



United States Department of Agriculture



Digital Mobile Sketch Mapping (DMSM)

Procedure for Crosswalking TPA and Percent Affected

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Forest Service

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Background

Aerial detection surveys (ADS) map pest and disease outbreaks on the landscape, providing data on host tree species, damage causing agent, type and severity of damage. The recently implemented Digital Mobile Sketch Mapping (DMSM) system standardized use of a percent affected damage severity classification, a significant change from the Trees per Acre (TPA) damage severity metric used previously. While many regions were using number of dead trees since the 1990's, starting in the early 2000's TPA gradually gained accepted as the ADS standard for recording severity on mortality damage polygons. In 2012, Forest Service regions 2 and 3 piloted an alternative to TPA, a four-class severity ranking system based on the percent of canopy occupied by recently dead trees. In 2013, a fifth "Very Light" class was added, and the system was operationally adopted in Regions 2, 3 and 10 (R2, R3 and R10). With full rollout of DMSM in 2016 and 2017 the 5-class percent affected rating became a software-enforced standard for all state & regional survey partners.

Percent Affected Codes	1	2	3	4	5
Rating Description	Very Light	Light	Medium	Severe	Very Severe
Percent Affected Range Classes	1-3%	4-10%	11 -29%	30 - 50%	> 50%
Percent Affected Range Mid Points	2%	7%	20%	40%	75%

Prior to adoption of the Percent Affected classification, the technique for integrating the amount of tree mortality area and the severity of mortality within each mapped polygon was to calculate dead tree counts by multiplying polygon acres by TPA. With Percent Affected the standard technique for integrating damage area extent and the severity of damage within each polygon is to multiply the Percent Affected class mid point by polygon acres to calculate 'Acres Of' damage. For example, given a 100-acre polygon rated as having 'Moderate 11 -29%' damage, we can speak of that polygon having 100 'Acres With' damage and 20 'Acres Of' damage.

To detect trends or calculate cumulative mortality impacts with an ADS tree mortality time series that spans the use of TPA and percent affected, analysts need a method to crosswalk one measure to the other. This document describes a method to bin ranges of TPA values that correspond with the five Percent Affected classes. This approach is based on the premise that, whether using Percent Affected classes or TPA, surveyors are rating mortality damage polygons along a very light to very severe scale and we can expect that the proportion of mapped damage acreages rated in the 5 categories will be similar regardless of the metric.

Crosswalk Procedure Steps

The basic crosswalk procedure consists of three steps:

- For Percent-Affected features:** Calculate the percentage of acreage in each of the five Percent-Affected classes.
- For TPA-attributed features:** Based on a low to high TPA sorted list, create five TPA-range bins that approximate the acreage percentages from step one.
 - For example, if from step one 25% of all tree mortality acreage mapped using Percent Affected was classed 'Very Light 1-3%', the analyst would determine what range of lowest TPA value features constitutes 25% of all TPA-attributed acreage.



- 3. Crosswalk TPA and Percent Affected:** Based on the TPA ranges calculated in step 2 either
- assign an estimated Percent Affected class for each TPA-attributed feature and/or
 - use the mean or area weighted mean value for each of the five TPA range bins to assign an estimated TPA for each Percent Affected mortality feature.

Since host types, pest conditions and survey practices can differ regionally and the method assumes that surveyors' assessments of damage areas on a very light to very severe scale will be similar between the TPA and Percent Affected eras, crosswalks are ideally developed with regional-specific datasets. Even within regions, a crosswalk that is based on a sample of all mortality damage should work best for the most common damage agents (e.g. western bark beetles) and may not work as well for less extensive mortality (e.g. western oak mortality) that may have very different proportions of damage along the light to severe scale. Similarly, if pest activity during the TPA-era (e.g. 2004 -2015) differed substantially from a region's Percent Affected era (e.g. 2016 – present) the 5-class apportionment of damage acreages may differ as well across those eras. While there may be interest in a standard TPA : Percent Affected crosswalk that could be applied nationally, this method relies on local experience and expertise to test and evaluate whether there should be different crosswalks for different agents, and/or host types or whether a crosswalk from Percent Affected classes to comparable TPA values should be based on the entire TPA-era archive or just a sub-period of TPA data that best matches Percent Affected era pest conditions and survey practices.

- ❖ **Note:** TPA was not widely adopted by state ADS programs in the east and because the sample of TPA data is so small, this crosswalk is not reliably applicable in Regions 8 and 9.

The method will be demonstrated using data from Region 10 (R10) from 1999-2018, but can be applied to any region, or historical date range. Given adequate samples of Percent Affected and TPA data, this same method could also be applied to data subsets (e.g. a crosswalk specific to bark beetle mortality).

