Base Harvest v5.1
LANDIS-II Extension
User Guide

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1 Introduction

This document describes the Harvesting extension ('plug-in') for the LANDIS-II model. Users should read the *LANDIS-II Model User's Guide* prior to reading this document. The Base Harvest extension generally follows the behavior of the harvest module as described in Gustafson et al. (2000).

1.1 The Harvesting Landscape

A landscape is divided into a hierarchy of areas for harvesting. These areas are defined prior to landscape simulation.

1.1.1 Management Areas

At the broadest scale, the landscape is divided into management areas. Management areas define collections of stands to which specific harvesting prescriptions will be applied. **An unlimited number of management areas can be defined.** Management areas need not be contiguous. Management areas need not have any harvesting prescriptions implemented, thereby remaining essentially non-active.

1.1.2 Harvesting Stands

At a finer scale, stands are collections of cells and represent typical or average forest management block sizes. Stands must be defined congruent with management area boundaries – **a stand may not belong to more than one management area**. Stands consist of multiple cells and an unlimited number of stands can be defined.

1.2 Harvesting Prescriptions

Harvest **prescriptions** must be defined that specify several harvesting criteria and which species cohorts will be targeted. Prescriptions determine which stands within a management area (MA) qualify for harvest, and define the order (**ranking**) in which these stands will be harvested. **Separate prescription rankings are derived for each MA.** Following the specification of prescriptions, a table defines the percentage of each MA that is to be harvested with each prescription. For each prescription in a MA, the extension begins harvesting in the highest ranked stand and proceeds down the ranked list of stands until the percentage of area in the MA has been cut. Prescriptions can be shared across MAs. More detailed information about prescriptions is provided below.

1.3 Prescriptions order

Prescriptions are stochastically selected for implementation after every harvest event. The reason is that if prescriptions were always implemented in a particular order, the first prescription implemented may harvest most or all of the highest quality stands. The last prescription implemented may find no suitable stands to harvest. The order of prescription implementation also affects availability of stands for later prescriptions when a harvest adjacency criterion is defined.

Therefore, the following algorithm is used to stochastically choose a prescription and implement a single harvest event. This process is repeated until all prescriptions reach their target percentage or there are no more stands available to be harvested.

First, within each management area, a ratio is calculated for each prescription, dependent upon the area designated for harvesting (3.5.4 Area/Stands To Harvest):

$$R_{PS,MA} = \frac{TotalAreaToHarvest_{PS,MA} - ActualAreaHarvested_{PS,MA}}{TotalAreaToHarvest_{PS,MA}}$$

Next, these ratios are then converted to a probability ($P_{PS, MA}$) for each prescription by normalizing $R_{PS, MA}$ such that the sum of all $P_{PS, MA}$ is equal to one. A uniform random number is then compared to an interval corresponding to each $P_{PS, MA}$. The interval in which the random number lies determines the next harvest prescription.

Finally, the highest ranked stand for that prescription is harvested. The area of the stand is added to Actual Area Harvested$_{PS, MA}$. **Stands cannot be harvested more than once per harvest time step.**

The process is repeated until all prescriptions within a management area have achieved their target percentage or there are no more stands available (ranking > 0).

Note: *If the user defines many limiting criteria for a prescription and many stands are ranked zero for that prescription, the desired harvest area may not be reached.*

1.4 Major Releases

1.1.1 Version 5.1 (October 2019)

Update with Succession Library v8. Planting information would only appear in the console if debug mode is enabled.

1.1.2 Version 5.0 (September 2019)

Fixed bug in SingleRepeat cutting to ensure that cells cut in the first entries are also the ones cut in subsequent cuts. Revised logfile to improve reporting of all repeat harvests, including recording every repeat harvest and which iteration of repeat it is on.

Fixed bug that prevented MultipleRepeat cutting from working correctly.

Fixed a bug where after the repeat step in a single repeat the SiteSelector would not be set back to its original parameters.

Added a keyword for MultipleRepeat "TimesToRepeat" which allows a user to specify how many times the selected stands should be repeat harvested.

Revised PatchCutting to allow two spatial options: 1) Default (nothing specified) - ensure that patches do not merge (i.e., all patches have an uncut border) to mimic group selection, 2) AllowOverlap – patches can merge to produce residual leave patches. Removed the redundant optional Priority parameter.

Revised PatchCutting to allow cutting of stands as long as at least one patch can be cut. Prior behavior prevented a stand from being cut unless the full target stand percentage could be reached.

Fixed bugs related to reporting harvest residues and dead pools to other extensions.

Updated for compatibility with other library revisions.

1.1.3 Version 4.1 (March 2019)

Updated with Succession Library v7.

1.1.4 Version 4.0 (August 2018)

Compatible with Core v7.

1.1.5 Version 3.1 (June 2017)

Add plant-only prescription; PlantOnly has been added as a new keyword for CohortsRemoved.

The extension also produces metadata files (*.xml) that allow it to be used with the LandViz tool.

Finally, column names in the log files were updated for clarity.

1.4.1 Version 3.0 (October 2015)

Added the Priority parameter to the Patch Cutting Site Selection option.

