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Scott Morken, Max Fellows, and Carolyn Smyth

Canadian Forest Service
Pacific Forestry Centre

Information Report
BC-X-457

Canada

The Pacific Forestry Centre, Victoria, British Columbia

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## Abstract

This report describes a general-purpose spatial inventory rollback tool that can be applied to any GCBM project to adjust the inventory age, spatial disturbances, regeneration delays and historical stand-establishment to a desired baseline year. The tool also provides inventory and disturbance statistics, and identifies discrepancies between the inventory and spatial disturbance datasets. We summarize the tool's procedures and describe how to configure and run the tool. Sample results are shown for a provincial scale run of British Columbia's public forests, where a 2015 vintage inventory was rolled back to 1990.



## Acknowledgements

We thank the Carbon Accounting Team (Canadian Forest Service) for their suggestions, Samantha Suddes and Alex Gray for their help in developing prototypes, and Stephen Kull and Werner Kurz (CFS) for providing comments on an earlier draft of the report. We also thank Juha Metsaranta (CFS) for providing comments on uncertainties which have been included in the Appendix.

# Introduction

The general-purpose spatial inventory rollback tool described in this report is a user-friendly tool that can be applied to any Generic Carbon Budget Model (GCBM) project. For the reporting of greenhouse gas (GHG) emissions and removals, model analyses are required for the period 1990 to the present. In many cases, forest inventories for 1990 do not exist.

The roll-back tool combines spatial information from a forest inventory for a post-1990 inventory year with data on disturbances and then rolls back the inventory from its reference year to the starting year of the planned analysis. This baseline year is typically 1990 (or another year chosen by the user).

This report describes how the rollback tool adjusts the inventory age, spatial disturbances, regeneration delays, and historical stand-establishment from the original vintage to a chosen baseline year. It also provides information on how to configure and run the tool, and displays the results of a provincial-scale test run.

# Rollback Cases and Procedures

The rollback tool handles ten different cases of configuring the inventory age, regeneration delay, historical stand-establishment disturbance (last-pass disturbance)[1], and stand-replacing disturbance layers that are processed in six procedures. Many of the cases consider inconsistencies between the stand age supplied in the inventory data, and the stand age inferred from spatial data on stand-replacing disturbances. Although the tool will successfully produce GCBM input layers, the user may wish to correct any issues and apparent inconsistencies in the underlying inventory and disturbance datasets. Inventory age and disturbance information are likely to contain errors and uncertainties, as discussed by Juha Metsaranta in the Appendix.

The tool also provides users with the option to specify whether they want inventory or disturbance data to be used, where conflicting information exists. In the case where the information about a stand-replacing disturbance and the age of the stand in the inventory year are in conflict, the user can decide whether to use the disturbance information and adjust the stand age in the inventory or use the inventory information and adjust the year of disturbance.

The rollback cases implemented in the tool, which are split into two categories—old and young stands— are described in Table 1. Figure 1 describes the cases for old stands, namely those established before the baseline year, while Figure 2 describes the cases for young stands, which were established after the baseline year.

Old stands have an original inventory age greater than the number of years to roll back (Figure 1 and Table 1). In most instances, these are the easiest stands to roll back because the rolled back age is the original stand age minus the number of years to roll back (Case 1). Any available information on older disturbances (before the rollback year) are converted to a stand establishment (last-pass) disturbance type (Case 2). If recent stand-replacing disturbances are available, these disturbances are retained under the assumption that the inventory has not yet been updated with the latest disturbance information (Case 3).

Young stands have an original inventory age less than the number of years to roll back. If historical disturbance information is provided, the tool will compute the baseline age based on the number of years between the year of the most recent pre-baseline disturbance and the baseline year.

In situations where no disturbance history is provided, the tool offers user-configurable methods to inform the pre-establishment age, establishment disturbance type, and historical disturbance type (most recent pre-rollback year disturbance). The user may supply a pre-disturbance age-class distribution from which a baseline age will be drawn.

If information on recent disturbances implied by inventory data is missing, the tool can insert a user-specified stand-replacing disturbance event at the establishment year. By default, the tool will associate recently occurring disturbances indicated by disturbance layers, with recent inventory establishment indicated by inventory layers, by using GCBM regeneration delays, or by adjusting inventory establishment or disturbance timeseries according to user preferences. These procedures are broken down into the young stand rollback cases (four through ten), shown in Figure 2 and Table 1.

1 The last-pass disturbance is used by GCBM to initialise the dead organic matter pools during the spin-up phase of the model.

**Table 1.** Description of ten cases for configuring the inventory age and disturbance information relative to a baseline year

| Rollback case | Description | Procedure | Information requirements |
|---|---|---|---|
| 1. Old stand, simple subtraction | Old stand with general information on the disturbance that established stands. | Adjust inventory age and configure the last disturbance type. | Stand establishment disturbance type. |
| 2. Old stand, simple subtraction | Old stand with spatial information on the disturbance that established the stand. | Adjust inventory age and use historical disturbance layers to set last disturbance type. | Spatial layers of historical stand-replacing disturbances. |
| 3. Old stand, recent disturbance[a] | Older stand with recent stand-replacing disturbance, suggesting inventory update hasn't occurred. | Allow the recent disturbance to occur and set the rollback age to the original age minus rollback years (same as Case 1 and 2). | Spatial disturbance layers. |
| 4. Young stand with no matching disturbance[a] | Young stand with no stand-replacing disturbance to establish the stand. | Create a stand-replacing disturbance to match the establishment date and set the pre-disturbance age based on the age-class distribution. | A configurable disturbance type for the missing stand establishment and the age-class distribution of the disturbance age for each disturbance type. |
| 5. Young stand with matching disturbance | Young stand with matching stand-replacing disturbance to establish stand. | Set pre-disturbance age based on age-class distribution. | Age-class distribution of disturbance age for each disturbance type. |
| 6. Young stand with almost-matching disturbance | Stand establishment may occur a few years after a stand-replacing disturbance. | Add in a regeneration delay to account for the time between the disturbance date and the stand establishment date, and set the pre-disturbance age based on the age-class distribution. | Age-class distribution of disturbance age for each disturbance type and spatial disturbance layers. Users may want to check the regeneration delay. applied to the stands in transition_rules.csv. |
| 7. Young stand with disturbance after establishment date[a] | Default assumption that the inventory information is accurate. | Disturbance date is adjusted to match stand establishment and set the pre-disturbance age based on age-class distribution. | Spatial disturbance layers and age-class distribution of disturbance age for each disturbance type. |
| 8. Young stand with disturbance after establishment date[a] | The user indicates that the disturbance information is correct. | Allow disturbances to occur, and set the pre-disturbance age based on age-class distribution. | Spatial disturbance layers and age-class distribution of disturbance age for each disturbance type. |
| 9. Young stand with multiple disturbances after the baseline year | Move the closest disturbance to the establishment date. | Adjust the closest disturbance date and set the pre-disturbance age for first disturbance based on age-class distribution. | Spatial disturbance layers and age-class distribution of disturbance age for first disturbance type. |
| 10. Young stand with multiple disturbances before and after the baseline year | Move the later disturbance to the establishment date. | Adjust second disturbance date and set the last-pass disturbance as the first disturbance. | Spatial disturbance layers. |

a Users may wish to understand the reasons for the discrepancies and/or correct the spatial layers.

Procedures developed to process the above cases were separated into six procedures, as described below.

BasicRollbackProcedure (Cases 1, 2, and 3):

- The rollback age equals the inventory stand age minus the rollback years.
- Keep all existing disturbances.
- Convert pre-rollback period disturbances to last-pass disturbance time series.
- Create a disturbance at establishment year if one does not already exist.

NoSupportingInfoRollbackProcedure (Case 4):

- The rollback age equals the stand age drawn from the age-class distribution minus a temporal shift, where the shift equals the establishment year minus the rollback year.
- Keep existing post-inventory-year disturbances and create a disturbance at the rollback establishment year (i.e., the rollback year minus the rollback age).

RegenDelayRollbackProcedure (Cases 5 and 6):

- A regeneration delay is added to the most recent stand-replacing disturbance event before the establishment year.
- The rollback age equals the age drawn from the distribution minus a temporal shift, where the shift equals the earliest post-rollback disturbance year minus the rollback year.
- Keep the existing non-stand-replacing disturbances after the rollback year, and stand-replacing disturbances after the establishment year.

ShiftDisturbanceProcedure (Cases 7 and 9):

- The rollback age equals the stand age drawn from the distribution minus a temporal shift, where the shift equals the earliest post-rollback disturbance year minus the rollback year.

- Move the stand-replacing disturbance closest to the establishment year to the establishment year and keep all disturbances except the ones between the establishment and inventory years.
- Create a new stand-replacing disturbance at the rollback establishment year (i.e., the rollback year minus the rollback age).

ShiftEstablishmentProcedure (Case 8):

- The rollback age equals the stand age drawn from the age class distribution minus a shift, where the temporal shift equals the earliest post-rollback disturbance year minus the rollback year.
- Keep all existing disturbance events and create a rollback establishment disturbance at the rollback establishment year (i.e., the rollback year minus the rollback age).

DisturbanceInformedRollbackProcedure (Case 10):

- The rollback age equals the rollback year minus the closest pre-rollback disturbance year.
- Shift the closest stand-replacing disturbance from the establishment year to the original establishment year and discard any remaining disturbances between the establishment and inventory years.