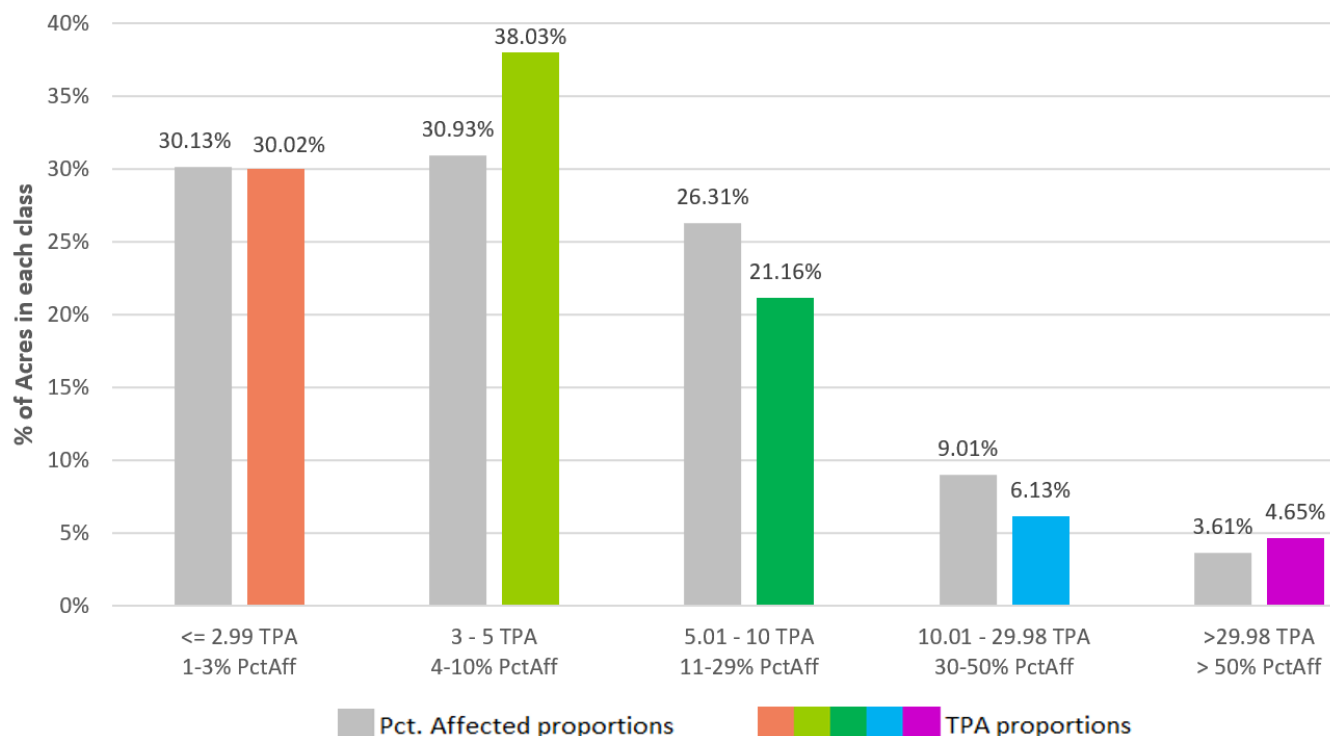


Region 10 Crosswalk Example

TPA to Percent Affected Crosswalk

The table and chart below show the Region 10 TPA range bins for TPA collected data (1999-2012) that best approximate the acreage proportions derived from the Percent Affected data (2013-2018).

Rating Description	Very Light	Light	Medium	Severe	Very Severe
Pct. Aff. range classes	1-3%	4-10%	11 -29%	30 - 50%	> 50%
Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606
% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%
TPA range bins	< 3	3 - 5	> 5 & <= 10	> 10 & <= 29.98	>29.98
Sum of TPA acres	582,383	737,765	410,356	118,965	90,249
% of total TPA Acres	30.02%	38.03%	21.16%	6.13%	4.65%