The simulation length can now be shorter than the prescription length(s). This allows the simulation length to be changed without needing to update the prescriptions.

Added the ability to set the target harvest to a proportion of eligible stands, rather than an area-based target. Added ability to use the time of the next outbreak from the Base BDA extension to determine stand eligibility for a particular prescription. This allows the application of pre-salvage harvesting.

The SummaryLog no longer duplicates lines when a prescription is used more than once in a management unit (e.g. with different time periods).

1.4.2 Version 2.2

Bug fixed that caused improper simulation of repeated harvests in Biomass Harvest. Repeat harvests (in both Base and Biomass extensions) can now use any kind of Site Selection (previously repeat harvests always applied Complete Stand).

Bug fixed that caused improper multiple repeat harvests. Bug fixed in Random stand ranking method that was leaving off 1 eligible stand. Bug fixed in repeat harvests that was reserving stands for repeat treatment even though not actually treated initially.

1.4.3 Version 2.1

Added the **FireHazard** stand ranking option.

1.4.4 Version 2.0

The extension is compatible with Core v6.0.

1.4.5 Version 1.2

The behavior of Complete and Partial Stand Spreading was changed such that if the initial stand size ***exceeds*** the desired stand size, then the harvest will begin at a random location within the initial stand and spread internally until the desired size is achieved and stop.

A minimum size was added to Stand Spreading (Complete and Partial) to allow users to more tightly control the area harvested if necessary.

A new optional keyword was added to Prescriptions: **MinTimeSinceDamage**. If this keyword is given, a minimum time since last damage (fire, wind, or harvest) test is applied ***at the site (cell) scale***. The new function will prevent harvesting of recently damaged sites and will provide better

control of the area actually harvested. The function will also allow more frequent application of patch cutting as previous patches will not be re-harvested until the minimum time has passed.

A new required log was added: **SummaryLog**. The new log file summarizes prescriptions by management area and by year.

1.4.6 Version 1.1

Beginning with version 1.1, a Forest Type table must contain zero or greater than one Optional statements. At least one of these must be true for a stand to qualify for harvesting.

1.5 Minor Releases for this Major Release

1.6 References

Gustafson, E. J.; Shifley, S. R.; Mladenoff, D. J.; Nimerfro, K. K., and He, H. S. 2000. Spatial simulation of forest succession and timber harvesting using LANDIS. Canadian Journal of Forest Research. 30:32-43.

1.7 Acknowledgements

Funding for the development of LANDIS-II has been provided by the Northern Research Station (Rhinelander, Wisconsin) of the U.S. Forest Service.

2 Harvest Prescriptions

The heart of the Harvest extension is the prescription(s). The user may define multiple harvest prescriptions. These prescriptions can be applied to multiple management areas over different time periods. A prescription defines how stands qualify (or are excluded) for harvest; how they are ranked (determining the order in which they are harvested); how conditions on neighboring stands affect qualification for harvest; how sites (cells) within stands are selected for harvest; the cohorts to be removed from those sites; and whether planting should follow harvesting.

Other extension inputs (e.g., input maps) and the percentage of stands harvested and the time steps of implementation are described in Chapter 3.

2.1 Prescription Keywords

Base Harvest expects keywords in a certain order, although some keywords are optional. *If they are not in this order, you may encounter errors.* See details below regarding expected values.

The expected order:

```
Prescription                          << Required
StandRanking                          << Required
MinimumAge                      << Optional
MaximumAge                      << Optional
StandAdjacency                  << Optional
AdjacencyType                         << Optional
AdjacencyNeighborSetAside             << Optional
MinimumTimeSinceLastHarvest     << Optional
ForestTypeTable                 << Optional
SiteSelection                         << Required
MinTimeSinceDamage                    << Optional
PreventEstablishment                  << Optional
CohortsRemoved                  << Required
Plant                           << Optional
SingleRepeat                          << Optional
MultipleRepeat                        << Optional
```

2.2 Prescription

This text parameter is the prescription's name. Each name must be unique.

2.3 Stand Rankings

Qualified stands can be prioritized for harvest (ranked) in several different ways. Stands are harvested in rank order. For most rankings, a value is calculated for each cell and cells are averaged to calculate the stand rank. Unqualified stands receive a rank of zero and will not be harvested during that time step. A stand ranking method must be designated for each prescription. **Stands are ranked within a management area**, i.e., each management area will have a separate ranking of the stands within it.

2.3.1 StandRanking

This parameter indicates which method to use to rank the stands in a management area. Valid values are `"Economic"`, `"MaxCohortAge"`, `"RegulateAges"`, `"Random"`, and `"FireHazard"`.

2.3.2 Maximum cohort age (keyword: MaxCohortAge)

Stands in a management area are ranked in descending order by age, resulting in oldest stands being harvested first. Stand age is computed as the mean of the oldest cohort on each site within the stand.