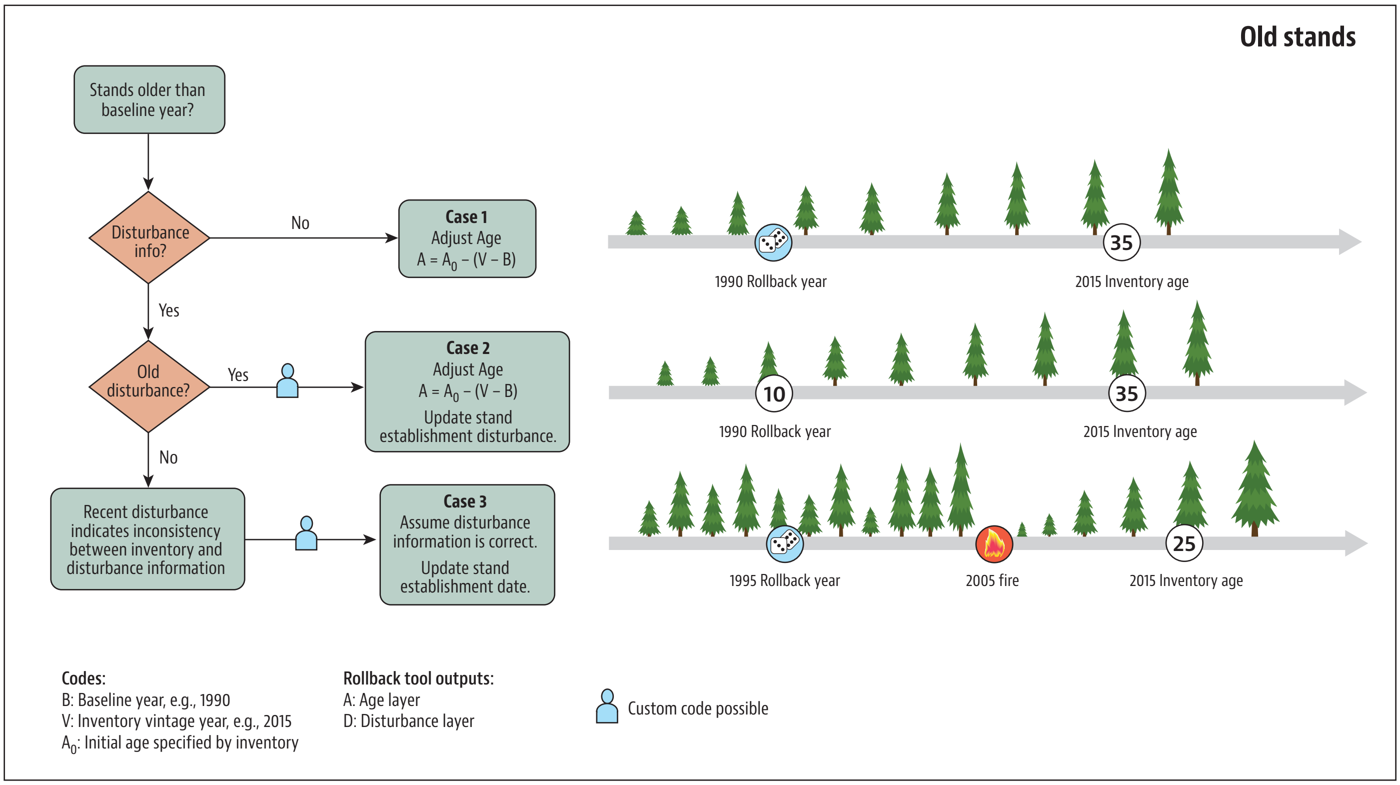


**Figure 1.** Rollback cases for old stands which the inventory indicates were established before the baseline year.

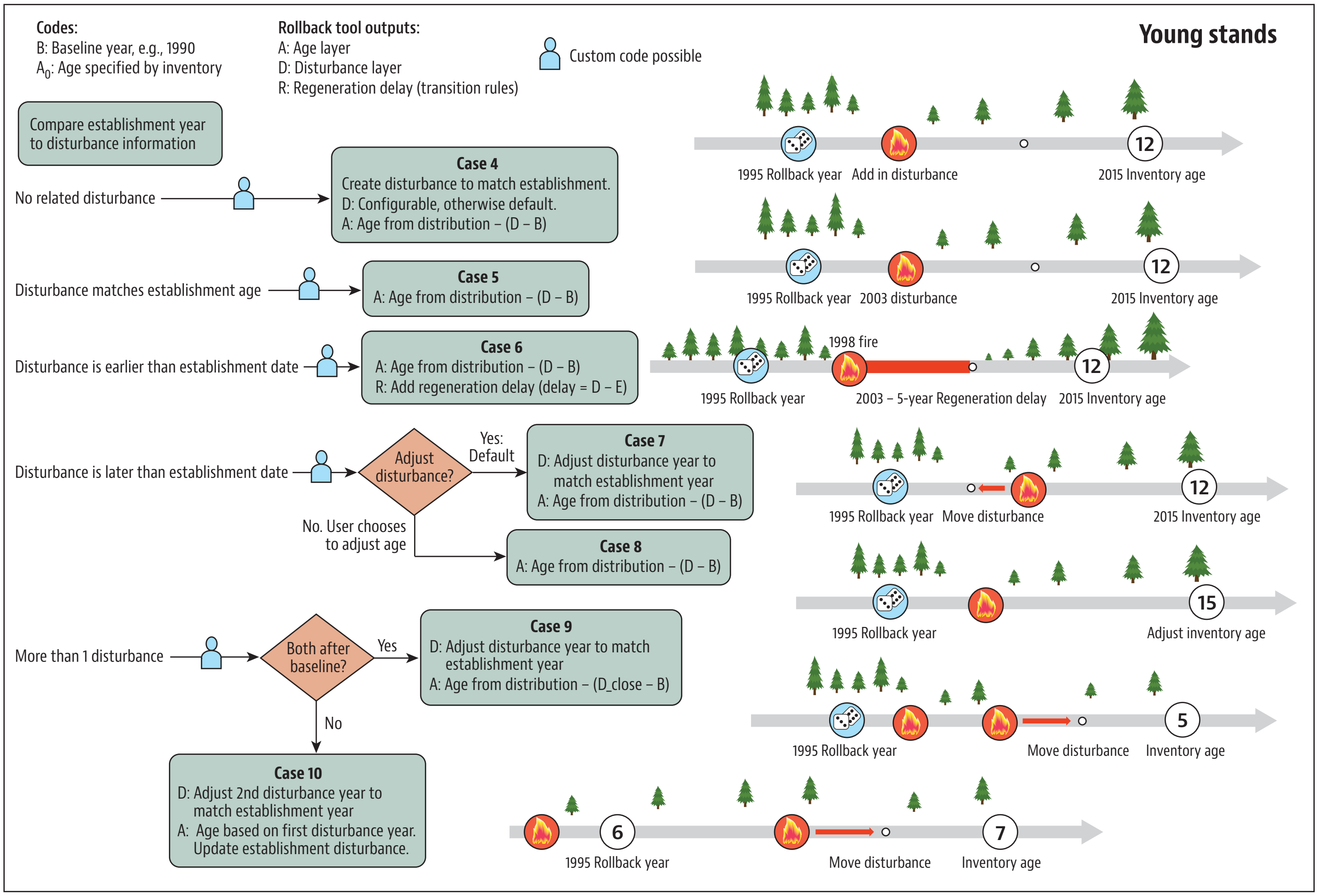


**Figure 2.** Rollback cases for young stands that were established after the baseline year.

## Information Requirements and Workflow

The rollback tool integrates into the middle of the pre-processing workflow of GCBM projects, as shown in Figure 3. Information required for the rollback tool includes tiled spatial information for the GCBM simulations, and additional spatial and aspatial information.

Required information includes:

- the inventory vintage and target year (baseline year) for the rollback;
- pre-disturbance age-class distribution for stand-replacing disturbances (one for each disturbance type or a general-purpose distribution); and
- historical stand-replacing disturbance layers, or information on the last known disturbance type that established the stands (i.e., last-pass disturbance).

If required information is missing, the rollback tool will stop and display a message regarding the missing information.

Optional information includes a list of stand-replacing disturbance types used in the GCBM simulation, which will be determined based on the disturbance matrix values, if not provided. A disturbance is considered stand-replacing if all live biomass is transferred to other pools in the matrix.

If there is a new combination of inputs that is not covered by any of the ten cases listed in Table 1, the rollback tool will stop and report the conditions encountered in the inventory age and disturbance data. The user will then either need to adjust the inventory age and disturbance information to fit within an existing procedure, adjust the rollback tool by modifying an existing procedure, or create a new procedure.

