**Insect Rules**

**Bark Beetle/Wood Borer Scenarios**

LANDFIRE supports three wood-borer severity classes including low, moderate and high. Forest insects are assumed to be bark beetles/borers, regardless of forest or rangeland fuel type.

Although LANDFIRE often changes EVT for recently disturbed pixels, we have decided not to change species and relative cover assignments for fuelbeds. This would require a specific assignments for each fuelbed and would make it difficult to auto-generate fuelbeds. Instead, these specifications are intended to apply to the previous LANDFIRE layer to represent post-disturbance fuelbeds based on the previous EVT-fuelbed crosswalk.

LANDFIRE definitions:

* Low severity: < 25% area affected by bark beetles or wood borers, including sage brush EVTs
* Moderate severity: >25 to < 75% area affected by bark beetle or wood borers
* High severity: >75% area affected by bark beetles or wood borers

Time since disturbance:

* Step 1: Immediately post disturbance
* Step 2: 2-5 years post disturbance – second growing season
* Step 3: 5-10 years post disturbance.

Note, for bark beetles and wildfires, the 10-year time step that then returns to preburn fuelbeds is too short. Snagfall is anywhere between 15 and 40 years, and after high severity fire or I&D events would result in high CWD recruitment in later time steps.

Also, because the insect rules are specific to wood borers, we assumed that bark beetles and other wood borers preferentially attack midstory and overstory trees and that understory trees are basically unaffected.

Because the SE and Hawaii have much faster recovery rates (same as since wildfire?):

* 2: 0-3 years post disturbance
* 3: 3-10 years post disturbance

Landfire disturbance codes

|  |  |  |  |
| --- | --- | --- | --- |
| **Type** | **Severity Class** | **Time step** | **Code** |
| Insects and Disease | Low Severity | 1 | 511 |
|  |  | 2 | 512 |
|  |  | 3 | 513 |
| Insects and Disease | Moderate Severity | 1 | 521 |
|  |  | 2 | 522 |
|  |  | 3 | 523 |
| Insects and Disease | High Severity | 1 | 531 |
|  |  | 2 | 532 |
|  |  | 3 | 533 |

**FORESTED FUELBEDS**

**Canopy updates**

511: Low Severity Time Step 1 (immediately post disturbance):

* 10% of overstory and midstory trees die. Changes to each canopy layer include a 10% reduction in canopy cover and density and a 10% increase in Height to Live Crown.
* Height and DBH are stand averages and are assumed to not change.
* Because 10% of overstory and midstory trees died, we assume that Class 1 Snags with Foliage increase by 10%. This requires a recalculation of Class 1 Snag with Foliage inputs including addition of 10% cover and increase in density equal to the reduction of overstory and midstory trees. Understory trees are not included.

*Reference: Page & Jenkins 2007 – 8% mortality in an endemic MPB attack. 10% would be on the low end of all Simard et al. (2011) %Severity, which ranges from 9-10% in controls to 38-78% in MPB outbreak stands*.

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* Additional 5% mortality of overstory and midstory tree layers. Changes to each canopy layer include a 5% reduction in canopy cover and density and a 5% increase in Height to Live Crown.
* Height and DBH are stand averages and are assumed to not change.
* Because 5% of overstory and midstory trees died, we assume that Class 1 Snags with Foliage increase by 5%. This requires a recalculation of Class 1 Snag Foliage inputs including addition of 5% cover and increase in density equal to the reduction of overstory and midstory trees. Understory trees are not included.
* Move Class 1 Snags with Foliage to Class 1 Snags All Others
* Snag fall would not be expected at this stage.

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No additional tree mortality.
* Move Class 1 Snags with Foliage to Class 1 Snags All Others
* Move Class 1 Snags to Class 2 Snags.
* An estimated 10% of Class 2 Snags fall and recruit as rotten wood. MOVE CLASS 2 SNAGS

521: Moderate Severity Time Step 1 (immediately post disturbance):

* 40% of overstory and midstory trees die (45% is the midpoint between the broad 20-70% class – we expect an additional 10% mortality in time step 2).
* This results in a 40% reduction in cover and density for overstory and midstory trees and a 20% increase in HLC.
* Because bark beetles tend to prefer larger size classes (MPB > 6” threshold), we assume a higher mortality of overstory and midstory trees and negligible mortality in understory trees.
* There is a concomitant increase in Class 1 Snags with foliage (40%). This requires a recalculation of Class 1 Snag Foliage inputs including addition of 40% cover and increase in density equal to the reduction of overstory and midstory trees.