2.3.3 Economic importance (keyword: Economic)

Stands are ranked on an index of economic value. Each species is assigned a relative economic value. The value of each age cohort within a species is linearly weighted so that older cohorts are more valuable. The economic value of a site is the sum of the weighted value for each age cohort present. The economic value of a stand is the mean of the economic value for each site in the stand. This ranking algorithm requires additional parameters that indicate the relative economic value of each species and the age of economic maturity (minimum age of merchantability) for each species.

Note: In early releases of Base Harvest, users used the Economic ranking method to target prescriptions to specific species. It is now more efficient and effective to use the Forest Type table (described below) to target prescriptions to specific species combinations.

2.3.3.1 Economic Rank Table

If the stands are ranked on their economic value, then a table of economic ranks must immediately follow the StandRanking parameter. Each row in the table has the economic rank for one species.

2.3.3.2 Species column

The species' name must be one of those listed in the species input file (see Chapter 5 in the *LANDIS-II Model User Guide*). The species can appear in any order in the economic rank table. The table does not need a row for every species. Any species that is not in the table is assigned the default economic rank of 0.

2.3.3.3 Economic Rank column

This parameter is the species' relative economic value (rank), with higher values representing higher value. Value: 0 ≤ integer ≤ 100.

2.3.3.4 Minimum Age column

This parameter is the minimum age at which the species has economic value. Value: integer ≥ 0.

Example:

```
      StandRanking    Economic
>>  Species     Economic Rank   Minimum Age
>>  -------     -------------   -----------
             acerrubr        85            50
```

2.3.4 Regulate cohort ages (keyword: RegulateAges)

Stands are ranked such that harvesting over time will produce an even distribution of stand ages across the management area. The highest priority is given to stands with sites having the most abundant age classes within the management area. Stand age is computed as the mean of the oldest cohort on each site within the stand. The ranking is defined as:

(relative frequency of stands with same maximum age) $e^{(\text{stand-age} / 10)}$

2.3.5 Random (keyword: Random)

Stands in a management area are randomly selected for harvest.

2.3.6 Time Since Disturbance (keyword: TimeSinceDisturbance)

To simulate salvage logging and/or post-disturbance planting, the TimeSinceDisturbance ranking can be used. If used, one of two possible inputs are required:

TimeSinceLastFire #years

OR

TimeSinceLastWind #years

If salvage logging (removal of fire or wind-killed woody biomass) is the desired behavior, then the chosen succession extension should allow dead wood removal by prescription name (versus a generic dead wood removal for all prescriptions). See the inputs for your specific succession extension.

2.3.7 Fire hazard (keyword: FireHazard)

Stands are ranked according to an index of fire hazard, which is based on a stand's fuel type classification. Each fuel type is assigned a fuel type rank. Each fuel type rank is user defined; typically it is based on each fuel type's associated maximum rate of fire spread. **This ranking option can only be used with a Dynamic Fuels extension.** The Dynamic Fuel extensions (there are multiple, but see "LANDIS-II Dynamic Fuel System v2.0 User Guide") classifies each site to a fuel type. The fuel type rank of a stand is the mean of the fuel type ranks for each site in the stand. This ranking algorithm requires additional parameters that indicate the fuel type rank for each fuel type.

2.3.7.1 Fire Hazard Table

If the stands are ranked on fire hazard, then a table of fuel type ranks must follow the FireHazard parameter. Each row in the table has the fuel type rank for each fuel type.

2.3.7.2 Fuel Type column

The fuel type index must be one of those listed in the dynamic fuels input file (see "LANDIS-II Dynamic Fuel System v2.0 User Guide"). The fuel types can appear in any order in the fire hazard table. The table does not need a row for every fuel type. Any fuel type that is not in the table is assigned the default fuel type rank of 0.

2.3.7.3 Fuel Type Rank column

This parameter is the fuel type's fuel type rank, with higher values having higher priority for harvesting. Several fuel types can have the same fuel type rank. Value: 0 ≤ integer ≤ 100.

Example:

```
StandRanking    FireHazard
>>  Fuel Type   Fuel Type Rank
>>  Index
>>  -------     -------------
              1           55
              2           55
```

```
5           36
3           24
```

2.4 Stand Qualifications

Stands may be required to meet one or more qualifications. If they do not meet the qualification criteria, their rank will be set to zero and they will not be harvested.

The stand qualification parameters specify criteria that a stand must satisfy to be eligible for harvesting. Each parameter is optional. If two or more of these parameters are present, they must occur in the order listed in this section.

2.4.1 MinimumAge

This optional parameter specifies a **minimum age** that a stand must be to be eligible for ranking. The age of a stand is the mean maximum age of all cells within the stand. Value: integer ≥ 0. Units: years.

Parameter: Age, in years

2.4.2 MaximumAge

This optional parameter specifies a **maximum age** that a stand can be to be eligible for ranking. The age of a stand is the mean maximum age of all cells within the stand. Value: integer ≥ minimum age; if no minimum age specified, then integer ≥ 0. Units: years.