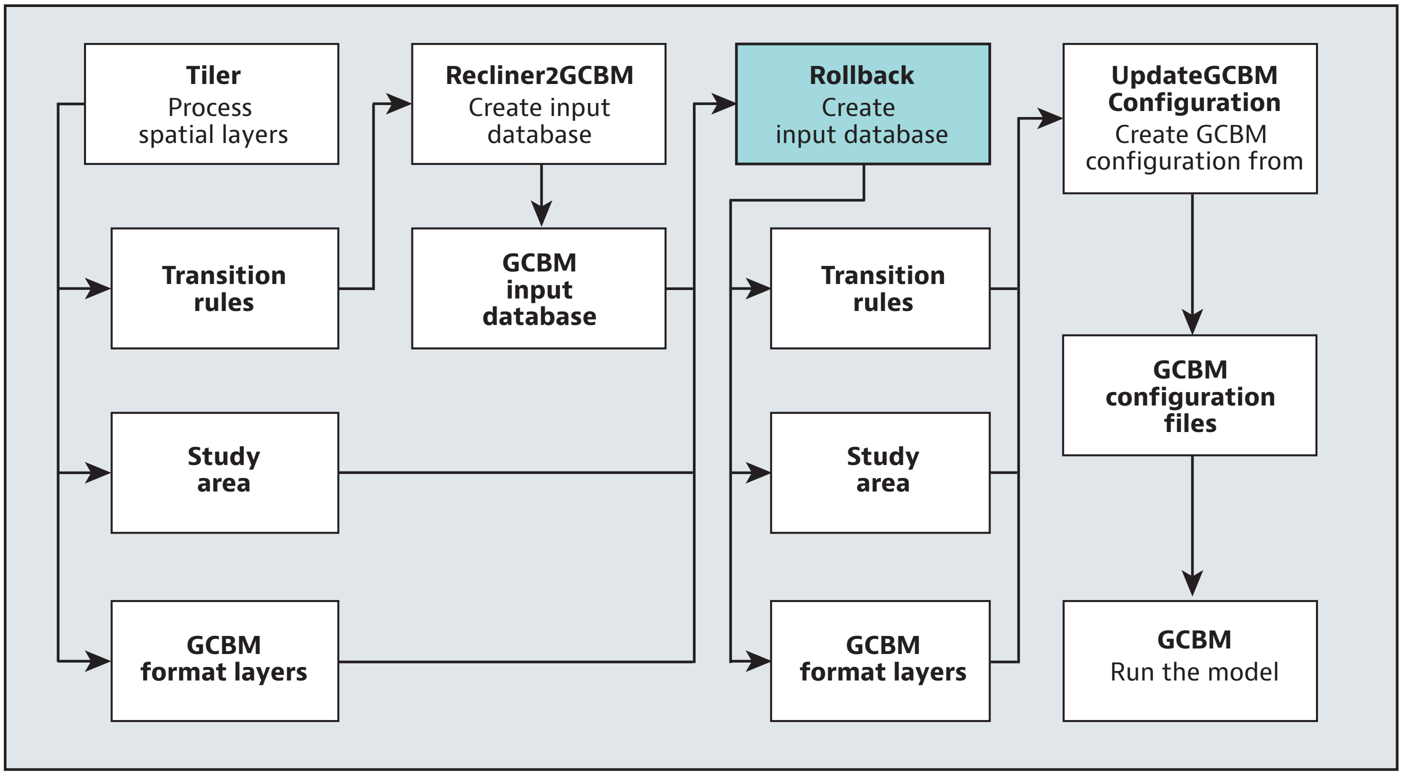


**Figure 3.** The pre-processing workflow of the GCBM indicating where the rollback tool (shaded blue box) was integrated.

## How to Run the Rollback Tool

Once all GCBM and supporting tools have been successfully installed, the rollback tool can be installed using pip in Python 3.7. The rollback tool is available upon request as a standard binary whl.

Configuration files provided with the rollback tool permit users to enter project-specific information and set default assumptions (as explained below). These files include information on age-class distribution by disturbance type, and an optional stand-replacing disturbance lookup, as described below.

The **age-class distribution** file contains the pre-disturbance age-class distribution for the rollback procedures that assigns a new age at the rollback year. Two formats are available. The first is a JSON format that can specify an age-class distribution for each stand establishment disturbance type, and a default distribution as follows:

```
[
  {
    "distribution": [
      [120, 1]
    ]
  },
  {
    "disturbance_types": ["Wildfire", "Wild Fires"],
    "distribution": [
      [30, 0.6],
      [40, 0.4]
  }
]
```

The tool expands the configured age class distribution to evenly fill each integer age between the specified value's age class with the associated proportion value. Tables 2 and 3 show examples of this. Table 2 shows the tool's expansion of the above default 120 age distribution, and Table 3 displays the expansion of the above 30 and 40 age class distribution. The expanded form of the input JSON, or CSV distribution is applied to draw random ages.

The second format is a CSV format that only specifies one default age-class distribution for all disturbance types, as follows:

```
60,0.33
70,0.33
80,0.33
```

**Table 2.** The tool's expansion of the configured distribution [[120, 1]]

| Age | *p* |
|---|---|
| 120 | 1 |

**Table 3.** The tool's expansion of the configured distribution [[30, 0.6], [40, 0.4]]

| Age | *p* |
|---|---|
| 30 | 0.06 |
| 31 | 0.06 |
| 32 | 0.06 |
| 33 | 0.06 |
| 34 | 0.06 |
| 35 | 0.06 |
| 36 | 0.06 |
| 37 | 0.06 |
| 38 | 0.06 |
| 39 | 0.06 |
| 40 | 0.04 |
| 41 | 0.04 |
| 42 | 0.04 |
| 43 | 0.04 |
| 44 | 0.04 |
| 45 | 0.04 |
| 46 | 0.04 |
| 47 | 0.04 |
| 48 | 0.04 |
| 49 | 0.04 |

The **stand-replacing disturbance lookup** is an optional file that contains a dictionary of disturbance types and a true/false descriptor that indicates if the disturbance type is considered stand-replacing for the rollback procedures. The format of the stand-replacing disturbance lookup file is as follows:

```
{
  "Wild Fires": true,
  "Clearcut harvesting with salvage": true,
  "Mountain Pine Beetle – Very Severe Impact": false
}
```

If a disturbance type is not present in this file, the rollback tool uses the disturbance matrix values to determine if it is stand-replacing.

A command-line interface exists to run the rollback tool, and it is also possible to write custom scripts to refine the procedures for a specific project.

The command-line interface has four required arguments, and six optional ones to further customize the rollback. The command-line call with four required arguments is:

```
spatial_rollback <path to tiled layers and study_area.json>
<path to GCBM input database> <inventory vintage year>
<path to age distribution CSV or JSON file>
```

where

- the study_area.json file contains metadata about the set of GCBM spatial layers which the rollback tool uses to find the original inventory age, classifiers, and disturbance layers;
- the GCBM input database provides information on the disturbances types;
- the inventory vintage year is the reference year of the inventory; and
- the age distribution CSV or JSON file provides the age-class distribution for rollback procedures that assign the pre-disturbance stand age.

The optional arguments include:

| | |
|---|---|
| *output_path* | This is the path where the rollback output should be stored (the default is the current working directory). |
| *rollback_year* | This designated the year to rollback to (the default is 1990). |
| *prioritize_disturbances* | Prioritize disturbances over inventory – ignore original inventory age if disturbances are contradictory (the default is to prioritize inventory data and adjust disturbances in cases of contradiction). |
| *stand_replacing_lookup* | This is the path to the stand-replacing disturbance lookup file. |
| *logging_level* | This represents the Python log level (the default is **INFO**, or: **error**, **debug**, **fatal**). |
| *establishment_disturbance_type* | This represents the establishment disturbance type for rollback procedures which need to generate a missing establishment disturbance event. |

When the rollback tool successfully completes, the text logfile includes the following spatial_rollback INFO statements: "load rolled back landscape, load GCBM input, reading gcbm inventory, reading gcbm disturbances, assemble landscape, process rollback stats, and generating report."

## Rollback Tool Output Information

Outputs produced by the rollback tool include adjusted spatial layers, adjusted transition rules (transition_rules.csv) with regeneration delays, and a rollback report. Adjusted spatial layers are available in the 'rollback' directory, including the inventory age relative to the baseline year, and stand-replacing disturbances.

Layers describing the landscape characteristics (stand age, disturbances, and age-disturbance combinations) before and after the rollback are provided for direct comparisons in the 'pre_rollback_landscape' and 'post_rollback_landscape' directories, respectively.

In addition, statistics on the adjustments to inventory age and disturbances are compiled and graphed in a summary report 'rollback_report.html', with corresponding data available in csv files.

Summary report graphs include:

- timeseries of disturbed area for stand-replacing disturbances, by disturbance type (note that the pre-rollback areas could include pixels outside of the simulation area, while the post-rollback areas are filtered only for those pixels which have enough data to be simulated);
- timeseries of the historical stand-replacing disturbed area that led to stand establishment (last-pass disturbance), by disturbance type;
- bar chart of the inventory area by rollback procedure; and
- pre- and post-rollback comparisons:
  - Raster and inventory area bar chart
  - Inventory area by stand-age plot
  - Histograms of the age-class distribution
  - Inventory classifiers by area plots

## Provincial-scale Example

The following is an example where the rollback tool was run on GCBM simulations for public forests in British Columbia using datasets compiled by Smyth et al. (2020). Input information included a 2015 vintage year for the inventory age, a baseline year of 1990, spatial wildfire and clearcut layers (1990 to 2015), and age-class distributions for wildfire and clear-cut disturbances.

The command line call was "spatial_rollback layers\tiled input_database\gcbm_input.db 2015 tools\Rollback\age_distribution.csv", which assumed default configurations for historical disturbance (wildfire), and that inventory was prioritized over disturbances for young stands (Case 7 and 9 over Case 8).

The age-class distribution in age_distribution.json was used for all disturbances and is displayed in Table 4.

**Table 4.** The age-class distribution for example stand-replacing disturbances, where the sum of the proportions is one

| Wildfire | | Clear-cut harvest | |
|---|---|---|---|
| **Age** | **Proportion** | **Age** | **Proportion** |
| 30 | 0.1 | 50 | 0.35 |
| 40 | 0.1 | 60 | 0.3 |
| 50 | 0.1 | 70 | 0.25 |
| 60 | 0.1 | 80 | 0.05 |
| 70 | 0.1 | 90 | 0.03 |
| 80 | 0.1 | 100 | 0.02 |
| 90 | 0.1 | | |
| 100 | 0.1 | | |
| 110 | 0.05 | | |
| 120 | 0.05 | | |
| 130 | 0.05 | | |
| 140 | 0.05 | | |

The rollback tool took approximately two hours to process the 63 Mha of forest inventory data at 1 ha resolution, generate output layers, and create the statistics report on an AMD Ryzen 7 3800X (4.3 GHz) desktop computer with 32 GB RAM.