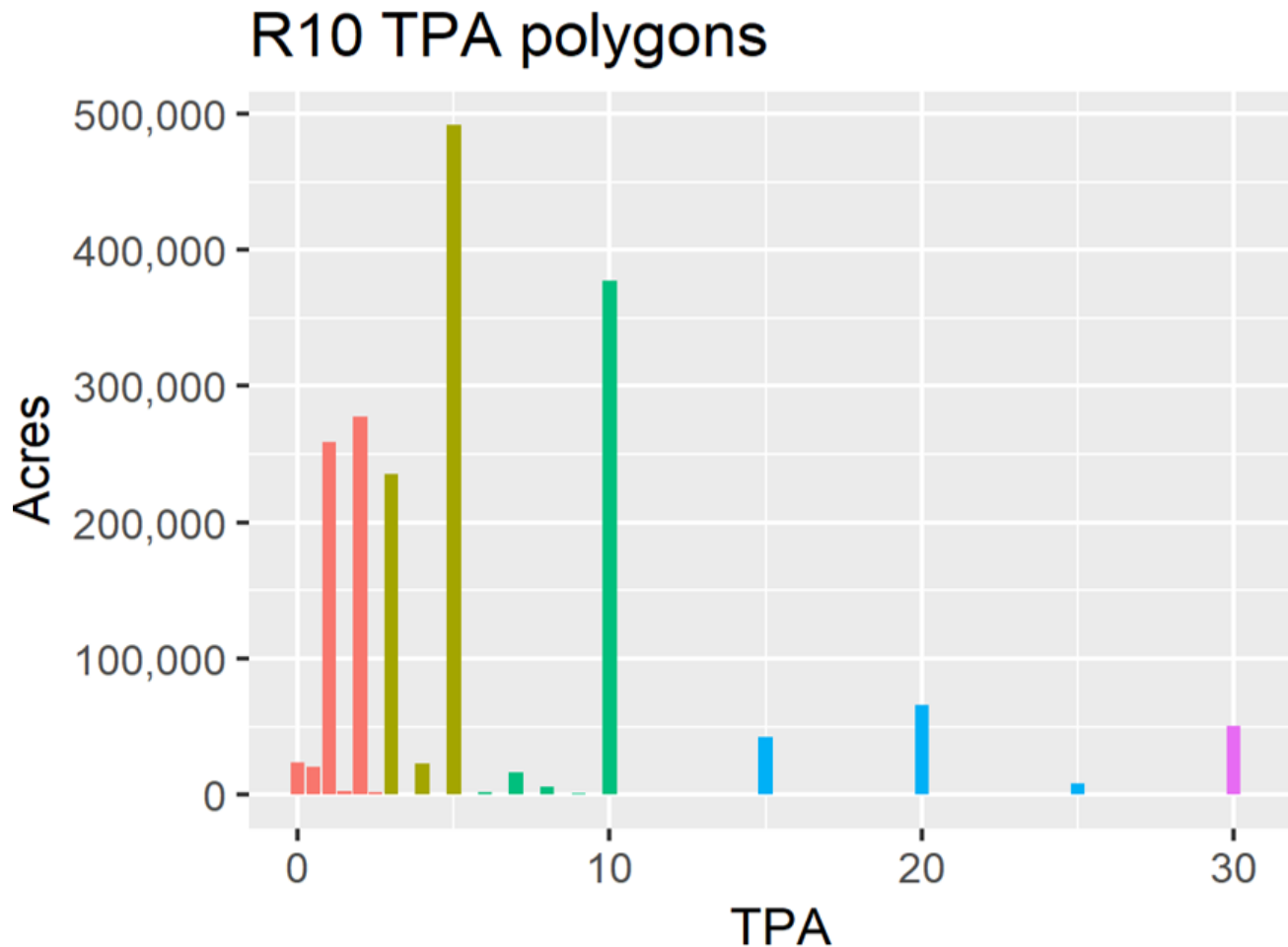
TPA: Percent Affected crosswalk based on Region 10's 1999 - 2018 ADS archive.

The percent of TPA-attributed acres from 1999- 2012 ADS are binned to match as closely as possible the acreage of mapped mortality using the 5-class percent affected system in use from 2013 -2018.



Distribution of acres mapped using TPA

The chart below shows the distribution of acres mapped by R10 from 1999-2012 using TPA. The clustering of acreage at certain TPA values suggests that surveyors tended to use TPA values like an ordinal rating, not that different than the 5-class Percent Affected system.



Rating Description	Very Light	Light	Medium	Severe	Very Severe
Pct. Aff. range classes	1-3%	4-10%	11 -29%	30 - 50%	> 50%
Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606
% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%
TPA range bins	< 3	3 - 5	> 5 & <= 10	> 10 & <= 29.98	>29.98
Sum of TPA acres	582,383	737,765	410,356	118,965	90,249
% of total TPA Acres	30.02%	38.03%	21.16%	6.13%	4.65%