*Reference: Simard et al. (2011) reported % mortality for over 20 MPB-attacked chronosequence stands. Average mortality was 57% with several sites in the 40% mortality range. Page & Jenkins (2007) reported 46% and 48% mortality in two epidemic stands of LP/ESSF stands in Utah.*

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* An additional 10% of overstory and midstory trees die due to delayed mortality. This results in another 10% reduction in cover and density for overstory and midstory trees with no increase in average HLC.
* Because 10% of overstory and midstory trees died, Class 1 Snags with Foliage increase by the 10% of trees that died. This will require a recalculation of Class 1 Snag Foliage inputs including addition of 10% cover and increase in density equal to the reduction of overstory and midstory trees.
* In addition to the above changes, move Class 1 Snags with Foliage from Time Step 1 to Class 1 Snags without foliage. Existing Class 1 Other and Class 2 snags move to Class 2 and 3 snags, respectively.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No additional tree mortality.
* Move Class 1 Snags with Foliage (from time step 2) to Class 1 Snags without Foliage
* Move Class 1 Snags to Class 2 Snags
* An estimated 10% of class 2 Snags fall and recruit as rotten wood (DID NOT IMPLEMENT)

531: High Severity Time Step 1 (immediate post disturbance)

* 75% of overstory and midstory trees die (midpoint between 70 and 100% is 85% - expect additional 10% mortality in time step 2).
* This results in a 75% reduction in cover and density for overstory and midstory trees and a 30% increase in HLC.
* We assume no change in understory trees.
* There is a concomitant increase of 75% in Class 1 Snags with Foliage. This requires a recalculation of Class 1 Snag Foliage inputs including addition of 75% cover and increase in density equal to the reduction of overstory and midstory trees.

*Reference: Only a couple of the Simard et al. (2011) fell in this % mortality range. Page & Jenkins (2007) reported around 50% mortality, but it really depends on stand composition (100% host tree or mixed conifer).*

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* An additional 10% of overstory and midstory trees die. This results in another 10% reduction in cover and density for overstory and midstory trees with no increase in average HLC.
* Because 10% of overstory and midstory trees died, Class 1 Snags with Foliage increase by the 10% of trees that died. This will require a recalculation of Class 1 Snag Foliage inputs including addition of 10% cover and increase in density equal to the reduction of overstory and midstory trees.
* Move Class 1 Snags with Foliage from Time Step 1 to Class 1 Snags without foliage. Existing Class 1 Other and Class 2 snags move to Class 2 and 3 snags, respectively.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No additional tree mortality.
* Move Class 1 Snags with Foliage (from time step 2) to Class 1 Snags without Foliage
* Move Class 1 Snags to Class 2 Snags.
* An estimated 10% of class 3 Snags fall and recruit as rotten wood.

**Shrub updates**

*If shrub layers are present in forested fuelbeds, then we could expect a modest increase in shrubby vegetation with more open canopy conditions. However, references on MPB attack were mixed in recording any response. Donato et al. (2013) report no change. Jenkins et al. (2013) hypothesized a small increase during the first 10 years during major outbreaks. We assume shrub cover only changes in high severity events.*

511: Low Severity Time Step 1 (immediately post disturbance):

* No change

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change

531: High Severity Time Step 1 (immediate post disturbance)

* No change.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 25% increase in shrub cover and optional loading (if specified).
* No change in percent live.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change from time step 2.

**Herb updates**

*If herb layers are present in forested fuelbeds, we expect a modest increase in herbaceous vegetation with more open canopy conditions. Based on some evidence in the MPB literature (Donato et al. 2015) and hypothesized responses (Jenkins et al. 2013) we assume no change for low or moderate severity insects and disease, a 25% increase following moderate severity events, and a 40% increase following high-severity events.*

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511: Low Severity Time Step 1 (immediately post disturbance):

* No change.