Confirming the conservation of area between the rollback tool and GCBM outputs can be done by comparing the post_rollback_inventory_area number in rollback_stats\inventory_area_summary.csv to the result of this query in the GCBM output database

> "SELECT SUM(area) FROM v_age_indicators WHERE year = (SELECT MIN(year) FROM v_age_indicators)".

A statistics report with a series of graphs and accompanying data in text files (in the layers\rollback\rollback_stats directory) are produced by the rollback tool. Graphs from the statistics report are included for reference in Figures 4 to 16.

Figure 4 shows the disturbance timeseries for 1990 to 2015 for both the pre-rollback disturbances and the post-rollback disturbances. The pre-rollback disturbances are the sum of the annual area affected by wildfires and clear-cut harvest in the spatial layers. In the test run, the post-rollback disturbance timeseries differed from the input disturbance timeseries because of the rollback procedures:

- Case 4 added approximately 500,000 ha of wildfire area across the timeseries to compensate for young inventory area that had no corresponding establishment disturbance.
- Case 7 shifted the time step of the inventory establishment year of nearly 1 million ha of clear-cut and wildfire area for cases where the input event occurred after the inventory establishment year.

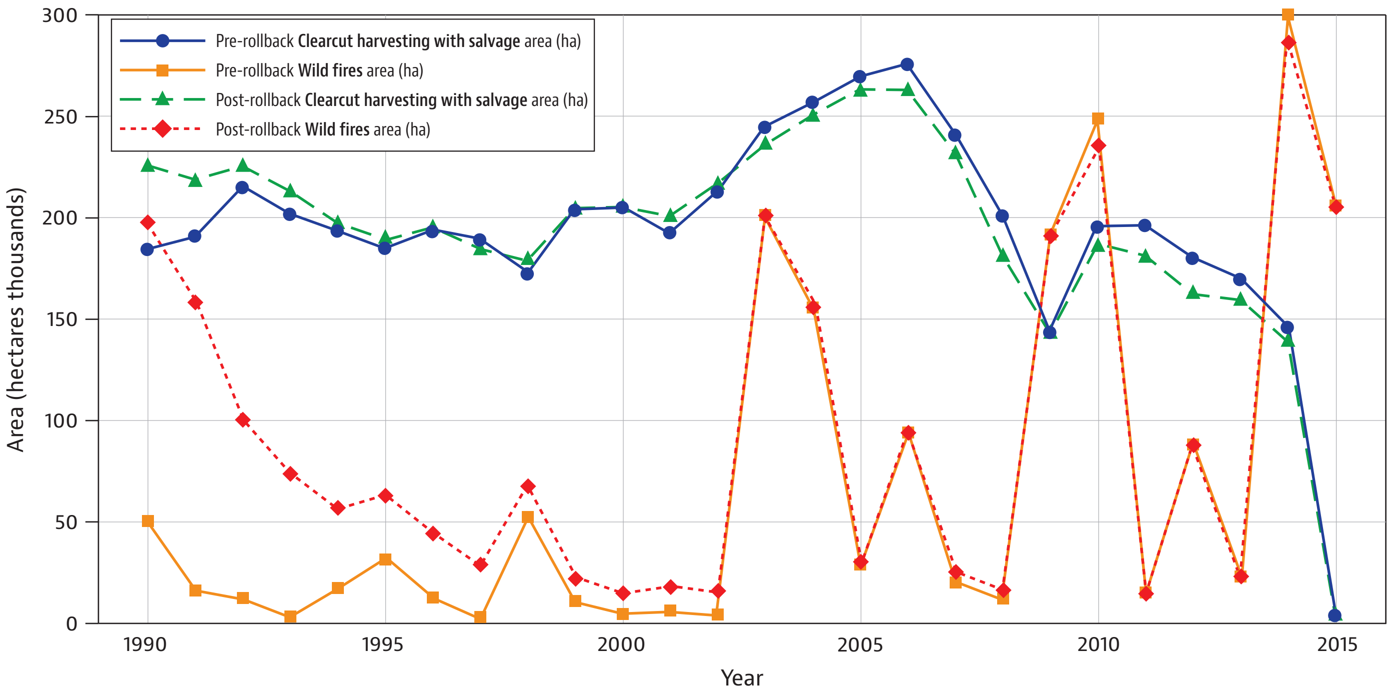


**Figure 4.** Timeseries of disturbed area before and after the rollback tool was run for public forest areas in British Columbia as modeled in the GCBM.

Figure 5 shows the pre-1990 timeseries of disturbance events that were added to the simulation by the rollback tool. The input data used in the provincial example provided no information on pre-1990 disturbances, so the rollback procedures assigned a single disturbance type to all inventory areas.

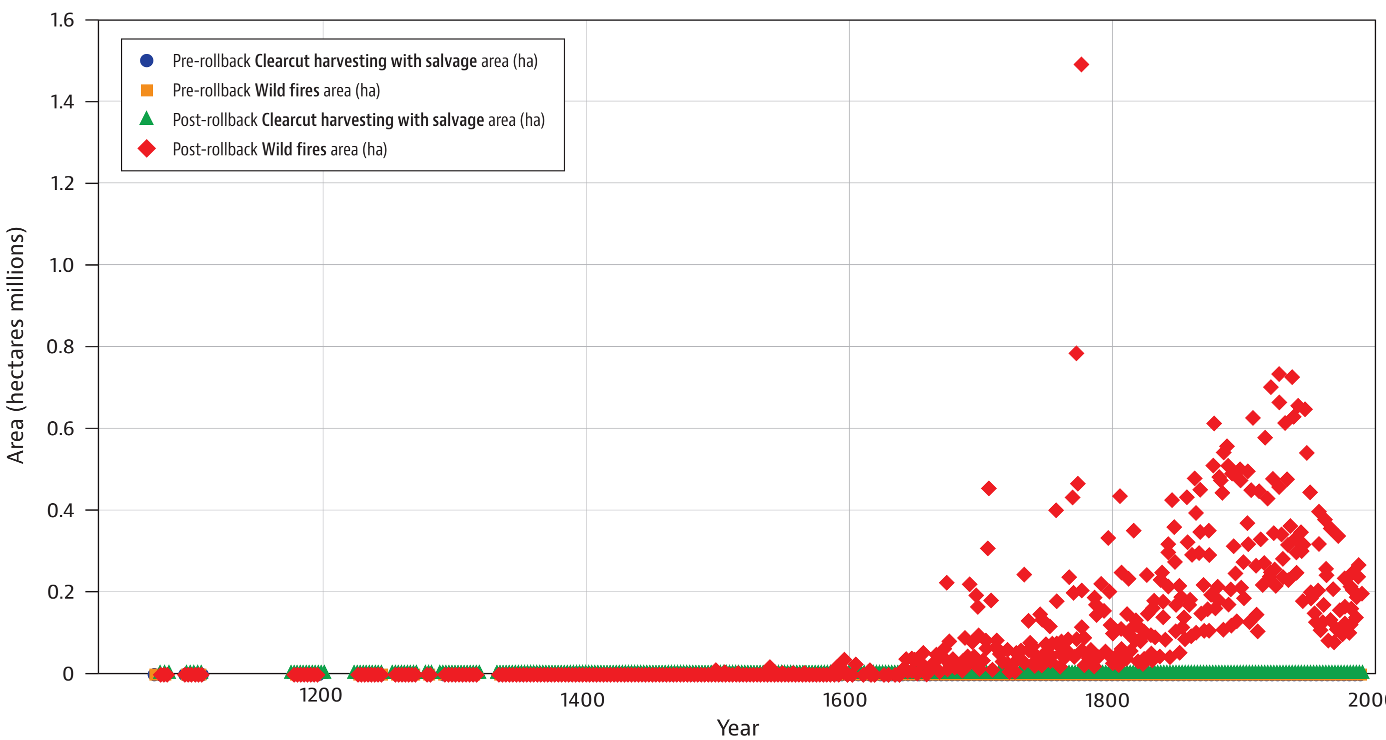


**Figure 5.** Scatterplot of inventory establishment year for public forest areas in British Columbia as modeled in the GCBM.

Figure 6 displays a diagnostic plot to determine if the total area was conserved after running the rollback process. The larger raster area bars are a reflection of the total raster area, while the inventory area bars reflect the total area of pixels with defined inventory area.