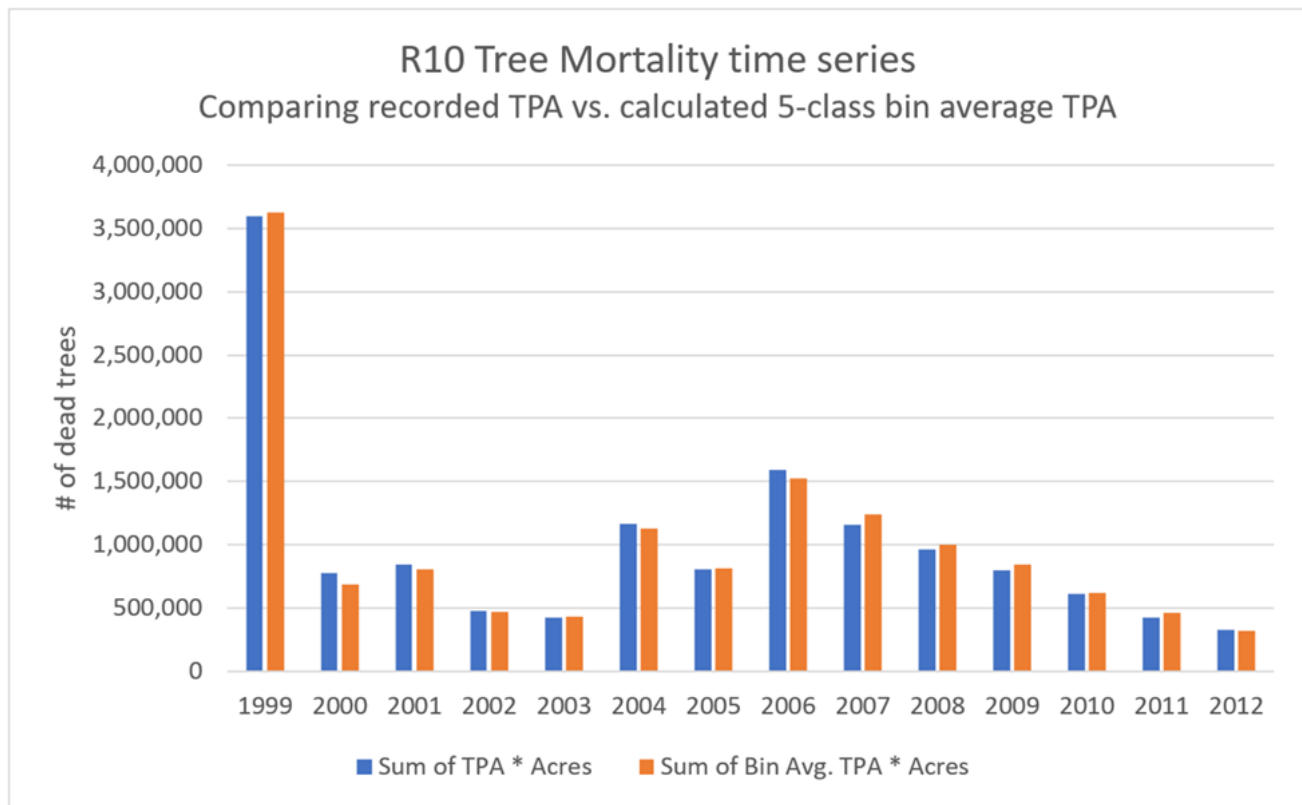
Clustering of TPA values prevents an exact match of acreage percentage in each TPA range bin with its associated Percent Affected class. For example, TPA value of 5 was commonly used by R10 surveyors which results in the "Light 3 -5" TPA range bin to be higher than the "Light" Percent Affected proportion (38.4% versus 30.9%) and the "Medium 5.01 – 10" TPA bin to be lower (20.8% in the "Light" TPA bin versus 26.3% for Percent Affected).

The tendency of R10 surveyors to use certain TPA values (1, 2, 3, ,5, 10, 20, 30) supports a premise of this crosswalk method that though TPA is a continuous measure, in practice it was applied like an ordinal rating.



This crosswalk does not purport to show what range of accurately measured TPA values equates with actual percent of tree canopy affects. Air survey severity ratings are quick estimates and should not be confused with detailed field measurements. The test of the crosswalk's utility is if it allows reasonable comparisons of damage impacts across the TPA - Percent Affected eras. If a surveyor in R10 had had rated mortality damage as 'Light 4-10%' with DMSM in 2019 would that surveyor have likely mapped that same Damage between 3 -5 TPA in 2012? This is not a crosswalk to measurements on the ground, but rather between two different damage severity rating metrics assessed by surveyors travelling at 120 miles per hour in an airplane.

