Forest Product Sector Module (FPSM) Version 1.0

User's Guide

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Last Revised: Nov 18, 2024

The Extension

This document describes the Forest Products Sector Module (FPSM) for the LANDIS-II model. This version is designed to work with output from the Forest Carbon Succession (ForCS) extension (Dymond et al. 2021). For information about the LANDIS-II model and its core concepts including succession, see the LANDIS-II Conceptual Model Description (https://drive.google.com/file/d/15gSueug-Rj9I2RZqdroDbad-k53Jq7j3/view?usp=sharing). However, it can process any harvested carbon information that is presented in the appropriate file format, see Section 4.

This module is designed to take harvested carbon and track it through several processing steps. Each step moves carbon between different product or waste pools and reports output. The extension allows users to see how much C is stored in forest products over time, as well as the resulting emissions.

While the number of processing steps is fixed, the complexity and the details in each is largely user defined and will be described below. This extension is compatible with Intergovernmental Panel on Climate Change (IPCC) accounting and can be adapted to IPCC default approaches or the methods used by the US Forest Service and Dymond (2012).

Overview

This guide provides examples for convenience. All pools, transfers, “markets” and emissions are user defined within the broader framework allowing extensive customization (Figures 1, 2 and 3). At each step there are different pools (pale ovals in figures) and parameters (dark rectangles) that describe the instructions on moving C between one set of pools and the next.

In general terms, the first step reads the harvest stream and divides that stream into mills that produce primary products such as lumber and chips, which are then sent to different markets (Figure 1). These are then processed into secondary products such as houses and paper. These are eventually sent into ‘retirement’ (Figure 2). Once disposed of the C decays or is burned and is emitted (Figure 3). Landfill gas management effects are available as well, and substitution calculations can also be included (Figure 4).

Details given in Section 2 describe working with the input tables, but it is important to note here that the “Name” column is provided to make the table more readable for humans only. The software reads the “Code” columns! Any user defined codes must be integers less than 1000, since codes of 1000 and greater are internally assigned by the FPSM to special pools (Table 1). The keywords in the figures refer to the table names the FPSM will be looking to for parameterization of that step.

To bridge the different unit conventions of LANDIS and common carbon reporting requirements, carbon in the **input** files (see Section 0) is in units of gC/m^2 and carbon in the **output** files is expressed by default in unites of metric tonnes C/ha. Output is produced for each **annual** step of the model.

Users of the FPSM working outside the LANDIS-II development and runtime environment will need to obtain and install a copy of the DotNet 2.2 Runtime software, currently released as version 2.2.8 and found at

https://dotnet.microsoft.com/en-us/download/dotnet/2.2

After downloading the FPSM software, model users will need to create a configuration text file. Two examples are provided but these do not contain default values. One example provides a structure like the US Forest Service and Dymond 2012 approach, the other follows the IPCC approach. Details are provided in Section 2.

The model is run using a Windows Batch file that points at the Landis.Extension.FPS-v1.dll and the configuration file. If you haven't used a batch file before you simply right click to edit in Notepad or something similar so the file paths match your computer system. Then double click on it in Windows Explorer to run. You may need to right click to run as administrator.