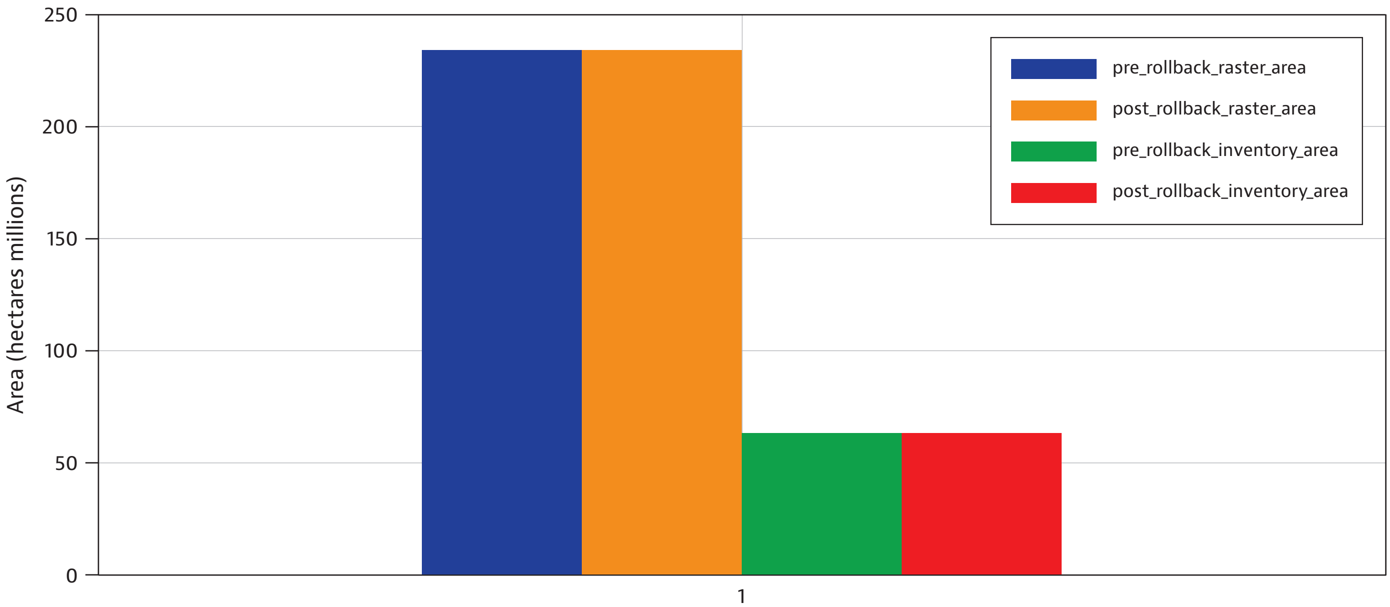


**Figure 6.** Inventory and raster area before and after the rollback tool was run on public forest areas in British Columbia as modeled in the GCBM.

Figure 7 displays the inventory area by age for the pre- and post-rollback landscape. For a large portion of the landscape (around 90%), the inventory age was shifted back by the rollback period using rollback Case 1.

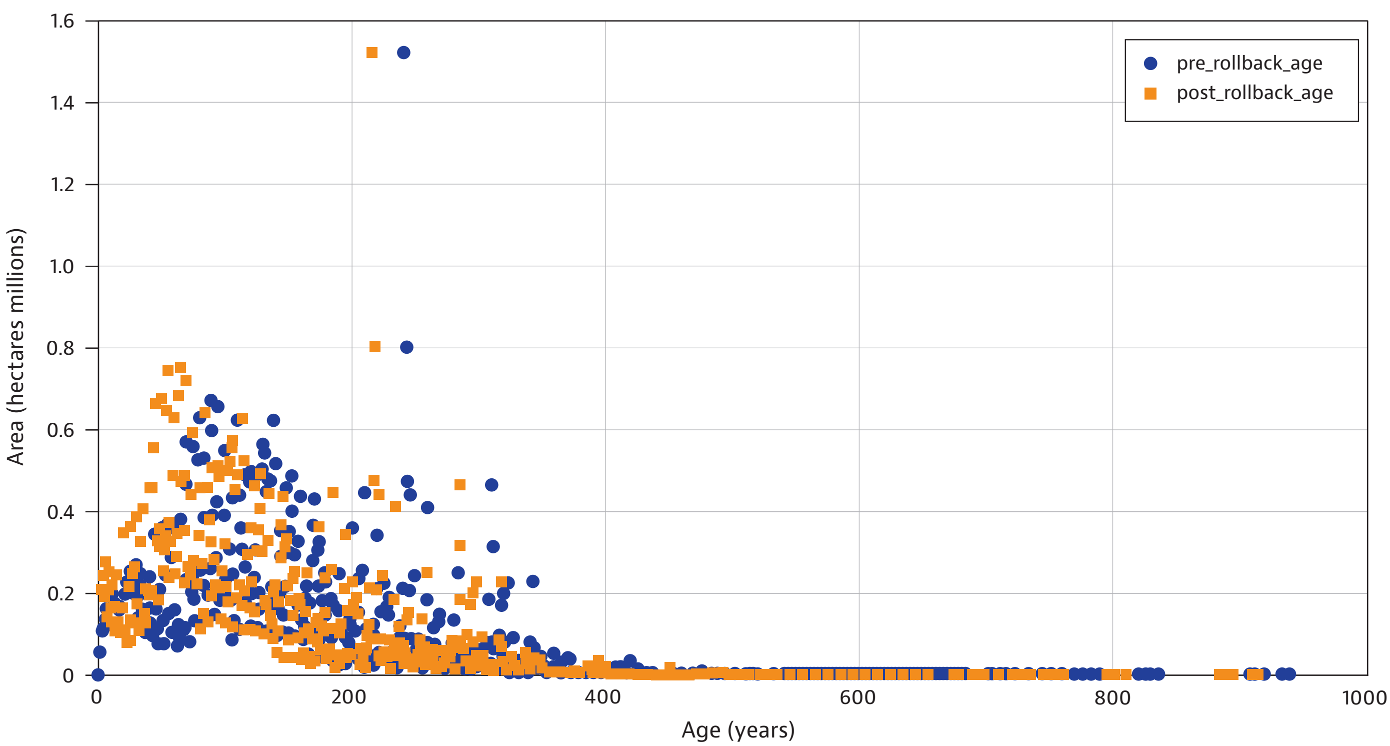


**Figure 7.** Stand age by area, before and after the rollback tool was run on public forest areas in British Columbia as modeled in the GCBM.

Figure 8 is based on the same information as Figure 7, with the x-axis displaying stands less than 100 years old. The sawtooth pattern is a result of the inventory data, and not the rollback tool.

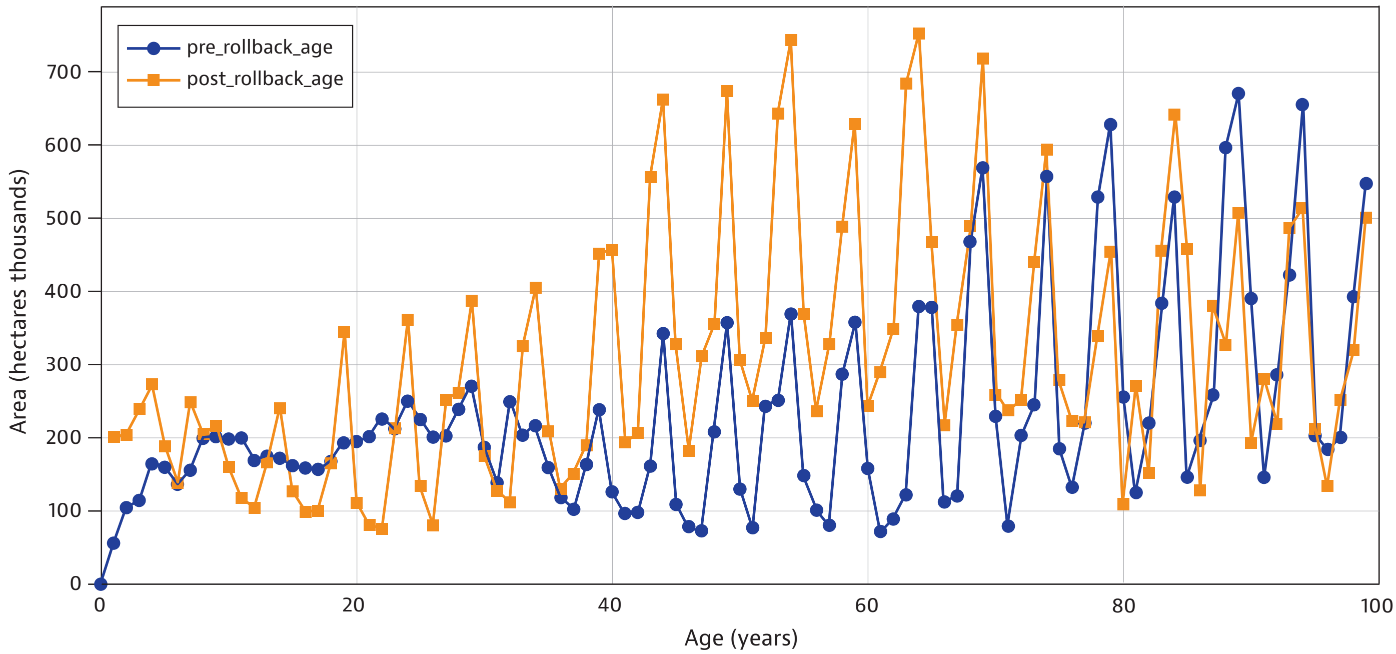


**Figure 8.** Inventory area by age plots, before and after the rollback tool was run for public forest areas in British Columbia as modeled in the GCBM.

The inventory age classes in 20-year intervals for the pre- and post-rollback landscape are shown in Figure 9.

