LANDIS-II Dynamic Fuel System Extension (v2.1) User Guide

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1 Introduction

This document describes the **Dynamic Fuel System** extension for the LANDIS-II model. For information about the model and its core concepts, see the *LANDIS-II Conceptual Model Description*.

The **Dynamic Fuel System** extension described herein uses species age, conifer mortality, and post disturbance information at each site to classify every active site into a season-independent fuel type. This extension will produce maps of fuel types, percent conifer, and percent dead fir. Assigning active sites to fuel types is a required input for the external **Dynamic Fire System** extension. Therefore, the Dynamic Fuel System is a disturbance extension and should be run immediately prior to the Dynamic Fire System within the scenario file.

1.1 Fuel Types

A fuel type can be defined as “an identifiable association of fuel elements of distinctive species, form, size, arrangement, and continuity that will exhibit characteristic fire behavior under defined burning conditions" (Merrill and Alexander 1987). For example, the Canadian Fire Prediction System fuel types are described qualitatively based on stand structure, composition, surface fuels, ladder fuels, and forest floor characteristics, including cover and duff (FBP; Forestry Canada Fire Danger Group 1992). The Canadian FBP System includes five major groups and 16 discrete fuel types (Appendix, Table 1).

The LANDIS-II **Dynamic Fuel System** extension (‘fuel extension’ henceforth) allows up to 100 different fuel types, limited to the following base fuel types: Conifer, ConiferPlantation (type C-6 in the Canadian FBP System), Deciduous, Slash, and Open. The rules defined below determine which fuel type each site is assigned. These types – each given a numeric index - must match the fuel types and indices defined in the **Dynamic Fire System** extension. If a site is assigned a fuel type that is not listed in the Dynamic Fire System extension, the default values will be zero and fire will be unable to spread and burn across that site.

1.2 Fuel Classification

The fuels classification is determined by where a cohort falls within a fuel type age range. The formula is:

$$SpeciesValue = \sum_{0}^{n} \frac{CohortAge - RangeMinimum}{RangeMaximum - RangeMinimum} \times SppCoefficient$$

where CohortAge is the age (years) of the oldest cohort of that species that falls between RangeMaximum and RangeMinimum; RangeMaximum is the maximum of the age range for a given fuel type; RangeMinimum is the minimum of the age range for the same fuel type; and SppCoefficient is a user specified weight (0 – 1.0) that can be assigned to each species (default = 0). For each species, RangeMaximum is truncated to the species longevity if it exceeds longevity.

For each fuel type, these species values are summed (or subtracted if given the negative switch, see below), depending upon which species are listed for the fuel type. The fuel type with the highest overall score is assigned to the cell.

The species coefficients provide flexibility in determining the influence of a particular species on fire spread rates for mixedwood fuel types, and is a user input value ($0.0 \leq SppCoefficient \leq 1.0$). Species coefficients are generally recommended at or near 1.0 (the default value) for all species. For instance, a species coefficient value of 0.95 for a particular conifer species in a mixedwood type can substantially reduce conifer dominance (see below), giving more influence to the deciduous component on fire spread rates. If a deciduous species is assigned a *SppCoefficient* < 1.0, then the conifer component in a site with that species will have more influence on fire spread rates.

In order to accommodate mixed fuel types, a deciduous fuel type is also calculated based solely on the fuel types that are designated ‘Deciduous’ base type.

1.3 Conifer and Deciduous Dominance

Conifer and deciduous dominance (CD and DD, respectively) is used to determine if sites are initially assigned to either a coniferous, deciduous, or a mixed fuel type. The actual blending of a conifer type and a deciduous type to create a mixed type occurs within the Dynamic Fire System and the user need not create mixed types in the Dynamic Fire System.

The conifer dominance is calculated using the sum of dominance values for the two conifer base types (Conifer and ConiferPlantation). Deciduous dominance is

the sum of dominance values for the Deciduous base type. To determine their respective types, each is divided by the sum of conifer plus deciduous dominance.

An optional, maximum percent hardwood (PH) "cut-off" value can be set that will determine whether sites containing both deciduous and coniferous species are treated as a single fuel or a mixed fuel type. The default maximum PH value for placement of a site into the coniferous fuel group category is 0% (i.e., CD = 1.0). Under this default setting, active sites that contain both deciduous and coniferous species (i.e., PH > 0%; CD < 1.0) are treated as a mixed fuel types and fire spread rates will be calculated as a proportional blend of the deciduous and coniferous fuel types (see equations 27 & 28 in the **Dynamic Fire System** Users Guide). The PH can be adjusted such that an active site containing both coniferous and deciduous species being placed into either a coniferous or deciduous fuel type. This enables the user to prevent sites from being treated as a mixed fuels when either the deciduous or coniferous component is minor (e.g., a mature-conifer dominated site that contains one young-age cohort of a single deciduous species). The PH can also be used to categorize mixed sites as entirely deciduous (when CD > 100 – PH). Therefore, if the PH value is > 0, mixed types occur only when CD is between PH and 100 – PH. Caution should be used in setting the maximum PH value above the default value (zero), and interactions with the user-defined fuel coefficient set in the CD equation should be carefully considered and tested.

