Fuel Type Output Extension for LANDIS-II
User Guide (v1.0)

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1 Introduction

This document describes the **Fuel Type Output 2006** extension for the LANDIS-II model. For information about the model and its core concepts, see the LANDIS-II Conceptual Model Description.

The fuel type output extension described herein uses species cohort and conifer mortality information at each site, combined with fire season, to classify every active site into a fuel type, based on fuel types defined in the Canadian Forest Fire Behavior Prediction System (FBP; Forestry Canada Fire Danger Group 1992). This output extension will produce a single map of fuel types, and it produces 2 site variable that can be seen by all other extensions: fuel type and conifer dominance.

1.1 Overview of 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). The Canadian FBP 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). Seasonal stand characteristics (spring leaf-off, summer leaf-on, fall leaf-off) based on the Canadian Fire Weather Index (FWI) further define some fuel types. The Canadian FBP System includes five major groups and 16 discrete fuel types (Table 1).

Table 1. Canadian FBP System fuel types.

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

The LANDIS fuel type output extension requires up to 7 parameter inputs to assign active sites to a fuel type, including:

1) an index of conifer dominance for all types;
2) a list of characteristic species for each coniferous and deciduous fuel type;
3) a cohort age range for characteristic species (required for some coniferous fuel-types);
4) the fire season;
5) a dead conifer index;
6) a slash index; and
7) a curing coefficient, required for O-1a and O1b (grass) fuel types only.

1.2 Conifer Dominance

Conifer dominance (CD) is used to determine if sites are initially assigned to either a coniferous (CD = 1.0), deciduous (CD = 0.0), or mixedwood (0.0 < CD < 1.0) fuel group. Conifer dominance is calculated using the sum of dominance values for conifer species divided by the sum of dominance values for all species for each site. Individual species dominance values are derived from a fuzzy algorithm:

$$D_{Species} = MaximumAge_{Species} / Longevity_{Species} \; x \; FuelCoefficient_{Species}$$

Maximum age is the oldest cohort for that species for that site. The fuel coefficient provides flexibility in determining the influence of conifer dominance on fire spread rates for mixedwood fuel types, and is a user input value ($0.0 \leq FC \leq 1.0$). The fire extension uses conifer dominance (CD) as a surrogate for percent hardwood (where PH = 1- CD) and percent conifer (where PC = CD) at each mixedwood site. Fuel coefficient values are generally recommended at or near 1.0 for all species. For instance, a fuel coefficient value of 0.95 for a particular conifer species in a mixedwood type can substantially reduce the relative conifer dominance for a site, in effect, giving more influence to the deciduous component on fire spread rates.

1.3 Characteristic Species for Coniferous and Deciduous Fuel Types

Once a site is assigned to a fuel group, LANDIS requires identification of the characteristic species for delineation of each of the coniferous (CD = 1.0; C-1 through C-6) and deciduous (CD = 0.0; D-1) fuel types. Characteristic species inputs are not needed for the boreal mixedwood types (M1 and M-2).

To assign sites to fuel types, the individual species dominance values are summed for each fuel type to which they are assigned. Some species may have a negative dominance for a given fuel type, as determined by the User. A site is assigned to (given the value of) the fuel type with the highest total species dominance value.

1.4 Cohort Age Range for Characteristic Species

A cohort age range is required for 3 [or 4] of the coniferous fuel types. Mature jack pine (C-3) and immature jack pine (C-4) fuel types require mutually exclusive cohort age ranges for the species *Pinus banksiana*. Similarly, the red and white pine (C-5) fuel type is based on mature stand structures, and requires a cohort age range for *Pinus resinosa* and *P. strobus*. Younger red and white pine stands are equivalent to the conifer plantation type (C-6). [Alternatively, if the C-

6 fuel type is too cumbersome to build into the fire extension, we could consider designating the young red/white pine stands into the C-2 or C-4 fuel types. We also need to include an age distinction for the C-7 fuel type (ponderosa pine – Douglas fir).]

1.5 Season

The fuel type output extension expects a fire season input from the external Fire Weather Module, which is based on the Canadian Fire Weather Index (FWI). The required fire season input can include 3 possible values: spring leaf-off, summer leaf-on, and fall leaf-off. The deciduous, mixedwood, and grass fuel types are dependent on the fire season input, as indicated in the matrix below. The fire season input does not alter the fuel types in the coniferous or slash fuel groups.