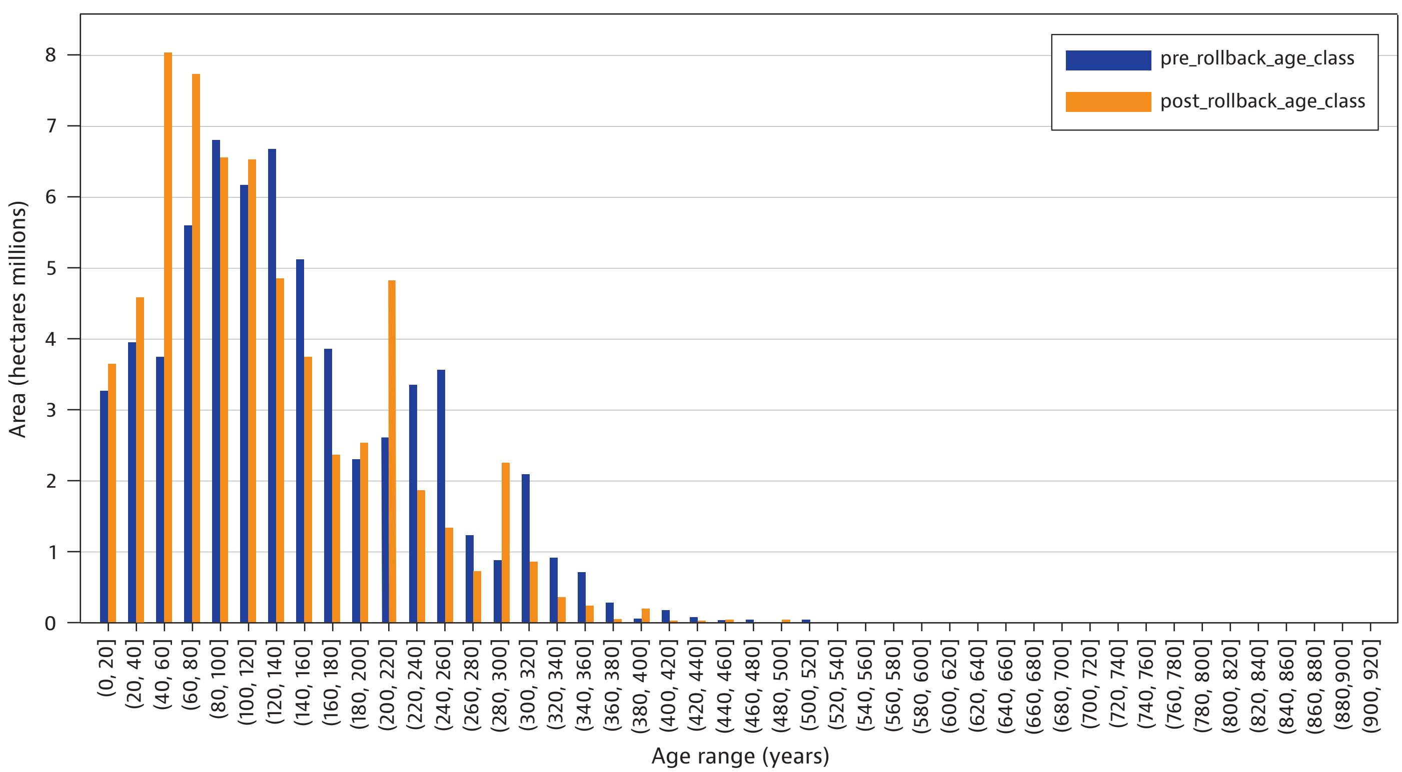


**Figure 9.** Stand age-class distribution before and after the rollback tool was run on public forest areas in British Columbias as modeled in the GCBM. Age ranges include the lower value and exclude the upper one.

Figures 10 and 11 are diagnostic plots displaying the area by classifier value for the classifiers included in the simulation. The area of each classifier value is conserved through the rollback process because the tool does not change the classifier values.

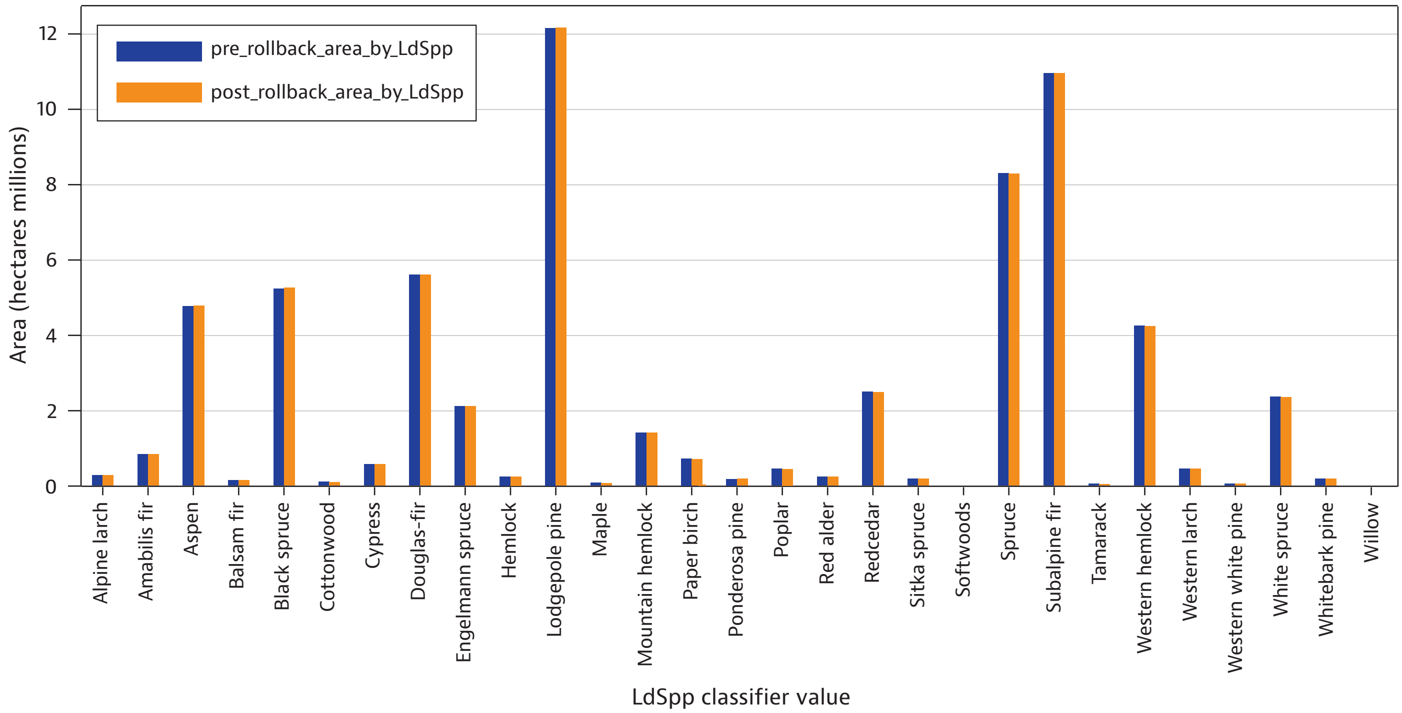


**Figure 10.** The leading species (LdSpp) classifier value by area, before and after the rollback tool was run on public forest areas in British Columbia as modeled in the GCBM.

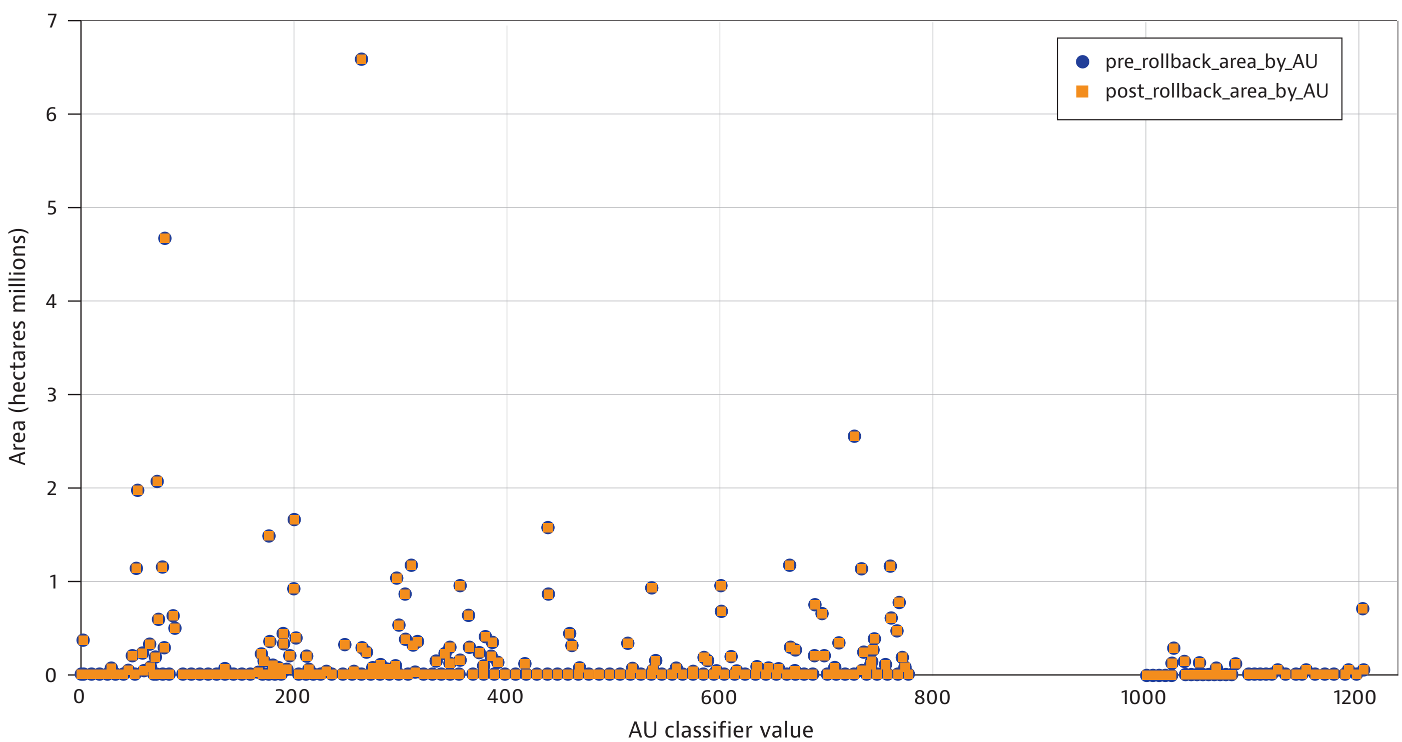


**Figure 11.** The analysis unit (AU) classifier value by area, before and after the rollback tool was run for public forest areas of British Columbia as modeled in the GCBM.