Harvest To Primary Products

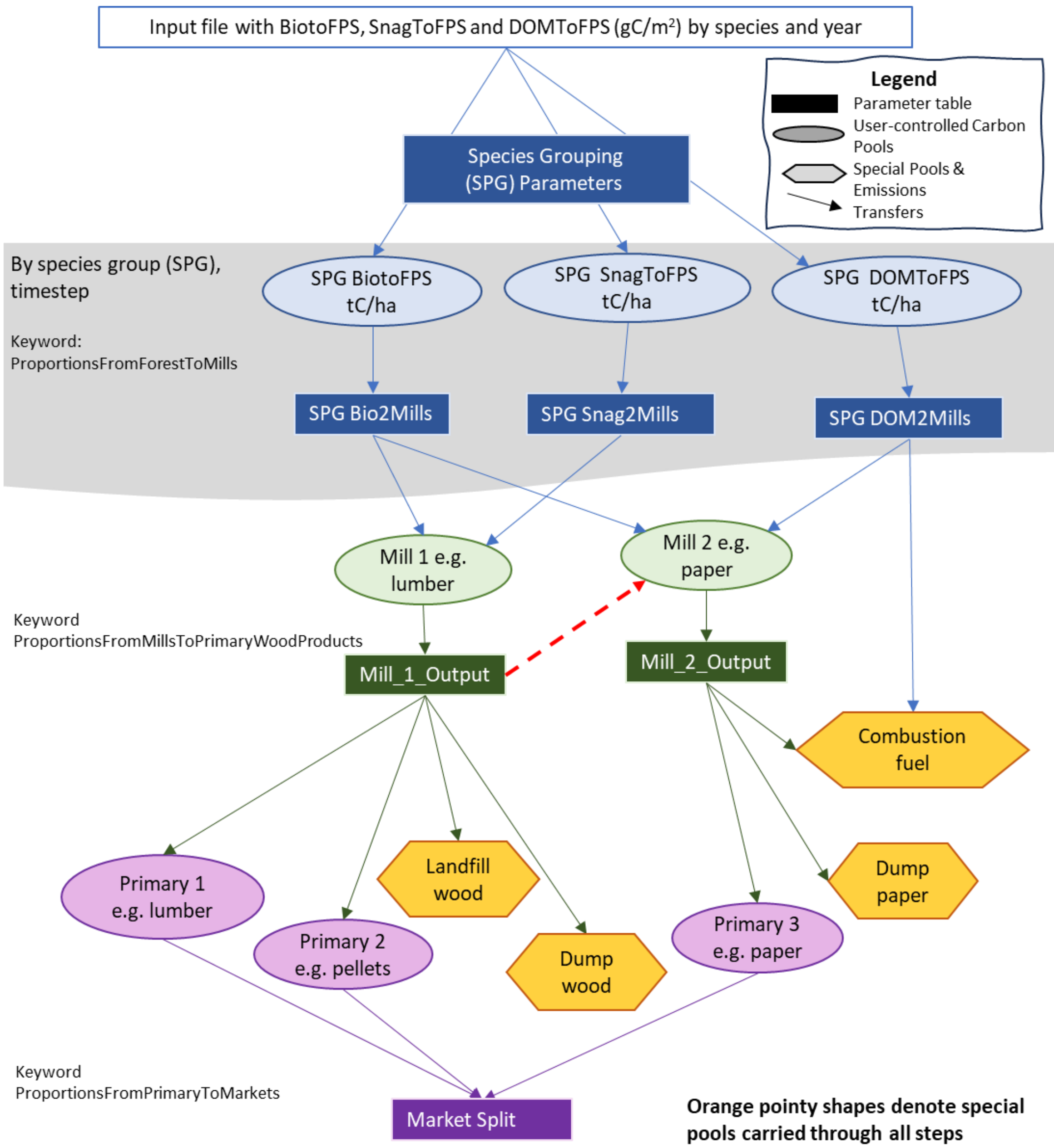

Figure 1: From forests to markets. Schematic of ***an example*** *of how the first part of the Forest Products Sector Module can be used. Orange shapes with points on either side denote special pre-defined pools carried through all steps. See Section 2 for more information on keywords. The model schematic continues in Figure 2.*

The first step of the FPSM is to read the output provided by ForCS or similarly formatted input from the user (Figure 1, Section 4). The module reads two CSV-formatted text files which respectively contain the amount of harvested live biomass over time, and harvest of snags and dead organic matter (DOM), by species. The code calculates the sum of harvested carbon in each

“ToFPS” pool by timestep and species. The user can group these species into units that are most likely processed together, depending on their needs. For example, a group “All” could be created, which encompasses all species; or two groups “Hardwood” and “Softwood” could be created, to model the two kinds of wood products separately.

Note: *In future versions, users will be able to provide the model with a management unit map so that this first processing step can include a dependence on location.*

The processing of the harvest is defined in a table in which the user states, for each species group and harvest type, how the C is divided into different products. Users can define any number of different products, and both the destination mills and the proportions that go into each kind of mill, can change over time.

Mills to Primary Wood Products

At the end of the previous step, the C had been transferred to user-defined mills. In this step, the user defines what happens in each of these mills: how the C is processed into primary products such as lumber, chips, and panels. **The user must create at least one destination for the carbon in each mill that was defined in the previous step.**

One feature of this step is the ability to simulate one mill sending material to another mill to simulate chips going from a plywood mill to a paper mill, for example.

Primary Products to Markets

The module then provides the opportunity to simulate the movement of primary wood products to different markets. The notion of “market” can be defined in any way the user wishes, whether it is by province, state, region, country, or not relevant. The parameters for most later processing steps are stratified by market, so it makes sense to define the market at the level at which there are differences in processing or storage, or at the level at which reporting is important. For example, if one region mostly processes lumber into building material, and another into pallets, the regional difference is important. Alternatively, if regions process identically, but tracking needs to account for regional processes, then regions should also be used. However, markets do not affect landfill and dump parameters in this version of the FPSM.

Primary Products to Secondary Products

There are two steps to setting up the transfer from Primary to Secondary products. The first step is much like the previous step where Harvest was transferred to Primary Products. In this step, Primary products are divided into Secondary products by defining transfer parameters by time, and by Primary product (Figure 2). Because the previous step added the primary products to different markets, the parameters defining the proportions of primary products going into different secondary products can be further refined by market.

The second part of this step defines the rate at which these secondary products retire out of the product pool over time. To do this, FPSM uses decay/retirement functions with parameters provided by the user. These functions are:

- Instant, no parameters (e.g., for fuel)
- Exponential, with 1 parameter defining the half-life

