accidental; 3 = Lightning; 4 = Rx.

3.5. Fine Fuels Maps

Range from 0.0 – 1.0 and equal the fine fuels (from a succession extension) divided by maximum fine fuels (SCRPPLE user input) with a maximum of 1.0.

3.6. Event ID Maps

These maps give the event ID, to be paired with the Event Log (below). Map values: 0 = Inactive or unburned site, > 0 = A disturbed site an assigned Event ID.

3.7. Fire Ignition Log

The Fire ignition table is designed to capture the relationship between attempted FWI and number of fire ignitions for each type, for each day and year. This log file tracks the number of ignitions and the climatic conditions under which they occurred: year, Julian day of year, number of attempted ignitions, Fire Weather Index, and type of ignition

3.8. Fire Event Log

The Fire event table is designed to record the fire characteristics of each individual fire event. The event log is a text file that contains information about every fire event:

- Year
- ignition row number
- ignition column number
- initial Fire Weather Index
- initial Julian day
- ignition type
- number of days a fire burned
- total sites burned
- number of cohorts killed
- mean wind speed
- mean effective wind speed
- mean wind azimuth direction
- mean suppression effectiveness level
- mean Fire Weather Index
- mean spread probability
- mean fire severity
- total biomass killed

The information is stored as comma-separated values (CSV).

3.9. Fire Summary Log

The Fire landscape summary table is designed to summarize fire characteristics at the landscape scale. The fire time step log is a text file that contains summary information about all the events that occurred during each fire time step:

- Year
- number of cells burned by accidental human ignited fires
- number of cells burned by lightning ignited fires
- number of cells burned by prescribed fires
- number of accidental human ignited fires
- number of lighting ignited fires
- number of prescribed fires
- total biomass killed by human accidental ignited fires (g m^{-2})
- total biomass killed by lightning ignited fires (g m^{-2})
- total biomass killed by prescribed fires (g m^{-2})

The information is stored as comma-separated values (CSV).

4. Sample Input File

Sample input date are available at

https://github.com/LANDIS-II-Foundation/Extension-Social-Climate-Fire/tree/master/Testing