Parameter: Age, in years

2.4.3 MinimumTimeSinceLastHarvest

This optional parameter specifies the minimum amount of time between successive harvests of a stand. Therefore, in order for a stand to be eligible for ranking, the time since it was last harvested must equal or exceed this parameter. This is useful when the harvest prescription does not change stand age enough to preclude harvest in subsequent time steps. Within the designated period, the stand is disqualified. Value: integer ≥ 0. Units: years.

Parameters: Time, in years

2.4.4 Adjacency constraints

This optional parameter specifies a **minimum stand age** required for all neighboring stands for the stand to eligible for ranking. Three parameters control the adjacency constraints on the stands within a management area. There are two types of adjacency constraints: StandAge and TimeSinceLastHarvested. Specifying a stand adjacency of X years and the adjacency type of **StandAge** will prevent any stand from being cut if any of its neighboring stands are less than X years old. Specifying an adjacency type of **TimeSinceLastHarvested** will prevent a stand from being cut if any of its neighboring stands have been harvested within the last X years. Additionally, setting the AdjacencyNeighborSetAside parameter at Y years will set aside each neighbor of a harvested stand for Y years. This will prevent stands adjacent to a stand just cut from being harvested until Y years have passed. Value: integer ≥ 0. Units: years.

Parameters: StandAdjacency

AdjacencyType

AdjacencyNeighborSetAside

2.4.5 Forest Type

Prescriptions can be targeted to specific species (forest type). A set of rules are specified to define a forest type. **These criteria are used to qualify and disqualify stands for harvesting.**

Each line of the table specifies a species composition condition and inclusion rule that can be either true or false for a stand. The condition is defined by the presence of cohorts within a range of ages for one or more species and a minimum percentage of cells in the stand in which the cohorts must be present. Each rule specifies whether the condition qualifies or disqualifies the stand for harvest.

InclusionRule. Determines how the condition qualifies the stand for harvest. There are three possible values: **Required** = condition must be true. **Optional** = at least one Optional condition must be true. **Forbidden** = condition cannot be true. A stand will qualify for harvest if all Required conditions (if present) are true AND at least one Optional condition (if present) is true AND no Forbidden conditions (if present) are true. No combination of statements is required although there must be more than one Optional statement if there are any Optional statements.

Species and AgeRange. Presence of cohorts within this species and range of ages is evaluated. Multiple species can be listed, separated by a space. If multiple species are listed, then all listed species will contribute to the percent cells requirement. AgeRange indicates the ages that will be evaluated for the species listed.

PercentofCells. Cohorts within the species and range of ages must exist on at least this percentage of cells in the stand for the condition to be true. Valid values ($0 \leq$ PercentofCells ≤ 100; highest). "Highest" indicates that the species listed has the greatest (or is a tie) number of cells with condition = true of **all** the species found in the stand, and is used to identify the dominant species in the stand. Species not explicitly listed will be evaluated using their full age range. The keyword "highest" can occur only once if used on a line with the "Required" or "Forbidden" InclusionRule. If the keyword "highest" occurs on more than one line with the "Optional" InclusionRule, then one of those condition lines MUST be true for the stand to qualify for harvest.

Examples are provided in Chapter 6.

2.4.6 PresalvageYears (Optional)

This optional parameter only works in conjunction with the Base BDA extension, which calculates when the next BDA outbreak is going to occur, before it occurs. The assumes that managers have knowledge of impending outbreaks. For example, in many defoliator systems, outbreaks are fairly regular, and monitoring efforts often offer some advance warning that populations are approaching outbreak levels. Presalvage operations are part of the rationale behind the monitoring efforts.

When PresalvageYears is used as a stand qualifier, the average BDATimeOfNext value for the sites within the stand must be <= the parameter value for PresalvageYears. There is no spatial variability in the timing of BDA outbreaks, they are universal, so all sites and stands will have the same value for BDA.TimeOfNext. (Note: actual impacts of BDA can be spatial, but the outbreak status is a landscape attribute.) So, for example, if the PresalvageYears value is 10, and the next BDA outbreak will happen in 5 years, then all stands meet the Presalvage qualification for that prescription.

In application, a prescription with this stand qualifier is paired with the %Stands option within the implementation table and therefore a certain treatment rate is applied to the stands that qualify for presalvage. The more stand are eligible (at risk), the more harvesting gets done.

If the Base BDA extension is not run, no stands will meet this stand qualification. Value: integer ≥ 0. Units: years.

2.5 Site Selection

For each harvest event, the number of sites within a stand to be harvested must be indicated. Part of a stand, an entire stand, or multiple stands may be specified. A single site selection method must be given for each prescription.

2.5.1 SiteSelection

This parameter indicates the method for selecting sites for harvesting (see section 2.5 *Site Selection*). Valid method names are `"Complete"`, `"CompleteStandSpread"`, `"PatchCutting"` and `"PartialStandSpread"`.

2.5.2 Complete Stand (keyword: Complete)

All sites (cells) within a stand are harvested. The size of a harvest event is determined by the size of the stand selected.

2.5.3 Stand Spreading (keyword: CompleteStandSpread or PartialStandSpread)

This allows more control of the size of harvest events, which can be larger or smaller than a stand.