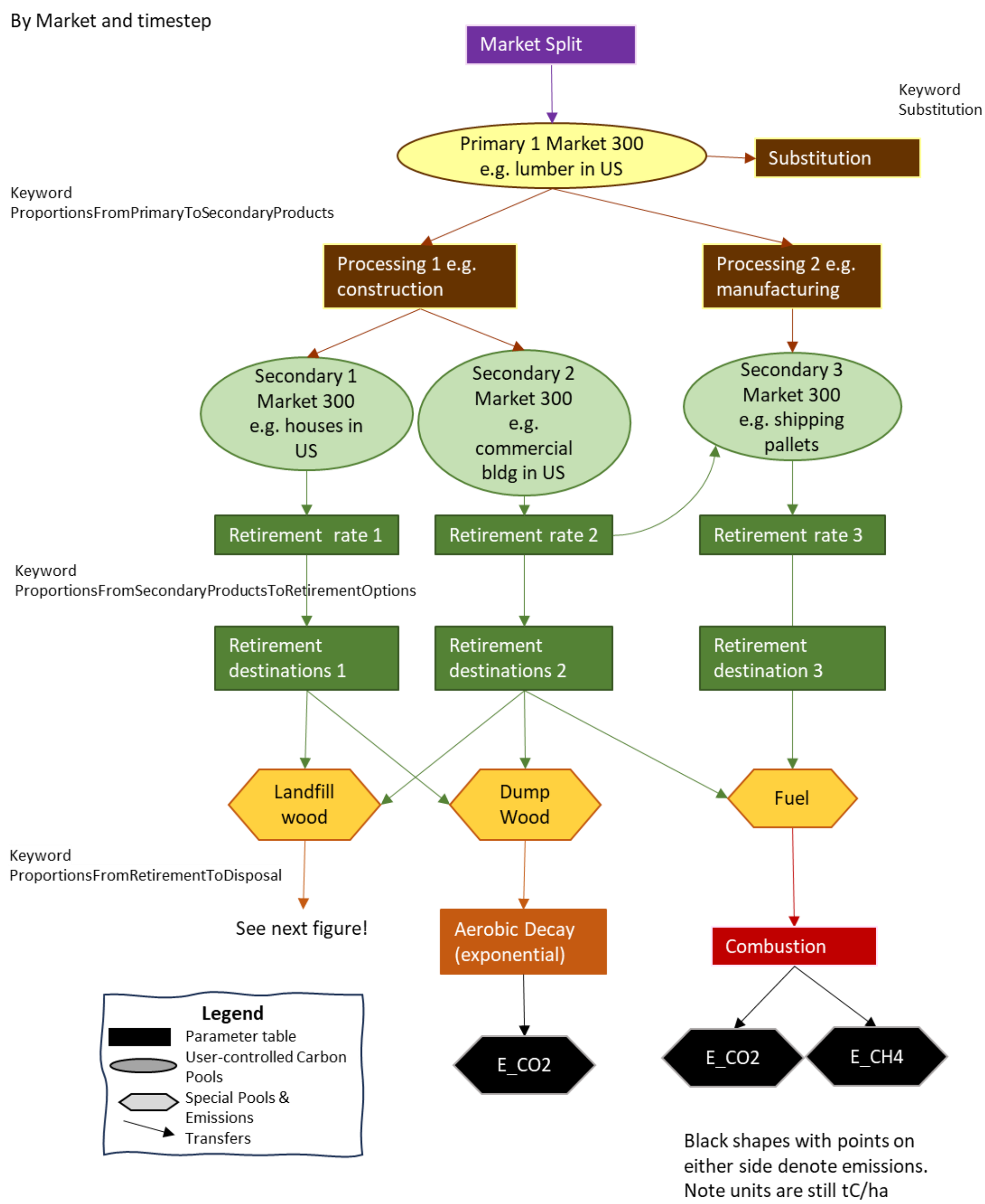

Figure 2: From market split to disposal including substitution, aerobic decay and combustion. Schematic of ***an example*** *of application of the second part of the Forest Products Sector Module. Orange shapes with points on either side denote special pre-defined pools carried through all steps and do not vary by market. Black shapes denote emissions although they are tracked cumulatively like another pool. Model schematic continues in Fig 1 and 3. Output units are tC/ha.*

Secondary Product Retirement

The previous step defined *how* C is removed from the secondary products pools using the given retirement function and parameters. This step defines *where* the C ends up once leaving the product pool and entering disposal pool (s).

The table is much like the others. Proportions are defined for each combination of market, product and destination. Note that **recycling is an option** here since a secondary product can become the same or another secondary product.

Also note that the disposal pools are all predefined special pools with codes 1000 and above. Users can define the input proportions, and whether or not they use a pool, but not how they are processed. A list of these definitions is in Table 1.

Table 1. Special predefined pools and codes.

Fixed Code	Description (can be changed by user)	Comment
1000	LandfillWood	Will be split into degradable and non-degradable components.
1001	DumpWood	Used for aerobic decay.
1002	CombustionFuel	Used for burning and bioenergy in forest sector.
1003	DumpPaper	Used for aerobic decay.
1004	LandfillPaper	Will be split into degradable and non-degradable components.
1005	Fuel	Used for burning and bioenergy outside of forest sector.
1009	DegradeableLandfillWood	The amount of Landfill Wood that is subject to decay.
1010	DegradeableLandfillPaper	The amount of Landfill Paper that is subject to decay.
1500	Anaerobic	Anaerobic decay pathway.
1511	Aerobic	Aerobic decay pathway.
2006	E_CO2	End point emissions in the form of CO_2.
2007	E_CH4	End point emissions in the form of CH_4.
2008	PotentialCH4	CH_4 produced through anaerobic decay that, depending on model configuration may be released as an end point emission or may be treated by landfill gas management and oxidation.

Disposal

At the end of the previous step, the C is mostly in special pools such as fuel, dumps, or landfills (Figure 3). Because there are different pathways for the carbon that are all handled in one table, this is the most complicated table to understand and to parameterize.

There are three different options for what happens to these special pools (Table 1).

1) The pool immediately and entirely transforms to gasses. Examples of this would be for fuel or combustible fuel. The definition for this case is like most of the other tables: the destination gas, and the proportion of the material that goes to the gas.

2) The entire pool follows anaerobic or aerobic decay. An example would be DumpPaper or DumpWood. In this case, only the type of decay and the half-life of the pool are defined by the user.

3) The pool is partially decayed and partially transferred to another pool. In this case, the user will define the proportion that goes to the other pool as well as the decay type and half-life that new pool. For example, LandfillWood will in part go to a degradable landfill wood pool. This pool will then decay using anaerobic decay with a half-life.

Respiration Rules & Landfill Gas Management

There are two predefined sets of respiration rules. Users should note that the FPSM does not currently recognize market-specific respiration, and the respiration rules are applied identically across all markets. To accommodate market differences users may have to weight respiration parameters based on the data available to their market context and the possible of mix of landfills with and without LFGM.