Fuel Group	**Spring (Leaf-Off)**	**Summer (Leaf-On)**	**Fall (Leaf-Off)**
Deciduous	D-1	Non-fuel	D-1
Boreal mixedwood	M-1	M-2	M-1
Dead balsam fir mixedwood	M-3	M-4	M-3
Open (Grass)	O1a	O1b	O1b

1.6 Dead Conifer Index [needs work]

The fuel type output extension expects a dead conifer index input from the external BDA Module. The dead conifer index is used to delineate the M-3 (dead balsam fir mixedwood leaf-off) and M-4 (dead balsam fir mixedwood leaf-on) fuel types, and it serves as a surrogate for the percent dead conifer (PDF) input required by the Canadian FBP System that is used in the LANDIS fire extension. The dead conifer index is based on the total number of dead spruce and fir cohorts relative to the total number of species cohorts at each site, with possible values ranging from 0 to 1. The dead conifer index is further modified by a "time since disturbance" coefficient that incorporates the effects of decay, and that gradually (over time) resets the dead conifer index value to zero.

The dead conifer index input is applied to all [?] fuel types, such that any [?] dead conifer index value > 0 effectively converts coniferous (C-1 through C7), deciduous (D-1), and boreal mixedwood (M-1, M-2) fuel types to either the M-3 or M-4 fuel type (depending on the fire season input). However, note that a pre-existing conifer fuel type (i.e., C-1 through C-7) with a dead conifer index > 0 will only be converted to the M-3 (dead balsam fir leaf off) fuel type, whereas the deciduous and boreal mixedwood fuel types with a dead conifer index > 0 can be converted to M-3 or M-4 fuel types, depending on the fire season input.

1.7 Slash Index [needs work]

The fuel type output extension expects a slash index input from the external Base Harvest Module. The slash index is used to delineate the S-1 (Jack or lodgepole pine slash), S-2 (white spruce-balsam slash), and S-3 (coastal cedar-hemlock-Douglas-fir slash) fuel types. The slash index is based on user-defined list of timber harvest techniques within sites of user-selected forest types. The slash index is further modified by a "time since logging" coefficient that

incorporates the effects of decay on slash fuels, and that gradually resets the slash index value to zero.

1.8 Curing Coefficient [needs work]

The fuel type output extension expects a curing coefficient input from the external Fire Weather Module. The curing coefficient is a user-defined value that determines the degree of grass curing (proportion of grass stems dried out) within each fire season (spring, summer, fall). The curing coefficient is used to calculate the rate of fire spread for the O1 (grass) fuel type, and to partition the O1 fuel type into either the O1a (spring live-grass) or the O1b (late-summer and fall dead-grass) fuel types.

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 Example File

```
LandisData  "Fuel Type 2006"

Timestep  10

>> Conifer     Fuel
>> Species     Coefficient
>> --------    -----------
   abiebals    1.00
   larilari    1.00
   picemari    0.95
   piceglau    0.95
   pinubank    1.00
   pinustro    1.00
   pinuresi    1.00

FuelTypeMaps
>> Fuel Type   Species                                Age Range
>> ---------   ---------                              ----------
   C2          picemari piceglau abiebals larilari    0 to 400
   C3          pinubank                               0 to 40
   C4          pinubank                               41 to 100
   C5          pinustro pinuresi –abiebals            100 to 400
   C6          pinustro pinuresi                      0 to 100
   D1          poputrem betupapy acerrubr fraxamer    0 to 300


MapNames  fire/FuelType-{timestep}.gis
```

2.2 LandisData

This parameters value must be “Fuel Type 2006”

2.3 Timestep

This parameter is the extension's timestep. Value: integer > 0. Units: years. [Does this timestep need to be coordinated with the fire extension timestep?]

2.4 Conifer Dominance Species List with Fuel Coefficients

This parameter is a list of conifer species with user-assigned fuel coefficients for determining relative conifer dominance as a fuel type. If a species is not listed the default value is zero.

2.5 Fuel Type Descriptions

This suite of parameters defines the desired fuel type classification outputs [map and site variable?], and must be preceded by the keyword `FuelTypeMaps`. The input is a table with Canadian FBP System fuel type codes, the cohort age range for the characteristic species in each fuel type, and age range for the characteristic species for each fuel type (Table 2).

Table 2.

Parameter	Data Type	Units	Example
Fuel Type Code	string		`C2`
Species	string		`pinustro`
Age range	{int} to {int}	years	`0 to 40`

If a species should contribute to the dominance value of a fuel type, list the species name. 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 and deciduous fuel groups only. 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).

2.6 Map Name

The next parameter, MapNames, describes where 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.

Types in order: C1, C2, C3, C4, C5, C6, C7, D1, S1, S2, S3, M1, M2, M3, M4, O1a, O1b, NoFuel