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change.

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change.

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 25% increase in herb cover and loading.
* No change in percent live.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change from time step 2.

531: High Severity Time Step 1 (immediate post disturbance)

* No change.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 40% increase in herb cover and loading.
* No change in percent live.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change from time step 2.

**Downed Wood updates (for forested fuelbeds)**

*Based on the MPB literature, there was variable response in the timing of downed wood accumulation following red attack. In general, there was no change in fine or coarse wood accumulations immediately following the outbreak but a large increase in fine wood at time step 2 (2-5 years post disturbance). Hoffman et al. (2013) report a 140% increase in fine wood, and Armour (1982) a 100% increase. Donato et al. however, report a slight decrease during this stage. A generic models by Hicke (20XX) predicts an increase in litter, 1 and 10hr wood following MPB attack whereas Jenkins hypothesize a slight decrease in fine wood followed by peak accumulations at 10, 15 and 25 years depending on major forest species. We followed the Hicke model here because the paper represents the most recent and comprehensive synthesis of available literature*

Recommended minimum values for moderate and high severity Time Step 2 – loosely based on literature values LWD = all >=1000hr size classes.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | |  |
|  | Time Step 2  tpa | Time Step 3  tpa |  | |
| 1hr | 1 | 1 |  | |
| 10hr | 2 | 2 |  | |
| 100hr | 3 | 3 |  | |
| SLWD |  | 4 |  | |
| RLWD |  | 4 |  | |

511: Low Severity Time Step 1 (immediately post disturbance):

* No change

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 10% increase in fine wood cover, depth and loadings (1, 10, 100-hr).
* No change in coarse wood loadings (1000hr, 10,000hr, >10,000hr)

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 10% additional increase in fine wood cover, depth and loadings (1, 10, 100-hr).
* 10% increase in coarse wood loadings (1000hr, 10,000hr, > 10,000hr)
* 25% of sound wood transitions to rotten wood by category (1000hr, 10,000hr, > 10,000hr)

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 25% increase in fine wood cover, depth and loadings (1, 10, 100-hr).
* If fine wood is lower than minimum, use tabled minimum values for time step 2

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 25% additional increase in fine wood cover, depth and loadings (1, 10, 100-hr)
* 25% increase in sound coarse wood loadings (1000, 10,000, >10,000-hr)
* 25% of sound wood transitions to rotten wood by category (1000hr, 10,000hr, > 10,000hr)

531: High Severity Time Step 1 (immediate post disturbance)

* No change

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 75% increase in fine wood cover, depth and loadings (1, 10, 100hr). Assume greater accumulation due to fine wood fall from dead trees.
* If necessary, use min value from above table by timelag class.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 50% additional increase in fine wood cover, depth and loadings (1, 10, 100-hr)
* 100% increase in coarse sound wood loadings (1000hr, 10,000hr, >10,000hr). If necessary, use minimum values in above table by timelag class.
* 25% of sound wood transitions to rotten wood by category (1000hr, 10,000hr, > 10,000hr)

**Stump updates (for forested fuelbeds)**

*No change in stumps from insects and disease.*

**Pile updates (for forested fuelbeds)**

*No change in piles from insects and disease.*

**Litter-Lichen-Moss updates**

An increase in the litter layer is expected in the event of a moderate or high severity insect and disease outbreak. Donato et al. (2013) documented a 15% increase in red attack, whereas Hoffman et al. (2012) reported 119%. No changes are expected for lichen or moss layers.

511: Low Severity Time Step 1 (immediately post disturbance):

* No change

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 10% increase in litter cover, depth, and optional loading (if specified). No change in type or arrangement.

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* Return to pre-attack cover and depth (and loading if specified).

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 50% increase in litter cover, depth, and optional loading (if specified).

No change in type or arrangement.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* Return to pre-attack cover and depth (and loading if specified).

531: High Severity Time Step 1 (immediate post disturbance)

* No change.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 100% increase in litter cover, depth, and optional loading (if specified).

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* Return to pre-attack cover and depth (and loading if specified).