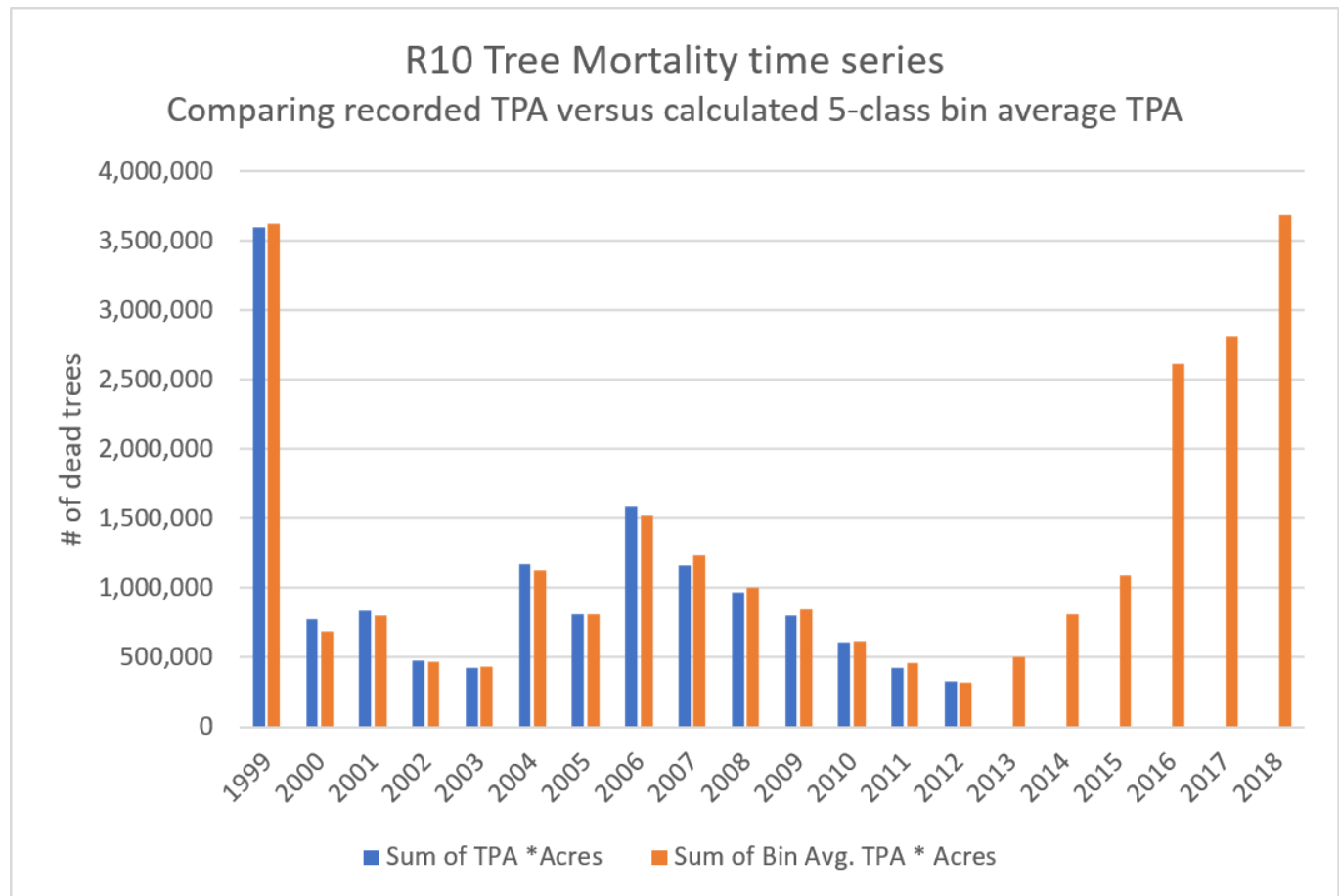
The following chart uses the R10 crosswalk to compare annual dead tree totals from 1999 -2012 calculated from recorded TPA as compared to an average TPA value for each of the five 'Very Light' to 'Very Severe' bins calculated by the crosswalk. Given the methodology it is not surprising, but never the less reassuring, that the time series charts very similar totals between the bin average versus the recorded TPA dead tree totals. Furthermore, the bin-average estimator is unbiased with similar number of years having estimated annual tree totals higher versus lower than the recorded annual tree totals.



Rating Description	Very Light	Light	Medium	Severe	Very Severe	Total Acres
Pct. Affected range	1-3%	4-10%	11 -29%	30 - 50%	> 50%	
Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606	1,538,477
% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%	
TPA range bins	< 3	3 - 5	> 5 & <= 10	> 10 & <= 29.98	>29.98	
Sum of TPA acres	582,383	737,765	410,356	118,965	90,249	1,939,718
% of total TPA acres	30.02%	38.03%	21.16%	6.13%	4.65%	
Area weighted Avg. TPA	1.43	4.34	9.72	18.45	41.52	



In the next chart we continue the annual dead tree time series into the Percent Affected era of 2013-2018 by applying area weighted TPA bin averages based on the polygon's Percent Affected class. An evaluation of whether the 2013-2018 time series is consistent with 1999-2012 trends must heavily rely on local experts with long experience in the region. For example, the time series suggests that pest mortality in 2015 is very similar to the magnitude of mortality in 2007. 2018 dead tree totals appear to be the largest since 1999. Are those comparisons reasonable? And if not, could discrepancies be explained by operational factors like how much survey was flown in 2007 versus 2015? Given our current technology, the opinions of local experts with long experience in the regions can best judge a crosswalk's suitability for traversing the switch from TPA to Percent Affected.