- Aerobic (1500)
  - The portion of DumpWood and DumpPaper that is decayed goes to E_CO2.
- Anaerobic (1511)
  - When the LandfillWood and LandfillPaper pools decay, 50% goes to E_CO2 and 50% to PotentialCH4.
  - Users must define the oxidation efficiency, which represents the proportion of PotentialCH4 that is converted to CO_2 as it passes through the landfill cap. An oxidation efficiency of 1.0 will convert 100% of potential CH_4 to CO_2.
  - Besides defining the oxidation efficiency, users can further define the fate of intermediate methane as it is handled by landfill gas management systems. The model then calculates the final emissions as:
    - E_CO2 = 50% of anaerobic decay +
      PotentialCH4 * ProportionofLandfillsWithLGM * CaptureEfficiency +
      (PotentialCH4 – (PotentialCH4 * ProportionofLandfillsWithLGM * CaptureEfficiency) * Oxidation)
    - E_CH4 = the remainder.

> **Note:** The three variables E_CO2, PotentialCH4 and E_CH4 shown above all represent units of tC/ha and not the molecular mass (e.g., tCO_2/ha, tCH_4/ha) which their names may suggest.

Substitution

Substitution does not affect the distribution of C in pools. It is a basic calculation to provide a sense of the substitution effects, i.e. the CO_2e benefit if the total harvest was used instead of higher global warming potential products.

For each market and primary product, users can define two values: a substitution ratio and a displacement factor. The ratio represents the proportion of the market where consumers are using wood to replace higher Global Warming Potential products. The typical Life Cycle Assessment or mitigation study assumes 1.0. The displacement factor is the impact of the use of wood instead of other products. The total substitution impact is calculated as:

C in PrimaryPool * SubstitutionRatio * DisplacementFactor

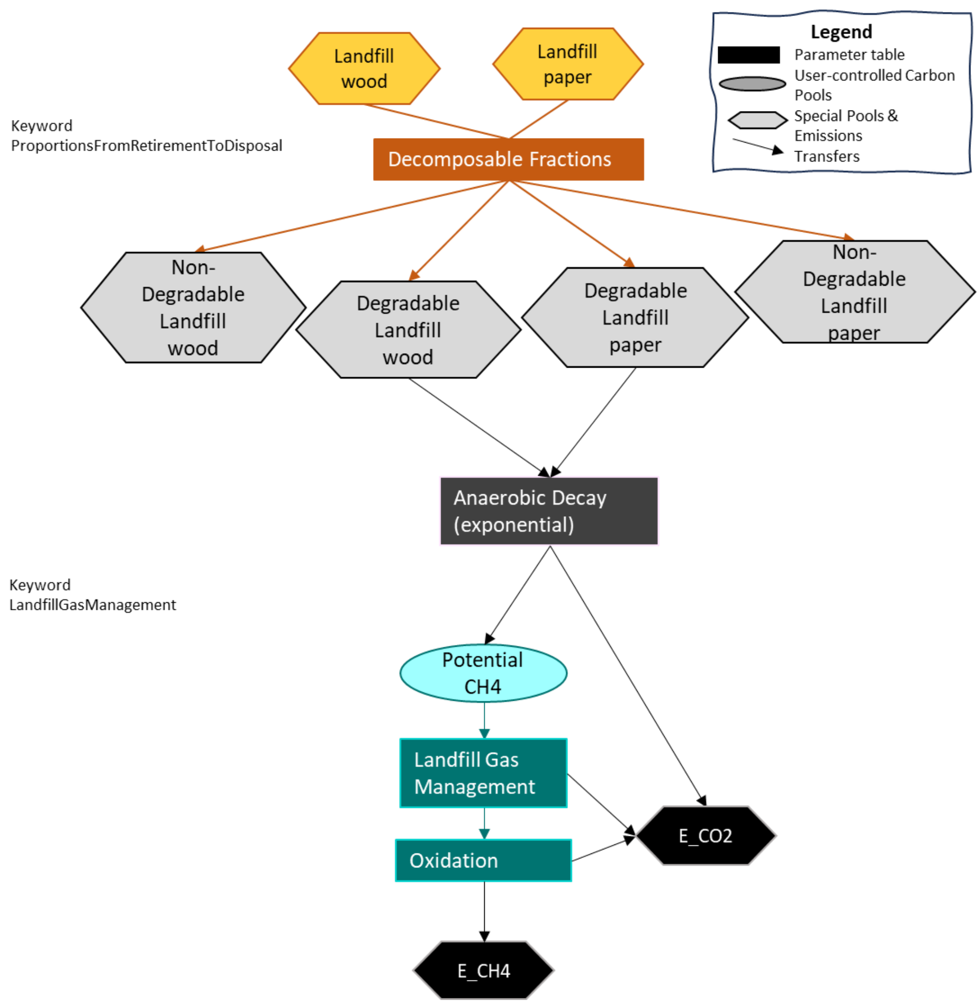

Figure 3. Landfill emissions. Schematic of the third part of the Forest Products Sector Output extension. Orange shapes with points on either side denote special pre-defined pools carried through all steps and do not vary by market. Black shapes denote emissions although they are tracked cumulatively like another pool. Model schematic continues from Figure 2. Output units are tC/ha.

References

Dymond, C.C., 2012. Forest carbon in North America: annual storage and emissions from British Columbia's harvest, 1965–2065. Carbon Balance and Management, 7(1):1-20. https://doi.org/10.1186/1750-0680-7-8

Dymond, C.C., Beukema, S, and Scheller, R.M. 2021. Landis-II Forest Carbon Succession Extension Version 3.1. 36 p. https://github.com/LANDIS-II-Foundation/Extension-ForCS-Succession/blob/master/docs/LANDIS-II%20ForC%20Succession%20v3.1%20User%20Guide.pdf

Marland, E.S., Stellar, K. and Marland, G.H., 2010. A distributed approach to accounting for carbon in wood products. Mitigation and Adaptation Strategies for Global Change, 15: 71-91. https://doi.org/10.1007/s11027-009-9205-6

Acknowledgments

Funding was provided by the British Columbia Ministry of Forests.