2.5.4 Target Harvest Size

If the site-selection method is complete stand spreading (`"CompleteStandSpread"`) or partial stand spreading (`"PartialStandSpread"`), then a target harvest size (minimum and maximum) must follow the method's name. Values: number ≥ 0. Units: hectares.

2.5.4.1 Targeted Stand Size – Partial Stand Spreading

Beginning at a random point within a stand, the harvest event spreads until the desired size is reached. A stand may be partially harvested or the harvest event may spread to cells in neighboring stands, depending on the size of the stand relative to the target size. When the selected stand is smaller than the target size, harvesting spreads to the neighboring stand (a neighbor of any stand already selected for the current event) with the highest stand ranking. A neighboring stand will be completely harvested before spreading to additional neighbors. Therefore, at most only one stand will

be partially harvested. **Harvesting may not spread into stands that do not meet the prescription constraints (e.g., stand qualifiers or ranking = 0) or into neighboring management areas.** Harvesting will continue until the target size is reached, or the initial stand has no more qualified neighbors.

Parameters: Minimum Target Size, in hectares

Maximum Target Size, in hectares

2.5.4.2 Targeted Stand Size - Complete Stand Spreading

All sites (cells) within a stand are harvested. If the number of sites harvested is <95% of the target size, **all** cells in a neighboring stand are harvested until the desired size is reached or exceeded. Harvesting spreads to the neighboring stand (a neighbor of any stand already selected for the current event) with the highest stand ranking. **Harvesting may not spread into stands that do not meet the prescription constraints (e.g., stand qualifiers or ranking = 0) or into neighboring management areas.**

Parameters: Minimum Target Size, in hectares

Maximum Target Size, in hectares

2.5.5 Patch Cutting (Group Selection)

Randomly selected patches (clusters) of sites within a stand will be harvested. The User indicates the percentage of cells within a stand to be harvested and the desired patch size (ha) of the groups. Initial entry sites are randomly selected. From the initial entry site, the patch spreads to neighboring sites until the desired patch size is reached or there are no available neighbors within the stand. If the target percentage of cells in the stand has not been cut, a new entry site within the stand is chosen and the process is repeated. This site selection method may also be used to produce residual patches of uncut sites by specifying a relatively large percentage of the stand.

AllowOverlap is an optional parameter that allows patches to overlap, which in concert with a high Percentage value can mimic residual-leave cutting practices.

Parameters: Percentage, 0% < n <= 100%

Target Patch Size, in hectares

Priority (optional), PatchSize or PercentCut

Optional: AllowOverlap

Note: Only the actual area harvested in a stand (some fraction of the total stand) will be counted toward the target percent area harvested in the Implementation Table. As a result, a prescription with smaller patches will result in more harvest events but the **same total area** (assuming that other restrictions don't come into play) harvested as a prescription with larger patches but the same target area cut.

2.6 Cohort Removal List

The User must designate which cohorts are to be removed during each harvest event. A cohort list must be included in each prescription.

2.6.1 CohortsRemoved

This parameter indicates which cohorts will be removed by the prescription. Valid values are:

- `"ClearCut"` – All the cohorts of all species present at the selected sites will be removed.
- `"PlantOnly"` – No cohorts of any species will be removed but reproduction will occur according to the succession extension.
- `"SpeciesList"` – A list of species that will be harvested follows this parameter

2.6.1.1 Species List for Cohort Removal

The list has at least one species. Each species is on a separate line. The species do not need to appear in any particular order.

On each line, after the species' name, is either a keyword or a list of cohort ages. The keyword or age list indicates which of the species' cohorts will be harvested.

Valid cohort keywords are:

- `"All"` – All the species' cohorts will be removed.
- `"Youngest"` – Only the youngest cohort will be removed.
- `"Oldest"` – Only the oldest cohort will be removed.
- `"AllExceptYoungest"` – All the species' cohorts except the youngest cohort will be removed. Only the youngest cohort is left.
- `"AllExceptOldest"` – All the species' cohorts except the oldest cohort will be removed. Only the oldest cohort is left.

- "1/*N*" – A fraction of the species' cohorts are removed, by going through the cohorts from youngest to oldest, and removing every N^{th} cohort that is present. *N* is an integer > 0. No whitespace is allowed in the fraction (i.e., no whitespace is allowed before or after the "/" character).

An age list has one or more items separated by whitespace. An item is either an individual cohort age or a range of ages. The format for an age range is "age_{start}-age_{end}" where $age_{start} \leq age_{end}$. Each age in the list, whether individual or the endpoint of a range, is an integer between 1 and 65,535.

The ages and ranges in the list can appear in any order. An individual age cannot be repeated in the list. Also, a range cannot overlap any other range or include any listed individual age.

A species cohort will be removed if the cohort's age is one of the individual ages in the list or if its age lies within one of the ranges in the list.

Example:

```
>>  Species     Cohorts removed
>>  -------     ---------
    abiebals    35-100 140 150-160
    acerrubr    AllExceptYoungest
    pinubank    1/3
```

2.6.2 Plant

This optional parameter indicates which species should be planted at a site after it is harvested. Value: A list of one or more species names separated by whitespace.