Data Prep Considerations

The crosswalk requires that Percent Affected Damage Areas (i.e. polygons) be matched with TPA attributed polygons. A challenging phase is selecting valid data for the analysis. Considerations include:

❖ **Only use damage type = 'mortality' features:**

- While in DMSM the Percent Affected rating is applied to all damage types (mortality, defoliation, dieback, etc.), TPA was only to be used with the mortality damage type. Only mortality Percent Affected features should be used for this crosswalk.

❖ **Legacy mortality features must have populated TPA or Tree Count values:**

- Prior to DMSM, surveyors had the option to use a 'number of dead trees' attribute instead of TPA. When a feature only has a dead tree count, TPA must be calculated from 'number of dead trees' and polygon acres.
- Prior to DMSM there was no software enforced requirement that all mortality features be attributed with a TPA or a 'number of (dead) trees' severity rating. Therefore, there are three conditions to look for when selecting TPA-attributed features for the crosswalk:
 - Features that have "valid" (TPA values greater than zero).
 - The IDS database also has records with TPA of, -1, 0 and NULL
 - Features that do not have a valid TPA, but instead have a dead tree count
 - Mortality features that neither have TPA nor a tree count.

❖ **Identify and exclude buffered points from the legacy ADS archive:**

- In DMSM there are separate feature classes for damage areas and damage points. Point data are attributed on the tablet using a 5-class rating based on tree count ranges or specific tree count values.

DMSM Tree Count Classes
1
2 - 5
6 - 15
16 - 30
31 - 99

Pre-DMSM, surveyors also had the option to map with either points or polygons in the airplane, but point data were buffered to convert points into circular polygons for submission to the ADS GIS, with each state or region determining the buffer distances used. Since DMSM point data already have a severity rating that parallel the legacy 'number of dead trees' attribute, only true polygons require a TPA: Percent Affected crosswalk. Furthermore, inclusion of buffered point data could adversely bias the crosswalk. The relatively small areas of concentrated damage that are typically mapped using points are qualitatively different than polygons describing broadly dispersed tree damage. This document discusses an option for including pre-DMSM buffered points and DMSM point features in ADS damage analyses.



❖ Other examples of data exclusion options:

- There may be data in the archives which are non-representative of the damage conditions of greatest interest. For example, you can find some extremely large TPA-attributed damage polygons (e.g. polygons greater than 1,000 acres) in the archive for abiotic damage events like fire, wind damage or flooding. If primarily interested in developing the crosswalk for insect and disease damage, an analyst could elect to exclude abiotic events to avoid having that abiotic data unduly bias crosswalk results.
- While TPA was introduced in the early 2000s, adoption of the metric was not necessarily consistent nor universal within a state or region. An analyst may choose to only use TPA attributed features from survey years after the state or region had a trained survey team experienced in estimating TPA. A similar consideration is whether to use data from a state or region's first year using the Percent Affected metric.

Step by Step Crosswalk Example

A note about these procedures

The procedural steps below should be treated as an example and not prescriptive. There are certainly different, and perhaps more efficient techniques to achieving the goal of finding TPA range bins that match acreage proportions from the Percent Affected archive.

As a companion to these procedures, please use ArcMap or ArcPro to refer to the file geodatabase 'R10_Xwalk.gdb' and the Excel workbook 'R10_Xwalk.xlsx'.

1. Building the Crosswalk

- 1.1.** Download the "All Years" archive for the region of interest from the Insect & Disease Detection Survey (IDS) Data Download site <https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/detection-surveys.shtml>

- ❖ **Note:** The Region 10 (R10) All Years archive includes data from 1997 -2018, but we are only interested in data starting in 1999, the first year R10 mortality features have populated LEGACY_TPA or LEGACY_NO_TREES values.

In ArcMap or ArcPro: Data Preparation.

Note: The screenshots and procedures shown below were generated in ArcMap

- 1.2.** Make a copy of the DAMAGE_AREAS_FLAT feature class that will be manipulated in this procedure to generate crosswalk inputs. For purposes of this document we will call this new feature class 'X_Walk_Polys'
- 1.3.** Identify all pre-DMSM buffered points using a 'Circularity' field.
 - a.** Add a new float type field to the X_Walk_Polys attribute table called 'Circularity'
 - b.** Calculate 'Circularity' with the following formula (a value of 1 would indicate the feature is a perfect circle):

$$4 * 3.14 * [\text{Shape_Area}] / ([\text{Shape_Length}] * [\text{Shape_Length}])$$

- c. Examine the data to determine a circularity threshold that differentiates buffered points from near circular mapped polygons

❖ **Note:** The ideal threshold for a region is variable because of different native projections and GIS methods used by states and regions for point buffering and vertex thinning. Although there are exceptions, buffered points are typically under 5 acres

- i. Select for small pre-DMSM polygons with high circularity.