If the selected fuel type is either Slash or Open base fuel types, then both the conifer dominance and deciduous dominance are set to zero. If the selected fuel type is ConiferPlantation, then conifer dominance is set to 100 and deciduous dominance set to zero.

1.4 Dead Conifer Index

To reflect the ladder-fuel effects of dead conifers in a stand understory, the Dynamic Fuel System can apply an optional dead conifer index calculated from the **Base BDA** Extension. The dead conifer index is based on the total number of dead fir and spruce cohorts relative to the current total number of cohorts at each site, with possible values ranging from 0 to 100. An input duration determines how far back in simulation time to consider dead fir cohorts.

The dead conifer index input is applied to all mixed and conifer fuel types within the **Dynamic Fire System**. Any dead conifer index value > 0 alters the spread rate for any Conifer, Conifer Plantation, and any mixed fuel types (depending on the fire season input in the Fire Extension). A conifer fuel type combined with dead conifer index > 0 will be converted to the M-3 (dead balsam fir leaf off) fuel type in the Dynamic Fire System. The deciduous and mixed fuel types combined with a dead conifer index > 0 can be converted to either M-3 or M-4 fuel types, dependent upon fire season. If the optional dead conifer index or the Base BDA Extension are not active, the Dynamic Fuel Extension will assign a default value of "no effect" for the dead conifer index.

1.5 Post Disturbance Information

To simulate the change in fuels following a disturbance, the fuels extension provides an option to assign an active site to a new fuel type. The user must also indicate the duration (in number of years) for the conversion fuel types. These new fuel types can be any fuel listed in the **Dynamic Fire System** extension. After a stipulated number of years expire, the conversion fuel type is replaced by a new fuel type, based on other fuel extension inputs and parameters.

The name of the disturbance can be one of three general options: 1) a Harvest prescription name, 2) a wind severity, or 3) a fire severity. The rules for giving fire and wind severity names are given below.

If a harvest prescription results in a slash types, remember that slash typically persists for only a few years after harvest. Unless fuels are arranged to occur after harvesting and with the same time step, this short time frame requires setting yearly time steps in the Dynamic Fuel System.

1.6 Major Versions

1.6.1 Version 2.1

Added compatibility with the Metadata library. The Metadata Library outputs metadata for all model outputs, allowing compatibility with visualization tools.

1.6.2 Version 2.0

The Dynamic Fuel System v2.0 (and later) is compatible with LANDIS-II v6.0.

1.7 Minor Versions

1.7.1 Version 2.0.1

Version 2.0.1 fixes a bug that did not allow harvest prescriptions to alter the fuel type.

1.8 Acknowledgements

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2 Input File

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 parameters value must be "Dynamic Fuel System"

2.2 Timestep

This parameter is the timestep of the wind extension. Value: integer > 0. Units: years.

2.3 Species Fuel Coefficients

This parameter is a list of tree species with user-assigned fuel coefficients for determining relative dominance as a fuel type. If a species is not listed the default value is one (1).

2.4 Hardwood Maximum

The optional Hardwood Maximum value determines the maximum percent (%) hardwood acceptable for a site to be placed into a coniferous fuel group and must be an integer between 1 and 100. If this parameter is not present, then the default value of zero (0) is used.

2.5 Dead Fir Maximum Age

The DeadFirMaxAge value determines the duration of influence for the dead conifer index produced by the BDA Extension. After this amount of time has passed since the last BDA event for each site, the dead conifer index for that site will be reset to 0.

2.6 Fuel Type Table

This suite of parameters defines the desired fuel type classification outputs and must be preceded by the keyword FuelTypes. The input is a table with user-defined fuel types, a base fuel category for each fuel type, the characteristic

species for each fuel type, and the cohort age range for the characteristic species in each fuel type (Table 1).

Table 1.

Parameter	Data Type	Units	Example
Fuel Type Index	int		1
BaseFuel	string		Deciduous
Age range	{int} to {int}	years	0 to 40
Species	string		pinustro

The Fuel Type Index is an integer value that connects the fuel type to fuel parameters in the Fire Extension. The index values provided here should match index values included in the FuelTypeTable in the fire extension input file. All index values in the fuel input file must be included in the fire input file.

The BaseFuel category defines which fuel types are considered Conifer, ConiferPlanation, Deciduous, Open, or Slash. These categories are used in calculations of conifer dominance and for fire spread and severity calculations in the Fire Extension. The base fuel category identified for each fuel type here should match the base fuel category defined for the same fuel type in the Fire Extension FuelTypeTable input.