Example: Plant pinustro

Planting **may** prevent the establishment of other species in the current time step depending on the succession extension used. Please consult the user guide for your selected succession extension for details on Reproduction priorities.

2.7 Repeated Prescriptions

Prescriptions are typically applied at each time step, with stands selected for harvest based on a new ranking at each time step. However, some prescriptions require the same stand to be harvested later in a predictable way. Therefore, prescriptions can optionally specify a predictable repeat harvest in one of two ways: single repeat or multiple repeat. These options can be used in combination with any of the stand qualifiers or ranking procedures

given above. However, note that the multiple repeat harvests will only be qualified and ranked **once**.

Note: *Stands set aside for repeated harvests within one prescription are not available for harvesting by other prescriptions.*

Note: *The SiteSelector value used in initial entries is also used in all repeat entries.*

2.7.1 Single Repeat Harvests

A single repeat is necessary when performing seed tree or shelterwood harvests. For example, most cohorts of a white pine stand may be removed, leaving only the oldest cohort. After a designated interval, allowing enough time for regeneration via seeding, the oldest cohort is also removed. **These stands are re-harvested once after the designated interval.** Although stands are ranked for the initial harvest, **the second harvest will occur automatically without a re-ranking**. A second cohort removal list **must** be provided for repeat harvests. Time-since-last-harvest will be updated after both harvests.

The **SingleRepeat** optional parameter indicates that the prescription is a single repeat-harvest (see section 2.1). The parameter specifies the interval between the initial harvest and the repeat harvest of the selected stands. Value: integer > 0. Units: years.

2.7.1.1 CohortsRemoved and Plant Parameters for Single-Repeat Harvests

In order to specify which cohorts are to be removed during the repeat harvest, a 2nd use of the CohortsRemoved parameter (see section 2.6.1 above) must follow the SingleRepeat parameter.

Also, if the repeat harvest involves the planting of species, a second use of the Plant parameter (see section 2.6.2 above) may follow the second use of the CohortsRemoved parameter.

2.7.2 Multiple Repeat Harvests

Multiple repeat harvests can be used to mimic selective harvesting, clearcutting, and other silvicultural practices where stands are repeatedly entered to remove specific cohorts. At a regular, specified interval, typically allowing enough time for maturation, the stands are harvested again. **These stands are only ranked once during the initial harvesting period and are repeatedly (periodically) harvested.**

User Hint: *If re-ranking of multiple repeat harvests is desired, give the prescription an early ending in the Harvest Implementation Table, below and create a new entry in the same table with a later start date.*

The MultipleRepeat optional parameter indicates that the prescription is a multiple repeat-harvest. The parameter specifies the interval between the successive harvests of the selected stands. Value: integer > 0. Units: years.

Optional parameter: TimesToRepeat (positive integer). Can be used to limit the number of times that the MultipleRepeat is executed. By default it will repeat until the simulation ends because the end time step given in the implementation table applies only to the initiation of prescriptions.

2.8 Other Prescription Parameters

There are two parameters that do not fall easily into the other categories of behavior (ranking, qualification, site selection, cohort removal).

2.8.1 MinTimeSinceDamage

This is a site (cell) qualification whereby you can exclude individual sites within a stand if they have not reached a minimum time since damaged by disturbance, including fire, wind, insects, and harvesting.

2.8.2 PreventEstablishment

This keyword will prevent establishment within all sites selected for harvesting. However, any remaining cohorts on the site will continue to grow. The concept is designed to mimic the effects of housing development when sites are fully or partially harvested and do not regenerate back to forest.

3 Other Inputs

This extension has three input files: a text file containing input parameters and two input maps (see section 3.3). The text file must comply with the general format requirements described in section 3.1 *Text Input Files* in the *LANDIS-II Model User Guide*.

3.1 LandisData

This parameter's value must be `"Base Harvest"`.

3.2 Timestep

This parameter is the extension's timestep. Value: integer > 0. Units: years.

3.3 Input Maps

The extension requires two input maps. It reads the maps after it has finished reading this input file.

3.3.1 ManagementAreas

This parameter is the filename of the input map showing where the management areas are located on the landscape. The extension checks each cell value in the map at an active site on the landscape. Any value that is not in the Management Area column of the harvest implementations table (see section 3.5) is considered an **inactive** management area. After reading the management area map, the extension outputs a list of all the inactive management areas that were found.

3.3.2 Stands

This parameter is the filename of the input map showing where the harvest stands are located. The extension will report an error if any stand belongs to more than one management area.

3.4 Harvest Prescriptions

See the section above for details describing the harvest prescriptions.

3.5 Harvest Implementations Table

This table specifies which prescriptions are implemented in the various management areas. Each row in the table specifies one prescription that is applied to one or more management areas. More than one prescription can be applied to a management area.

3.5.1 Table Name

The table's name is `"HarvestImplementations"`.

3.5.2 Management Area Column

This parameter is the map code of the management area to which the prescription will be applied. The management area must contain at least one active site in the landscape. Value: 0 ≤ integer. If a prescription is to be applied to more than one management area, these should be listed on separate lines.