SELECT * FROM X_Walk_Polys WHERE:

ACRES < 5 AND DATA_SOURCE_NAME = 'IDS LEGACY FEATURES' AND Circularity > 0.9

Clear Verify Help Load... Save... Apply Close

- ii. Sort the selection set by 'Circularity' in ascending order.

iii. Visually inspect a sampling of features to determine a threshold. For example, look at several polygons in the .90 circularity range. If inspected features do not appear to be buffered point, move on to a sampling of features in the 0.91 range, and so on until you hit a threshold where near 100% of the features appear to be buffered points. In the R10 data set I set the threshold at 0.951.

- iv. Select all legacy features under 5 acres AND with a circularity greater than the threshold determined in the step above.

- v. Add a new text field called 'Buffered'.

- vi. Based on the selection set calculate the 'Buffered' field to "yes".

ACRES	SURVEY_YEAR	LEGACY_TPA	LEGACY_NO_TREES	DATA_SOURCE_NAME	US_AREA	SHAPE_Length	SHAPE_Area	Circularity	Buffered
4.2	2011	0.23	1	IDS LEGACY FEATURES	Alaska	471.025866	16804.172944	0.951299	yes
4.9	2011	-1	-1	IDS LEGACY FEATURES	Alaska	513.922834	20011.955874	0.951663	yes
3.9	1998	-1	-1	IDS LEGACY FEATURES	Alaska	455.195857	15700.413842	0.951709	yes
1.1	1999	5	6	IDS LEGACY FEATURES	Alaska	238.628768	4316.346609	0.952051	yes
1.1	1999	10	11	IDS LEGACY FEATURES	Alaska	238.058663	4316.346609	0.952461	yes

❖ **Note:** An option that analysts could consider is simply using an acreage threshold. Based on local understand of their archive, R6 decided not to use the circularity formula, but instead opted to exclude features less than 3 acres. R6's assumptions were that most of these less than 3-acre polygons were buffered points and even if originally mapped as polygons, severity for these small isolated damage areas was likely assessed by a dead tree count, no different than if mapped as a point. Acreage thresholds can also catch non-circular 'buffered' points that would be missed using the circularity approach described above.



- 1.4.** Calculate TPA for legacy mortality polygons that are only attributed with a count of dead trees.

- a.** Select legacy features that that have tree count but no valid (greater than zero) TPA

DATA_SOURCE_NAME = 'IDS LEGACY FEATURES' AND LEGACY_NO_TREES > 0
AND (LEGACY_TPA <= 0 OR LEGACY_TPA IS NULL)

	ACRES	SURVEY_YEAR	LEGACY_TPA	LEGACY_NO_TREES
▶	3.7	2002	-1	10
	3.5	2002	-1	20
	17.4	2004	0	435
	17.6	2004	0	264
	14.2	2004	0	264

- b.** Based on the selection set, calculate the missing values for LEGACY_TPA by dividing LEGACY_NO_TREES by ACRES.

- 1.5.** Flag legacy features that have no severity rating (no TPA, tree count or Percent Affected). This document will mention some options for how to handle these features if considering their use in cumulative mortality or historical time series analyses.

- a.** Select for legacy mortality features that have no severity rating

DAMAGE_TYPE = 'Mortality' AND DATA_SOURCE_NAME = 'IDS LEGACY FEATURES'
AND (PERCENT_AFFECTED_CODE < 1 OR PERCENT_AFFECTED_CODE IS NULL)
AND (LEGACY_NO_TREES <= 0 OR LEGACY_NO_TREES IS NULL) AND
(LEGACY_TPA <= 0 OR LEGACY_TPA IS NULL)

- b.** Add a text field 'no_severity'.

- c.** Based on the selection set calculate the 'no_severity' field to 'yes'.

- 1.6.** For Percent Affected attributed features:

- a.** Select for Percent Affected mortality features

DAMAGE_TYPE = 'Mortality' AND PERCENT_AFFECTED_CODE > 0

- ❖ **Note:** prior to DMSM, R10 used Percent Affected calls from 2013-15 so this selection set will include both legacy and DMSM polygons

- b.** Calculate the percentage of mortality acreage in each of the five Percent-Affected classes. These are the class proportions based on acreage that you will attempt to match when defining TPA bin breakpoints in the steps below.