Main Input Configuration File

This section describes in detail each of the tables and parameters the user must define. An example is provided in Section 3. Nearly all the input parameters for this extension are specified in one main 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 found here:

https://drive.google.com/file/d/1FliLjtmLKD_D4uAfo9d_VMs_6jRkOcNh/view.

Note that the "Name" column is provided to make the table more readable for humans, and any codes>1000 are pre-defined as they have specific processing steps.

TimeStart – the first column indicates when the parameters in the row should start being used. They will continue to be used until a new TimeStart is provided. This allows dynamic parameterization.

Header

LandisData	This parameter's value must be "FPS".
CellLength	The length in meters of a square simulation cell (pixel). Used to convert to tC/ha absolute value from gC/m2 input default. The module converts the units using the cell size input variable and should represent ¼ of the perimeter of a row in the input file, i.e. 100 m for a hectare cell. If the user doesn't want the units to change, simply set the CellLength to 1. Note the denominator only considers harvested area and not a landscape average.
YearsPostHarvest	The number of years past the last harvest in the input file to simulate. Value: >0. Units: years.

Input Files

HarvestFileLive	.csv filename containing harvested biomass carbon, see Section 4.
HarvestFileDOM	.csv filename containing harvested dead organic matter carbon, see Section 4.
ManagementUnits	Not functional in this version of FPSM
OutputInterval	How frequently the output will be written. Minimum 1, must be integer.

Species Group Table

The keyword “SpeciesGroupTable” must be prior to the table. This table is used to read input information and assign species to different groups that can be sent to different mills and products later on.

Species	The list of the species from the input files.
Group	An integer defining group membership. >1 and <1000. Use the code 99 to mean all species. (We’ve not tested with more than 3 groups).
Group Name	A name for the group.

Forest to Mills

This table contains the information about dividing up the harvest to different primary mills. The keyword “ProportionsFromForestToMills” must be prior to the table.

Time Start	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Unit Code	The management unit code is a placeholder for future development and is not currently functional.
Species Group	Code from Species Group Table.
Pool	Must be one of BioToFPS, SnagToFPS or DOMToFPS and align with column heading in input file.
Mill Code	Mills and other facilities that take in harvested fibre to create products. User defined unique integer >1 and <1000 or special pool code (Table 1).
Mill Name	User defined name.
Multiplier	User defined proportions that indicate how much of the carbon from the Species Group X Pool combination should end up in each Mill Code pool.

Mill To Primary

This table contains the information about how mills create primary products and dispose of their waste. The keyword “ProportionsFromMillsToPrimaryWoodProducts” must be prior to the table. Proportions must sum to 1 for combinations of time and mill.

Time Start	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Mill Code (From)	Defined in the previous table.
Mill Name (From)	Defined in the previous table.
Primary Code (To)	Products and waste disposal created from manufacturing using harvested fibre. User unique defined integer >1 and <1000 or special pool code (Table 1).
Primary Name (To)	User defined name.
Mill multiplier	Proportion of incoming pool (defined by the Mill Code) that will end up as the product or disposal pool (defined by Primary Code).

Primary Products to Markets

This table gives the proportions of how primary products are divided into different markets so that different parameter sets can be applied below. The keyword “ProportionsFromPrimaryToMarkets” must be prior to the table. Proportions must sum to 1.0 for time, output code combinations.

Time Start	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Primary Code (From)	Defined in the previous table.
Primary Name (From)	Defined in the previous table.
Market Code (To)	User unique defined integer >1 and <1000.
Market Name (To)	User defined name.
Market multiplier	Proportion of incoming pool that will be split among the different markets.

Primary to Secondary

This table gives the proportions that define how primary products are divided into secondary products and the retirement rate. This is the stage where products are stored while they are in use, and then are gradually retired out of use or disposed of. The keyword "ProportionsFromPrimaryToSecondaryProducts" must be prior to the table. Proportions must sum to 1.0 for the combination of time, market and primary codes. If users are following the IPCC default method, primary and secondary products are the same.

Time Start	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Market Code (From)	Defined in the previous table.
Primary Code (From)	Defined in the previous table.
Primary Name (From)	Defined in the previous table.
Secondary Code (To)	Products made from primary products and the resulting manufacturing and construction waste. User unique defined integer >1 and <1000 or special pool code (Table 1).
Secondary Name (To)	User defined name.
Secondary X	Proportion of the primary product pool (not including special pools) that will be transferred to the secondary pool.
Retirement Function	Function that will be applied to reduce secondary output pools annually. Only 'exponential' and 'instant' are accepted.
Parameter 1	Value to be used in the retirement function. For exponential it should be the integer half-life. For instant it should be –99. Value: >0. Units: years.
Parameter 2	Not currently used. Planned for gamma distribution functionality.

Secondary to Retirement

Once the exponential decay curve is applied to the secondary product pool, the amount removed from the pool is handled according to this table. The remainder stays in the secondary product pool until the next timestep. This table gives the proportions of how retired carbon from the secondary products are handled when they are disposed of **or recycled**. The keyword “ProportionsFromSecondaryProductsToRetirementOptions.” must be prior to the table. Proportions must sum to 1.0 for each time, market, secondary combination. For modelling where storage and landfills are not considered, send all carbon to 1005 (Fuel) for instantaneous oxidation.

Time Start	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Market Code (From)	Defined in the previous table.
Secondary Code (From)	Defined in the previous table.
Secondary Name (From)	Defined in the previous table.
Retirement Code (To)	The pool where carbon from the secondary products will go when the product is recycled or disposed of. Options include Secondary Output Codes or Special codes (Table 1).
Retirement Name (To)	User defined name.
Retirement multiplier	Proportion of the secondary product pool that will be transferred to the retirement pool.