**Ground Fuel updates**

Only slight increases would be expected in ground fuel following moderate and high severity insect outbreaks. Donato recorded a 43% increase in red attack phase whereas Hoffman recorded no change.

511: Low Severity Time Step 1 (immediately post disturbance):

* No change.

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change.

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change.

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 10% increase in upper duff cover, depth, and optional loading (if specified).
* No change in upper duff for Hawaii and SE US fuelbeds due to high rates of decomposition.

531: High Severity Time Step 1 (immediate post disturbance)

* No change.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 30% increase in upper duff cover, depth, and optional loading (if specified).
* No change in upper duff for Hawaii and SE US fuelbeds due to high rates of decomposition.

**SHRUBLAND FUELBEDS**

**Canopy updates**

None – should be not present or very sparse.

**Shrub updates**

For shrub fuelbeds (sagebrush EVGroups only), we would expect a reduction in shrub cover with an insect and disease outbreak: low severity (20%), moderate severity (45% reduction) and high severity (75% reduction).

511: Low Severity Time Step 1 (immediately post disturbance):

* 20% reduction in percent live.

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 20% reduction in cover and percent live. 10% reduction in optional fuel loading (if specified)

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

10% increase in shrub cover, percent live and optional shrub loading (if specified)

521: Moderate Severity Time Step 1 (immediately post disturbance):

* 45% reduction in percent live.

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 45% reduction in shrub cover. 25% reduction in optional shrub loading (if specified).

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 10% increase in shrub cover, percent live and optional shrub loading (if specified)

531: High Severity Time Step 1 (immediate post disturbance)

* 75% reduction in percent live.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 75% reduction in shrub cover, 50% reduction in optional shrub loading (if specified).

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 20% increase in shrub cover, percent live and optional shrub loading (if specified).

**Herb updates**

For shrubland fuelbeds (sagebrush only), we would expect an increase in herbaceous fuels after the reduction in shrub cover as follows: low severity (no change), moderate severity (50% increase) and high severity (75% increase).

511: Low Severity Time Step 1 (immediately post disturbance):

* No change

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 25% increase in herb cover and loading.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* 10% decrease in herb cover and loading (as shrubs recover)

531: High Severity Time Step 1 (immediate post disturbance)

* No change

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 50% increase in herb cover, percent live, and loading.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

20% decrease in herb cover, percent live and loading (as shrubs recover)

**Downed Wood updates**

For shrubland fuelbeds, a minimal increase in fine downed wood is expected in the event of a moderate and high severity insect and disease outbreak.

511: Low Severity Time Step 1 (immediately post disturbance):

* No change

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 20% increase in fine wood cover, depth and loadings (1, 10-hr). No change in 100-hr loadings or coarse wood.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* Return to pre-disturbance values.

531: High Severity Time Step 1 (immediate post disturbance)

* No change

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 40% increase in fine wood cover, depth and loadings (1, 10). No change in 100-hr or coarse wood loadings.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* Return to pre-disturbance values.

**Stump updates**

No change

**Pile updates**

No change

**Litter-Lichen-Moss updates**

In shrubland fuelbeds, increases in the litter layer are expected in the event of a moderate or high severity insect and disease outbreak.

511: Low Severity Time Step 1 (immediately post disturbance):

* No change.

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change.

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change.

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 20% increase in litter cover, depth, and optional loading (if specified).

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change after time step 2.

531: High Severity Time Step 1 (immediate post disturbance)

* No change.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* 40% increase in litter cover, depth, and optional loading (if specified).

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change after time step 2.

**Ground Fuel updates**

No change is expected in ground fuels.

511: Low Severity Time Step 1 (immediately post disturbance):

* No change.

512: Low severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

513: Low severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change.

521: Moderate Severity Time Step 1 (immediately post disturbance):

* No change.

522: Moderate Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

523: Moderate Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change.

531: High Severity Time Step 1 (immediate post disturbance)

* No change.

532: High Severity Time Step 2 (2-5 years post disturbance or 0-3 years for Hawaii and SE US)

* No change.

533: High Severity Time Step 3 (5-10 years post disturbance or 3-10 years for Hawaii and SE US)

* No change.