If a species should contribute to the dominance value of a fuel type, list the species name in the Species column. If a species should be subtracted from a fuel type, list the species name preceded by a '-' (negative) sign.

This table requires entries for fuel types within the coniferous, deciduous and open fuel groups. Descriptions for boreal mixedwood (M-1, M-2) and dead balsam fir mixedwood (M-3, M-4) fuel types are not entered into this table, as these are delineated differently, using conifer dominance and dead conifer index

inputs, respectively. Unforested sites will have a default value of zero (0), unless a default fuel type is specified for the ecoregion in the Fire Extension.

2.7 Post Disturbance Fuel Information

This optional suite of parameters defines the conditions under which the fuel types are modified by other disturbances and must be preceded by the keyword DisturbanceConversionTable. The input is fuel type index, the maximum duration (age in years) of each disturbance fuel type, and the exact name of the harvest prescription used in the Base Harvest Extension or disturbance type and severity class that will create that particular fuel type (Table 3). The fuel type index should correspond to fuel type indices included in the Fire Extension input file. The keywords FireSeverity and WindSeverity have been designated to cause fire and wind disturbances to change fuel types. Each keyword should be followed immediately (no space) by the severity class (1-5) of that disturbance to be used (e.g., FireSeverity3, WindSeverity4).

Table 3.

Parameter	Data Type	Units	Example
Fuel Type	integer		13
Duration	integer	years	3
Disturbance	string		JackPineClear
			WindSeverity4
			FireSeverity2

2.8 Fuel Type Maps

The next parameter, MapFileNames, describes where the fuel type map is placed and its format. This convention applies to all map names. The first portion lists the directory where the maps should be placed relative to the location of the scenario text file (e.g., fire/). The parameter value "timestep" must be included and will be replaced with the output time step.

Other characters can be inserted as desired. A meaningful file extension (e.g., .gis) should also be included.

Fuel types are mapped as their index + 1. Non-active sites are given a value of zero.

2.9 Percent Conifer Map Name

The next parameter, PctConiferMapName, describes where the percent conifer output maps are placed and their format. The first portion lists the directory where the maps should be placed relative to the location of the scenario text file (e.g., fire/). The parameter value “timestep” must be included and will be replaced with the output time step. Other characters can be inserted as desired. A meaningful file extension (e.g., .gis) should also be included.

2.10 Percent Dead Fir Map Name

The final parameter, PctDeadFirMapName, describes where the percent dead fir output maps are placed and their format. The first portion lists the directory where the maps should be placed relative to the location of the scenario text file (e.g., fire/). The parameter value “timestep” must be included and will be replaced with the output time step. Other characters can be inserted as desired. A meaningful file extension (e.g., .img) should also be included.

3 Example File

```
LandisData  "Dynamic Fuel System"


Timestep  10


>>            Fuel
>> Species    Coefficient
>> --------   -----------
   betupapy    0.90
   piceglau    0.95



>> Optional Percent Hardwood Value (%)
HardwoodMaximum    10


DeadFirMaxAge  15


FuelTypes
>> Fuel Type      BaseFuel    Age Range       Species
>> ---------      --------    ---------     ----------
   2              Conifer     0 to 400     piceglau abiebals
   3              Conifer     0 to 40      pinubank
   4              Conifer     41 to 100    pinubank
   5              Conifer     100 to 400   pinustro pinuresi –abiebals
   6              ConiferPlantation 10 to 100    pinustro pinuresi
```

```
   16              Open         0 to 10      pinustro pinuresi
   8               Deciduous    0 to 1000    betupapy


DisturbanceConversionTable
>> SlashType    Duration    Prescription (more than one allowed)
>> ----------   ------    --------------
13               5         JackPineClearCut
14               15        WhiteSpruceHarvest


MapFileNames    fire/FuelType-{timestep}.gis
PctConiferMapFileName fire/PctConifer-{timestep}.img
PctDeadFirMapFileName fire/PctDeadFir-{timestep}.img
```

4 Appendix

Table 1. Canadian FBP System fuel types. For a complete description of each type, refer to Canadian Forest Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992) These fuel type are **not required**.

Group/Identifier	Descriptive name
Coniferous	
C-1	Spruce-lichen woodland
C-2	Boreal spruce
C-3	Mature jack or lodgepole pine
C-4	Immature jack or lodgepole pine
C-5	Red and white pine
C-6	Coniferous plantation
C-7	Ponderosa pine-Douglas-fir
Deciduous	
D-1	Leafless aspen
Mixedwood	
M-1	Boreal mixedwood-leafless
M-2	Boreal mixedwood-green
M-3	Dead balsam fir mixedwood-leafless
M-4	Dead balsam fir mixedwood-green

Slash	
S-1	Jack or lodgepole pine slash
S-2	White spruce-balsam slash
S-3	Coastal cedar-hemlock-Douglas-fir slash
Open	
O-1	Grass