Disposal

Two tables are used to specify disposal parameters. The first table is shown below in 3 parts for clarity: each representing the details for disposal under conditions of combustion, aerobic and anaerobic decay. Valid respiration codes are: 1511 (Aerobic), 1500 (Anaerobic). Codes 2999 and –99 are N/A and are used for combustion. The second table (Section 0) shows how methane is handled. The keyword "ProportionsFromRetirementToDisposal" must be prior to the table. Proportions must sum to 1.0 for each time, retirement code combination.

Combustion	
Time Start:	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Retirement Code (From)	1002 or 1005
Retirement Name (From)	Defined in the previous table.
Disposal Code (To)	2006 or 2007
Disposal Name (To)	E_CO2 or E_CH4.
Disposal X	Proportion of pool 1002 or 1005 that will be transferred to the Disposal Code pools. For combustion (instantaneous oxidation) the proportion should be set to 1.0 for 2006.
Half-life	–99
Respiration Code	–99
Respiration Name	N/A

Aerobic Decay	
Time Start	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Retirement Code (From)	1001 or 1003
Retirement Name (From)	Defined in the previous table.
Disposal Code (To)	2999
Disposal Name (To)	N/A
Disposal X	1 (Other values not tested)
Half-life	The half-life applies to 100% of the 1001 or 1003 pool as defined by the Disposal X. It will be used in the exponential decay equation. Note that the amount decayed will be transferred to pool 2006 (E_CO2). The rest will remain in 1001 or 1003.
Respiration Code	**1511**
Respiration Name	**Aerobic**

Anaerobic	
Time Start:	The first timestep of the model run when these parameters must be applied. Value: >0. Units: years.
Retirement Code (From)	**1000 or 1004**
Retirement Name (From)	Defined in the previous table.
Disposal Code (To)	1009 or 1010
Disposal Name (To)	DegradableLandfillWood or DegradableLandfillPaper
Disposal X	The proportion of pool 1000 or 1004 that will be transferred to pools 1009 or 1010 because that carbon can decay.
Half-life	The half-life to be used in the exponential decay equation and applied to pool 1009 or 1010. Note that the amount decayed will be transferred to 50% to pool 2006 (E_CO2) and 50% to pool 2008 (Potential CH4). See the table LandfillGasManagement for further parameterization.
Respiration Code	**1500**
Respiration Name	**Anaerobic**

Substitution

This table gives information about how to calculate substitution effects. Substitution effects are based on the Primary products. Even if you are not using this functionality there must be at least one line of parameters. The keyword “Subsitution” must be prior to the table. There’s no requirement that proportions sum to 1.0 but products not included in this table will not have a substitution effect.

Time Start	The first timestep of the model run when these parameters must be applied. Value: $\geq$0. Units: years.
Market Code	Defined above.
Primary Code	Defined above.
Primary Name	Defined above.
Substitution Ratio	The proportion of the market where consumers are using wood to replace higher Global Warming Potential products. The typical Life Cycle Assessment or mitigation study assumes 1.0.
Displacement Factor	The displacement factor is the impact of the use of wood instead of other products (tC/tC).

Landfill Gas Management

This is the second table defining end-of-life parameters. This table gives information about how to calculate methane emissions including landfill gas management (LFGM). The values in this table are only used if Respiration Code 1500 (anaerobic decay) is used. If there is no LFGM, set the Landfills With LFGM X and Capture Efficiency parameters to –999 and set the Oxidation rate appropriately. Note that, unlike most other tables, there can only be one line of input per year. Even if you are not using this functionality there must be at least one line of parameters. The keyword “LandfillGasManagement” must be prior to the table.

Time Start	The first timestep of the model run when these parameters must be applied. Value: ≥ 0. Units: years.
Respiration Code	Defined above.
Landfills With LFGM	Proportion of the wood and paper in landfills that have LFGM.
Capture Efficiency	Proportion of the methane produced from the decay of wood and paper that will be taken up by the LFGM system and converted into CO_2. Note this combines several steps that occur in more sophisticated landfill models so users may need to do some calculations for parameterization.
Oxidation	Proportion of the methane produced from the decay of wood and paper that will **not** be taken up by the LFGM but will be converted into CO_2 by the cap on the landfill.

Sample Main Input File Example Tier 1 IPCC production approach with simple decay of commodity classes

Note: Lines beginning with “>>” are treated as comments.

```
>> Tables formatted in Notepadd++ v8.5.4
>> Example Tier 1 IPCC production approach with simple decay of commodity classes
LandisData  "FPS"

>> Length of cell side in m, used to convert m2 values to totals, should be the same as in ForCS run. Set to 1 for no unit conversion.
CellLength 100

>> Number of years past the last harvest to simulate
YearsPostHarvest 10

HarvestFileLive      "log_FluxBio.csv"
HarvestFileDOM       "log_fluxDOM.csv"
ManagementUnits  "manunits.gis"

OutputInterval  1

SpeciesGroupTable
>>Group: up to 2. Use word "all" to mean all species
>>  all    99    ALL
>>Species  Group  GroupName
>>----------------------------------------------
 all         99          all

ProportionsFromForestToMills

>> Time             Unit                                       Species   Pool            Mill Code       Mill Name
>> Start            Code                                       Group     (From)          (To)            (To)                        Multiplier
>>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------
         0                 1                                   99        BioToFPS        1               SawnwoodMill                     0.5
         0                 1                                   99        BioToFPS        2               WoodbasedPanelsMill              0.25
         0                 1                                   99        BioToFPS        3               Chipmill                         0.25
         0                 1                                   99        SnagToFPS       1               SawnwoodMill                     0.2
         0                 1                                   99        SnagToFPS       2               WoodbasedPanelsMill              0.0
         0                 1                                   99        SnagToFPS       3               Chipmill                         0.8
```