3.5.3 Prescription Column

This text parameter is the name of the prescription to apply to the management area(s).

3.5.4 Area/Stands To Harvest Column

This parameter is the target percentage of the cells in a management area to be harvested with the applied prescription **within a single harvest time step**. Value: 0% ≤ number ≤ 100%. Target percent is a fraction of sites within a management area. Note: non-active sites should not be included in any management area as this may lead to erroneous computation of the number of sites to be harvested.

This parameter can be used to target a proportion of stands by adding the keyword *Stands* immediately after the % in the input (e.g., *10%Stands*). When the Stands keyword is used, the target for the applied prescription will be to harvest x% of all eligible stands (i.e., ranking > 0) in each harvest time step. Note that when prescriptions include stand qualifications (2.4) this can impact the targeted number of stands to harvest, and the number of targeted stands can change through time.

3.5.5 Begin Time Column

This optional parameter indicates the year during the model scenario when the prescription should start being applied to the management area. Prior to the specified year, the prescription is inactive. Value: 0 ≤ integer ≤ end year of the scenario. Units: Year. **If this parameter is not specified, then the prescription starts at the beginning of the scenario.**

3.5.6 End Time Column

This optional parameter indicates the year during the model scenario when the prescription should stop being applied to the management area.

After the specified year, the prescription is inactive. Value: Begin Time ≤ integer ≤ end year of the scenario. Units: Year. **If this parameter is not specified, then the prescription is active until the end of the scenario.**

Note: this parameter can only be used if the Begin Time parameter is also used. In other words, in order to specify an end time for a prescription, the user must also specify a begin time.

Example:

```
  HarvestImplementations

>>Mgmt Area   Prescription   Harvest Area    Begin Time  End Time
>>---------   ------------   ------------    ----------  --------
  1           RandomClearCut  10%                          0          50
  2           RandomClearCut  20%
  3           RedMapleHarvest 8%                           50        100
  3           MaxAgeClearcuts 15%
```

4 Specifying outputs

4.1 PrescriptionMaps

This file parameter is the template for the names of the prescription output maps (see section 5.1). The parameter value must include the variable "timestep" to ensure that the maps have unique names (see section 3.1.8.1 *Variables* in the *LANDIS-II Model User Guide*). **The user must indicate if the output should be placed in a subdirectory.**

4.2 EventLog

The file parameter is the name of the extension's event log file (see section 5.2).

4.3 SummaryLog

The file parameter is the name of the extension's summary log file (see section 4.3).

5 Output Files

This extension generates two types of output files: a) a map of where prescription harvests occurred in each time step, and b) log files of harvest events and a summary for the entire scenario.

5.1 Prescription Maps

Each prescription is assigned a number that represents its position in the input parameter file. The first prescription is assigned 1, the second is assigned 2, and so on. The harvest map is labeled 0 for non-active sites, 1 for active and not disturbed sites, [prescription number + 1] for all harvested sites. A map is produced for each harvest time step.

5.2 Event Log

The event log is a CSV file that contains information about every harvest event over the course of the scenario: year, management area, prescription used, stand affected, event ID, that stand's current age, that stand's current rank, total event size (number of sites), number of sites where cohorts were removed, total number of cohorts removed, and number of cohorts removed for each species.

5.3 Summary Log

The summary log is a CSV file that contains summary information about harvest events for each year, management area and prescription: year, management area, prescription used, total number of sites where cohorts were removed, and total number of cohorts removed for each species.

6 Example Inputs

6.1 Example Forest Type Tables

```
ForestTypeTable  << Northern hardwood without hemlock
 >> InclusionRule ageRange    percentCells            species
    Optional      20-200            45                acersacc
    Optional      30-220            45                querrubr
    Forbidden     30-300            10                tsugcana

ForestTypeTable  << Scots pine
 >> InclusionRule       ageRange    percentCells      species
    Required            101-300     highest           pinusylv
    Forbidden           100-450     40                pinusibi
    Forbidden           1-151       60                betupend
    Forbidden           1-131       60                poputrem

ForestTypeTable  << Conifers
 >> InclusionRule       ageRange    percentCells      species
    Forbidden           1-151       60                betupend
    Forbidden           1-131       60                poputrem
    Optional            101-300     highest           piceobov
    Optional            101-211     highest           aibesibi
    Optional            101-380     highest           larisibi
    Optional            101-300     highest           pinusylv

ForestTypeTable  << uneven-aged Siberian larch
 >> InclusionRule       ageRange    percentCells      species
    Required            101-380           50          larisibi
    Optional            1-40              1           larisibi
    Optional            41-80             1           larisibi
    Optional            81-100            1           larisibi

ForestTypeTable   << light conifers (larch or Scots pine) dominate
>>and all conifers together comprise at least 50% of stand.

>>InclRule            ageRange  %Cells   species
 Required             101-380   highest    larisibi pinusylv
 Required             101-380   50         larisibi pinusylv piceobov
 Forbidden            1-151     60      betupend poputrem

ForestTypeTable   << mixed spruce forest
>> (spruce plus at least one other conifer and one deciduous)

>>InclRule            ageRange   %Cells  species
  Required            101-300    49     piceobov
  Required            101-380    25     larisibi pinusylv piceobov aibesibi
  Required            1-151      25     betupend poputrem
```