The total area for each rollback case (Table 1) applied in the provincial example is shown in Figure 12. Figure 13 is based on the same data but omits the most common case (Case 1) from the plot in order to better visualize the relative sizes of the lesser areas attributed to the other rollback cases. Rollback Cases 2 and 10 were not displayed in Figure 13 because there was no pre-1990 disturbance information provided in the example run.

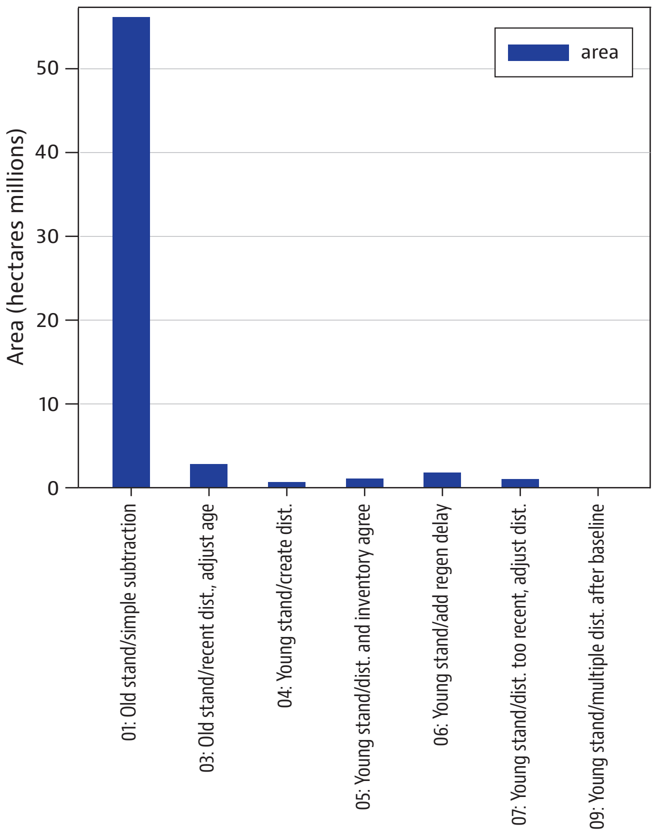


**Figure 12.** The area associated with each procedure assuming the user selected the default (Case 7) where the disturbance year was adjusted as modeled in the GCBM.

The total area of all the rollback cases was 63.35 million ha, which was consistent with the inventory data used. Approximately 90 percent of the area was covered by Case 1, which indicated that around 90% of the forest area was over 25 years old. The rollback procedure in this case subtracted the rollback period from the age and assigned the "Wild Fire" historical disturbance for the pre-simulation period.

The inventory area affected by Case 3 was 2.85 million ha (Figure 13) and corresponded to the area in the example where the inventory indicated stands were 25 years or older. At the same time, disturbance layers indicated at least one recent stand-replacing event after 1990, leading to a contradiction between those 2 sources of data for specific areas.

The 0.66 million ha affected by Case 4 (Figure 13) had inventory stand ages under age 25, but no recent disturbances were evident in the disturbance layers to explain the recent stand establishment.

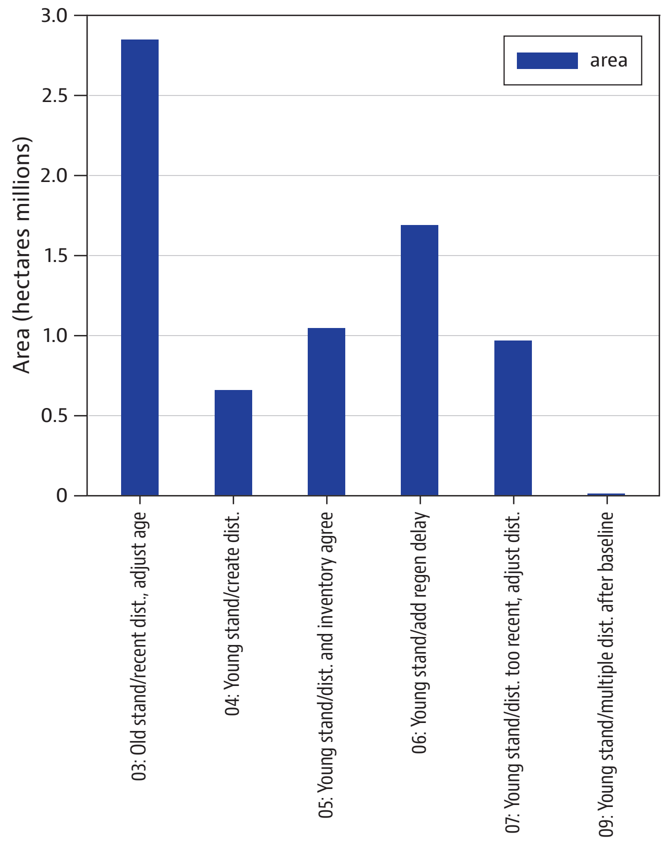


**Figure 13.** The area associated with each rollback case (except Case 1), assuming the user selected the default case where the disturbance year was adjusted as modeled in the GCBM.

This resulted in the large increase in burned area observed in the post-rollback fire area compared to the pre-rollback fire area in the first 25 years displayed in Figure 4.

In Figure 13, rollback Cases 5 and 6 represented 2.74 million ha where young stands were present in the inventory layer, and the disturbance layers indicated a recent stand-replacing disturbance. The majority of this area, 1.69 million ha, corresponding to Case 6, had at least a one-year gap between the inventory establishment year and the stand-replacing disturbance.

Figure 15 displays the area by the number of years of regeneration delay that were added to the rollback output for the Case 6 areas. The remaining 1.05 million ha, which corresponded to Case 5, had matching stand age and establishment disturbances.

Rollback Cases 7 and 9 showed 0.971 million ha of area where the stand was disturbed more recently than the inventory stand age would suggest. In the example run, data in this condition were treated under rollback Cases 7 or Case 9, meaning the disturbance timeseries was altered to align with the inventory establishment. Rollback Case 8 was not applied because the rollback tool could apply either Case 7 or Case 8, but not both. The results of re-running the rollback tool with Case 8 selected are shown in Figure 16: inventory establishment was altered to align with the disturbance timeseries.

Figure 14 displays a map of the rollback cases processed in the example simulation. It is clear that most of the area is processed as rollback Case 1, and it is possible to see the location of some of the areas under other cases as well. The graphic in this figure is not currently included as a standard report output in the tool, but may be included as part of future developments.

The number of years of regeneration delay applied in rollback Case 6 are shown in Figure 15. Over 90% of affected areas had an applied regeneration delay of less than or equal to 5 years, and over 99% had a delay of less than or equal to 12 years. This meant that in most cases, the gap between the disturbance and the inventory establishment was small.

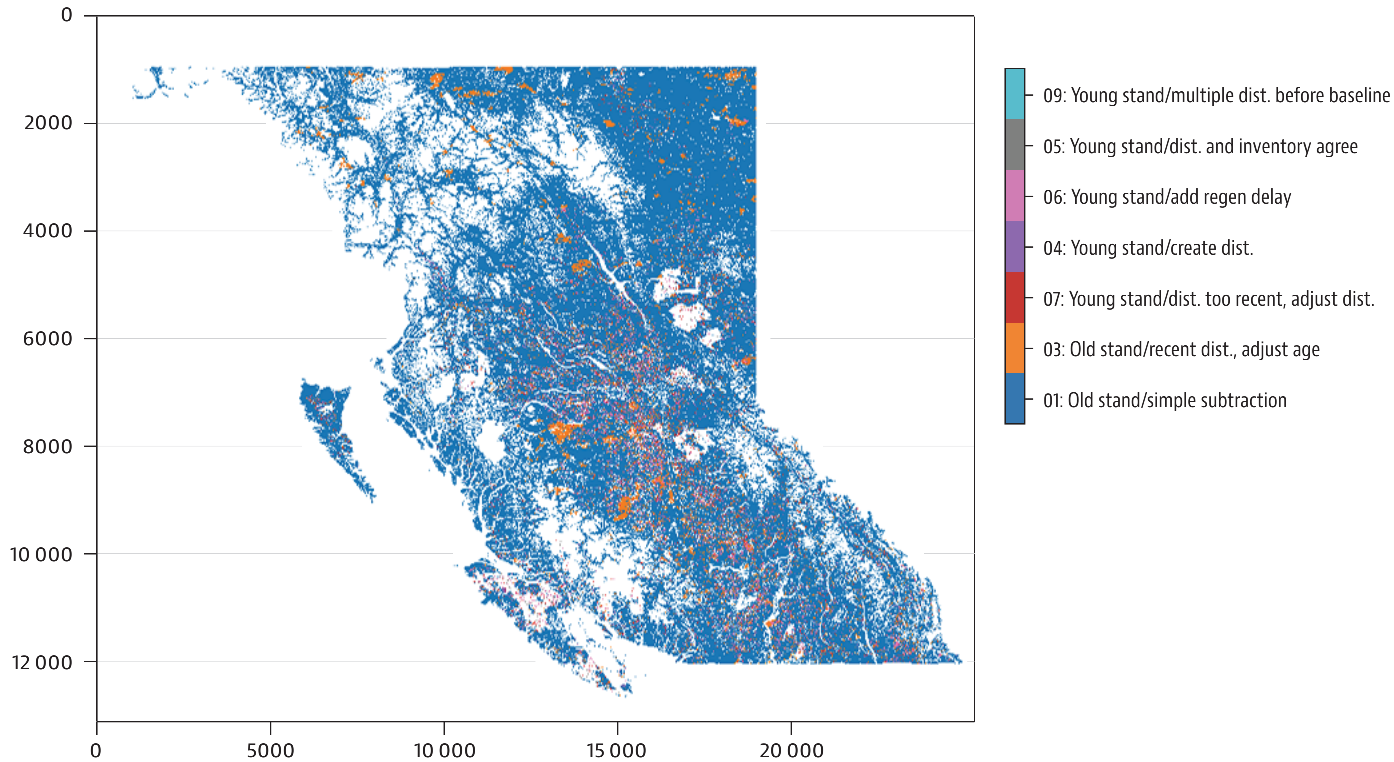


**Figure 14.** A map of rollback tool cases used for public forest areas of British Columbia as modeled in the GCBM (WGS 1984 coordinate system).