ProportionsFromMillsToPrimaryWoodProducts

>>	Time Start	Mill Code (From)	Mill Name (From)	Primary Code (To)	Primary Name (To)	Multiplier
	0	1	SawnwoodMill	104	Sawnwood	0.5
	0	1	SawnwoodMill	1002	InstantEmission	0.5
	0	2	WoodbasedPanelsMill	106	Panels	0.5
	0	2	WoodbasedPanelsMill	1002	InstantEmission	0.5
	0	3	Chipmill	105	Chips	0.7
	0	3	Chipmill	1002	InstantEmission	0.3

ProportionsFromPrimaryToMarkets

>>	Time Start	Primary Code (From)	Primary Name (From)	Market (To)	Market Name (To)	Multiplier
	0	105	Chips	300	Global	1
	0	104	Sawnwood	300	Global	1
	0	106	Panels	300	Global	1

ProportionsFromPrimaryToSecondaryProducts

>>Time >>Start	Market Code (From)	Primary Code (From)	Primary Name (From)	Secondary Code (To)	Secondary Name (To)	Secondary Multiplier	Retirement function	Param. 1	Param. 2
0	300	105	Chips	200	PaperPackaging	1	exponential	2	-99
0	300	104	Sawnwood	204	Sawnwood	1	exponential	35	-99
0	300	106	Panels	209	Panels	1	exponential	25	-99

ProportionsFromSecondaryProductsToRetirementOptions

>> Time >> Start	Market Code (From)	Secondary Code(From)	Secondary Name (From)	Retirement Code(To)	Retirement Name(To)	Retirement Multiplier
0	300	200	PaperPackaging	1002	InstantEmission	1
0	300	204	Sawnwood	1002	InstantEmission	1
0	300	209	Panels	1002	InstantEmission	1

ProportionsFromRetirementToDisposal

>>Time Retirement Retirement Disposal Disposal Disposal Half-life Respiration Respiration

>>Start	Code (From)	Name (From)	Code(To)	Name (To)	Multiplier		Code	Name
0	1002	InstantEmission	2006	E_CO2	1	-99	-99	NA

Substitution

>> Substitution = Primary * SubstitutionRatio * DisplacementFactor

>>Time >>Start	Market	Primary Code	Primary Name	Substitution Ratio	Displacement Factor
>> 0	300	104	Sawnwood	0	0

LandfillGasManagement

>>TimeStart >>Start	Respiration Code	Landfills With LFGM	Capture Efficiency	Oxidation
0	1500	-999	-999	0.22

Input Files from FORCS

The FPSM requires input of living and dead biomass. When created by the LANDIS-II ForCS extension these data are retrieved from the filenames called:

- log_FluxBio.csv and
- log_FluxDOM.csv

The filenames are under user control via the Main Input Configuration file (see Section 0). The content of these two files must follow the format described in Section 7.5 and 7.6 of the ForCS documentation (Dymond et al. 2021) as summarized below in Table 2 and Table 3.

log_FluxBio.csv

The file **log_FluxBio.csv** has 17 columns that gives information about the rate of C transfer from the live biomass pools on each site after a disturbance in that timestep. The time, species and BioToFPS are read by the FPSM (highlighted). If you are not using ForCS, you must structure your FPSM input in this manner, but only the highlighted fields matter.

Table 2. Columns found in the log_FluxBio.csv input file.

Column	Title	Value	Units	Notes
1	Time	Integer	–	Model timestep (annual)
2	Row	Integer	–	Raster grid row
3	Column	Integer	–	Raster grid column
4	Ecoregion	Integer	–	ID based on order in ecoregions text file
5	Species	Character	–	User defined name
6	Dist	Integer	–	Disturbance ID: 1 – fire; 2 – harvest; 3 – wind; 4 – Biological Disturbance Agent (BDA)
7	MERCH_ToDOM	Real	$gC/m^2/y$	C transferred from merchantable to snags or other DOM pools
8	MERCH_ToAir	Real	$gC/m^2/y$	C released from merchantable live biomass to the air
9	FOL_ToDOM	Real	$gC/m^2/y$	C transferred from the foliage to DOM pools
10	FOL_ToAir	Real	$gC/m^2/y$	C released from foliage to the air
11	OtherWoody_ToDOM	Real	$gC/m^2/y$	C transferred from other live woody to DOM pools
12	OtherWoody_ToAir	Real	$gC/m^2/y$	C released from other live woody to air
13	CrsRt_ToDOM	Real	$gC/m^2/y$	C transferred from coarse root to DOM pools

Column	Title	Value	Units	Notes
14	CrsRt_ToAir	Real	$gC/m^2/y$	C released from coarse root to the air
15	FRt_ToDOM	Real	$gC/m^2/y$	C transferred from fine root to DOM pools
16	FRt_ToAir	Real	$gC/m^2/y$	C released from fine root to the air
17	BioToFPS	Real	$gC/m^2/y$	C transferred to the forest product sector (e.g., from harvest).

log_FluxDOM.csv

The file **log_FluxDOM.csv** has 20 columns that give information about the rate of C transfer from the DOM on each site after a disturbance in that timestep. The time, species SnagsToFPS and DOMToFPS are read by the FPSM.

Table 3. Columns found in the log_FluxDOM.csv input file.