6.2 Example Parameter File

The following is an example parameter file, with several prescriptions defined, and later used in the HarvestImplementations table.

```
>>  SAMPLE HARVEST FILE

>>  If a parameter requires SPECIES information, it must be followed by a >>
table listing a species name, followed by a list of parameters,
>>  as outlined in the documentation.

>>------------------------------------------------------------------------
>> TYPE OF DATA

LandisData  "Base Harvest"

>>------------------------------------------------------------------------
>>  TIMESTEP

Timestep    10

>>------------------------------------------------------------------------
>>  MANAGEMENT AREAS: the .gis file which defines the management areas.

ManagementAreas "./management.gis"

>>------------------------------------------------------------------------
>>  STANDS: the .gis file which defines the stands.  A stand can belong to
>> one and only one management area.

Stands      "./stand.gis"

>>------------------------------------------------------------------------
>>  PRESCRIPTION NAME
>>  Each prescription must have a unique name, which can be referenced
>>  later in the HarvestImplementation section.
>>  The data following the prescription name defines the prescription.

    Prescription    RandomClearCut

>>  STAND RANKING METHOD:
>>  The different Stand Ranking methods are listed below.
>>  Some require extra  parameters, which are outlined in the user guide.
>>  Select 1 of the following:
>>  1. Economic         - requires SPECIES information
>>  2. MaxCohortAge
>>  3. Random
```

```
>>  4. RegulateAges

    StandRanking    Random

>>  AGE REQUIREMENTS:
>>  Define a Minimum or Maximum age to limit the prescription stand ages.

    MinimumAge  150
    MaximumAge  325
    TimeBetweenHarvests  40

>>  SITE SELECTION METHOD:
>>  The different Site Selection methods are listed below.
>>  Some require extra parameters, which are outlined in the user guide.
>>  Select 1 of the following:
>>  1. Complete
>>  2. CompleteStandSpread
>>  3. PartialStandSpread
>>  4. PatchCutting

>>                           Percentage  Patch Size
>>                  ----------  ----------
    SiteSelection   PatchCutting   15%     3

>>  COHORT REMOVAL METHOD:
>>  The different Cohort Removal methods are listed below.
>>  Select 1 of the following:
>>  1. ClearCut
>>  2. SpeciesList      - requires SPECIES information

    CohortsRemoved  ClearCut

>>  MORE PRESCRIPTION EXAMPLES:
>>  The following section is a set of example prescriptions
>>  These examples show how the 'stand ranking' methods,
>>  'site selection' methods and the 'cohort removal' methods can be
>>  recombined to make new prescriptions.


>>--------------------------------------------------------------------
>>  This example aims to show how species information can be used to
>>  refine a harvest prescription.

Prescription    MapleHarvest

    Minimum Age     20 << years
    StandRanking    Economic

>>  The 'Economic' ranking requires species information.
>>  Below is a table listing a species name, its 'Economic Rank', and
```

```
>> 'Minimum Age' requirement.

>>  Species     Economic Rank   Minimum Age
>>  -------     -------------   -----------
    acersacc    100             60
    acerrubr    50              60

    SiteSelection   Complete
    CohortsRemoved  SpeciesList

>>  The 'SpeciesList' cohort-removal method requires species information.
>>  The table below lists species' cohorts to be removed.
>>  The 'Selection' methods shown below provide three example.

    >>  Species     Selection
    >>  -------     ---------
        abiebals    All
        acersacc    AllExceptYoungest
        acerrubr    AllExceptYoungest
        pinubank    50

>>--------------------------------------------------------------------
>>  This example shows a simple and short harvest prescription.

Prescription    MaxAgeClearcuts

    StandRanking    MaxCohortAge
    SiteSelection   Complete
    CohortsRemoved  ClearCut

>>--------------------------------------------------------------------
>>  HARVEST IMPLEMENTATION TABLE
>>  The following table defines which management areas (defined in the
>>  ManagementArea file) are treated by which prescription(s).
>>  In the example below, both management areas 1 and 2 are treated
>>  by the same prescription, while management area 3 is treated by two
>>  different prescriptions.

>>  Also demonstrated is beginning and end times for each prescription
>>  implementation.

    HarvestImplementations

>>  Mgmt Area   Prescription    Harvest Area    Begin Time  End Time
>>  ---------   ------------    ------------    ----------  --------
    1           RandomClearCut  10%                   0     50
    2           RandomClearCut  20%
    3           MapleHarvest 8%                      50    100
    3           MaxAgeClearcuts 15%
```

```
>>------------------------------------------------------------------------
>> OUTPUT FILES

PrescriptionMaps    harvest/prescripts-{timestep}.gis
EventLog            harvest/log.csv
SummaryLog          harvest/summarylog.csv
>>------------------------------------------------------------------------
```