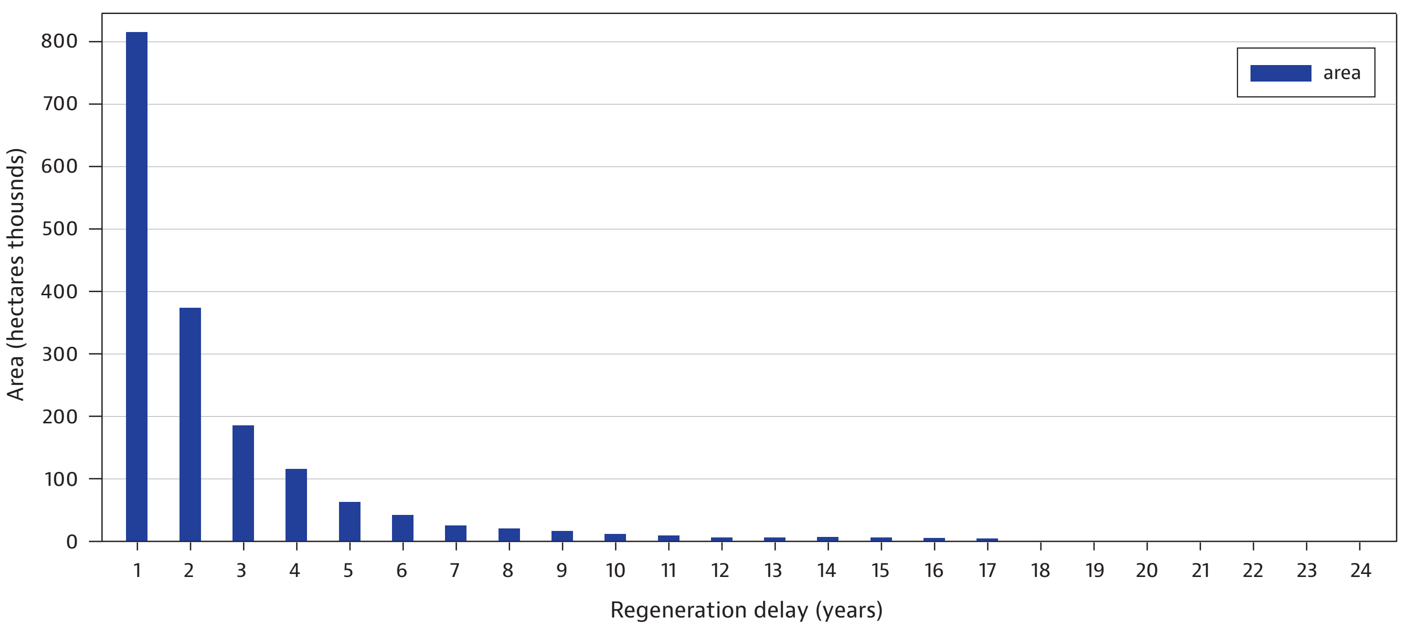


**Figure 15.** Area by regeneration delay (in years), generated by the rollback tool to match inventory establishment year and disturbance year for public forest areas of British Columbia as modeled in the GCBM.

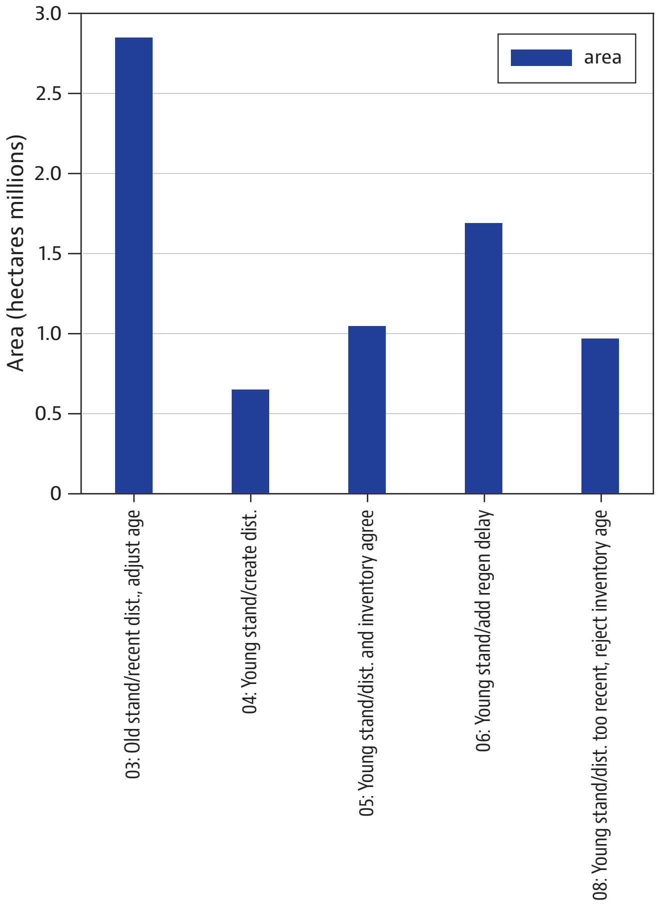


**Figure 16.** Inventory area by rollback case, where stand age was adjusted (Case 8) instead of the disturbance year (Case 7, the default) for public forest areas of British Columbia as modeled in the GCBM.

## Future Development

There are a number of areas where the rollback tool can be further improved by:

- using pre-rollback information for young stands to set the last-pass disturbance type and year;
- maintaining transition rules from the pre-rollback tiling;
- adding land-use change disturbances such as afforestation;
- allowing user-specified historical disturbance types, or the probability of an historical disturbance type by classifier set or other inventory/disturbance information;
- providing for more detailed age-class distributions by using other inventory or disturbance information;
- adding a random seed for draw distribution;
- improving memory usage and computational speed; and
- adding maps to the reports, including maps of pre- and post-disturbances, discrepancies between inventory and disturbance information, and rollback cases

## Summary

The general-purpose spatial inventory rollback tool is a user-friendly tool that can be applied to any GCBM project to adjust the inventory age, spatial disturbances, regeneration delays and historical stand-establishment to a desired baseline year. In addition to this, the tool provides information to the user that describes the inventory and disturbance statistics and highlights any discrepancies between the provided inventory and spatial disturbance data. This report summarized how to configure and run the tool, and displayed the results from a sample provincial scale run for British Columbia's public forests, where a 2015 vintage inventory was rolled back to a 1990 baseline year.

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# Appendix – Uncertainties

Comments provided by Juha Metsaranta (CFS).

The rollback procedure depends on two key pieces of information: the age of each stand in the forest inventory in the reference year, and a spatial layer of stand-replacing historical disturbances. The stand-replacing disturbance layers could include harvest, wildfire, and/or other disturbances. These data sources will inevitably contain errors and uncertainties that will propagate to uncertainty in the age assigned to the stand in the base year by the rollback tool. It may be possible to quantify or reduce some of these uncertainties.

However, some are essentially irreducible due to the "fading record problem" (Swetnam et al. 1999), which postulates that records of any phenomena become more fragmentary with the passage of time. Rolling back the age of forest inventories is subject to this issue. In the case of disturbances, spatial data on wildfire occurrence are considered most reliable only after 1970 or 1980, even if they exist as far back as 1950 or earlier for some parts of Canada (e.g. Erni et al. 2020; Hanes et al. 2019). Many of the older spatial wildfire data are generated from rough aerial sketch maps that can overestimate the actual area burned (Skakun et al. 2021). These data layers can be improved, but only to an extent because the satellite remote sensing era began with the launch of the first Landsat in 1972, and many forest stands originate before this date. Spatial harvest data has similar issues with the reliability and availability of spatial layers over time, with the additional complication that there have been monumental changes in forest harvest practices since the early 20th century from hand felling and horse logging to the mechanization of today, with many transitions in between.

Forests still contain many stands that could have originated from historical harvest practices. All of these issues also exist for forest insect damage. For example, many stands in eastern Canada likely originated after the severe outbreak of Spruce Budworm in the 1970's and 1980's, with the additional complication that many years of defoliation are often required before infestations are stand-replacing (e.g. Gray and MacKinnon 2006). Spatial layers of stand-replacing insect disturbance are not consistently available, and in situations where this is the case, the originating disturbance would not be correctly identified by this procedure. Age in forest inventories is also estimated with uncertainty, with some evidence of larger uncertainty for older stands (e.g. Metsaranta 2020). The output from an inventory rollback resulting from the procedures described in this report must be interpreted with these uncertainties in mind.

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