Column	Title	Value	Units	Notes
1	Time	Integer	–	Model timestep (annual)
2	Row	Integer	–	Raster grid row
3	Col	Integer	–	Raster grid column
4	Ecoregion	Integer	–	ID based on order in ecoregions text file
5	Species	Character	–	User defined name
6	Dist	Integer	–	Disturbance ID: 1 – fire; 2 – harvest; 3 – wind; 4 – Biological Disturbance Agent (BDA)
7	VF_A_toAir	Real	$gC/m^2/y$	C released from the very fast aboveground pool to air
8	VF_B_toAir	Real	$gC/m^2/y$	C released from the very fast belowground pool to air
9	Fast_A_toAir	Real	$gC/m^2/y$	C released from the fast aboveground pool to air
10	Fast_B_toAir	Real	$gC/m^2/y$	C released release from the fast belowground pool to air
11	MED_toAir	Real	$gC/m^2/y$	C released from the medium pool to air
12	Slow_A_toAir	Real	$gC/m^2/y$	C released from the slow aboveground pool to air
13	Slow_B_toAir	Real	$gC/m^2/y$	C released from the slow belowground pool to air

Column	Title	Value	Units	Notes
14	Sng_Stem_toAir	Real	$gC/m^2/y$	C released from the snag stems pool to air
15	SngStemToMed	Real	$gC/m^2/y$	C transferred from the snag stems pool to the medium pool
16	Sng_Oth_toAir	Real	$gC/m^2/y$	C released from the snag other pool to air
17	SngOthToFast	Real	$gC/m^2/y$	C transferred from the snag other pool to the fast aboveground pool
18	Extra_toAir	Real	$gC/m^2/y$	C released of from the extra pool to air
19	SnagsToFPS	Real	$gC/m^2/y$	C lost from snag stem to the forest product sector
20	DOMtoFPS	Real	$gC/m^2/y$	C lost from of any other dead C to the forest product sector

Output

Three output files are produced. The first file lists any input errors that occur. The second file contains a list of all the transfers that are done in the first several steps of the process, and the third file contains amounts in the pools and emitted. In the future, FPSM will provide summary output.

FPS_log.txt

This text file reports any potential non-fatal errors that may be in the input files. These errors may be detected as the FPSM does internal checking to make sure that all proportions add to 1, and that all values are assigned to defined pools. For example, errors might report that:

- Proportions do not add to 1 for pool x, or
- No substitution factors found for year: 1, market: 301, product: 105

In an ideal, well-parameterized run, this file will be empty.

This file could be empty, or it could have some minimal reporting such as:

```
No substitution factors found for year: 1, market: 300, product: 105
No substitution factors found for year: 1, market: 301, product: 105
No substitution factors found for year: 2, market: 300, product: 105
```

FPS_test_out.csv

This file contains 5 comma-separated fields and reports fluxes between pools as they happen, to help with error checking and debugging. Carbon units are expressed as tC/ha.

Table 4. Fields of the FPSM output file FPS_test_out.csv

Column	Title	Value	Units	Notes
1	Step	Integer	–	1 – Harvest to Mill transfers; 2 – Mill to Primary transfers; 3 – Primary to Market transfers; 4 – Primary to Secondary transfers; 5 – Secondary to Retirement transfers; 6 & 7 – *not used*; 8 – Substitution amounts; 9 – Retirement (buggy, not recommended)
2	Year	Integer	Year	Model timestep being reported.
3	Market	Integer	–	Market code defined by the input configuration (–99 when a market code has not been defined).
4	Pool	Integer	–	Destination pool code defined by the input configuration file.
5	Amount	Real	tC/ha	C transferred into the destination pool.

Table 5. A few lines of the FPS_test_out.csv output file showing a sample output of carbon transfers. These are essential for quality control by the users.

Step	Year	Market	Pool	Amount
1	1	-99	2	30777
2	1	-99	104	75299
2	1	-99	105	41826
2	1	-99	1000	15059
3	1	300	104	15059
3	1	301	104	6023
3	1	300	105	20913
3	1	301	105	20913
3	1	-99	1000	15059
1	2	-99	1	1503
1	2	-99	2	6678
2	2	-99	104	13255

FPS_raw_out.csv

This file contains eight comma-separated fields and provides detailed listing of transfers from the final stages of the processing. Having the year created field allows users to track emission estimates back to the harvest year. This is essential for users to do quality control on their models. Carbon units are expressed as tC/ha.

Table 6. Fields of the FPSM output file FPS_raw_out.csv

Column	Title	Value	Units	Notes
1	Type (for debugging can be ignored by most users)	Integer	–	1-3 – ID denoting transfer from a Retirement Pool to Disposal: 1-3 – debugging codes that can be ignored by most users; 4 – amount remaining in the special pool at the end of the simulation year; 5 – amount remaining in the secondary product pool at the end of the simulation year after some has been retired to a landfill or fuel
2	YearCreated	Integer	Years	Simulation year in which the From Pool was created, e.g., the harvest year
3	YearReported	Integer	Years	Simulation year in which the emission takes place, or the pool amount is reported; the year of the simulation, not the year since creation
4	Market	Integer	–	Market code defined by the input configuration file. Pools that do not have a Market number by design are assigned a zero.
5	FromPool	Integer	–	Code of the starting (source) pool
6	To_Gas/Pool	Integer	–	Code of the ending (destination) pool or emitted gas
7	AmountEmitted	Real	tC/ha	C transferred from the source to the destination pool
8	AmountRetained	Real	tC/ha	C retained in the destination pool at the end of the year

Table 7. A few lines of the FPS_raw_out.csv output file showing in part how some of the different types of output are reported. Notice that reports are either emitted or retained, and that amounts retained have the same from and to pools.

Type	Year Created	Year Reported	Market	From Pool	To_Gas/ Pool	Amount Emitted	Amount Retained
4	1	5	0	1001	1001	0	1821.59
5	1	5	300	205	205	0	28.17
4	2	5	0	1000	1000	0	1550.12
4	2	5	0	1001	1001	0	349.48
4	3	5	0	1009	1009	0	470.57
3	5	5	0	1002	2006	12211.69	0
3	5	5	0	1002	2007	0.0183	0