- i.** Right-click the PERCENT_AFFECTED_CODE field heading and select the 'Summarize' tool
- ii.** Summarize based on Sum of ACRES



iii. Save the output to a dbf or comma delimited text (*.csv) file.

Summarize

Summarize creates a new table containing one record for each unique value of the selected field, along with statistics summarizing any of the other fields.

1. Select a field to summarize:
PERCENT_AFFECTED_CODE
2. Choose one or more summary statistics to be included in the output table:
☐ ACRES
☐ Minimum
☐ Maximum
☐ Average
☒ Sum
☐ Standard Deviation
☐ Variance
☒ SURVEY_YEAR
☒ LEGACY_TPA
☒ LEGACY_NO_TREES
☒ DATA_SOURCE_NAME
3. Specify output table:
C:\Data\GMC_19\Histo_Match

☒ Summarize on the selected records

Look in: Home - GMC_19\Histo_Match

☐ R10
☐ Region10_AllYears_download

[About summarizing data](#)

iv. Import the ArcMap 'Summary' output into an Excel workbook (refer to the 'Output' worksheet/tab in the R10_X_Walk.xlsx). Transpose the Percent Affected class acreages and calculate percentages as shown in the screenshot below.

From ArcMap summary csv				Rating Description	Very Light	Light	Medium	Severe	Very Severe	Total Acres
PERCENT_AFFECTED_CODE	Cnt	PERCENT	Sum	ACRES						
1	4265		463,584	Pct. Aff. range classes	1-3%	4-10%	11-29%	30-50%	> 50%	
2	4560		475,892	Pct. Aff. range mid points	2%	7%	20%	40%	75%	
3	2824		404,771	Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606	1,538,477
4	1234		138,623	% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%	
5	785		55,606	Cum. % of Pct. Aff acres	30.13%	61.07%	87.38%	96.39%	100.00%	

c. Add a numeric (Float or Double) 'PctAff_MidPt' field

i. Calculate the Percent Affected class range midpoint by dividing the integer PERCENT_MID field by 100

d. Calculate 'Acres_Of' for non-buffered point mortality features that have a valid (> 0) PERCENT_AFFECTED_CODE

i. Add a numeric field (Double or Float) 'PctAff_x_Acres'

ii. Calculate 'PctAff_x_Acres' by multiplying PctAff_MidPt by ACRES.

1.7. For TPA features:

a. Select for non-buffered point mortality features that have a valid (> 0) TPA.

DAMAGE_TYPE = 'Mortality' AND LEGACY_TPA > 0 AND Buffered IS NULL

b. Add a numeric field (Double or Float) 'TPA_x_Acres'



- c. Based on the selection set calculate 'TPA_x_Acres' by multiplying LEGACY_TPA by ACRES.
- d. Export the selection set to an Excel workbook (refer to the 'TPA_gt_0_noBuf' worksheet in R10_Xwalk.xlsx).

In Excel: Calculating the TPA-bin range Crosswalk

Refer to the Excel workbook R10_Xwalk.xlsx for the procedures described below

Optional step: Remove double counted multi-observation LEGACY_TPA records from crosswalk analysis

- ❖ **Note:** In ADS a single damage polygon can have multiple observations. The DMSM software ensures that when multiple observations are made each observation has independent PERCENT_AFFECTED calls. However, for legacy features a common practice would be to use multiple observations to note multiple pest agents or multiple hosts on the same damage polygon but not specify separate TPA severities for each observation. In some cases, data managers would replicate the TPA value on the primary observation to all secondary observations rather than leave TPA for the secondary observations blank.

Depending on number and size of these doubled-up MULTIPLE observation legacy features the impact of this double counting to bias crosswalk results may or may not be significant. For the R10 dataset, there was no difference in the crosswalk's TPA bin ranges between keeping these doubled observations versus removing them. For simplicity sake, this example left "doubled up" records in the database and this document will not describe procedures for addressing apparent doubled up legacy PERCENT Affected and TPA features in the R10 dataset.

DAMAGE_AREA_ID	OBSERVATION_CO UNT	ACRES	LEGACY_ TPA
200510003447	MULTIPLE	170.1	1
200510003447	MULTIPLE	170.1	1
200510003448	MULTIPLE	246.7	1
200510003448	MULTIPLE	246.7	1
200510003449	MULTIPLE	83.2	1
200510003449	MULTIPLE	83.2	1
200510003450	MULTIPLE	1044.3	10
200510003450	MULTIPLE	1044.3	10
200510003451	MULTIPLE	1.9	5
200510003451	MULTIPLE	1.9	5

Apparent 'doubled up' records with identical DAMAGE IDs, ACRES and TPA values

1.8. In the 'TPA gt_0 no Buf' worksheet:

- a. Insert three new columns to the right of the LEGACY_TPA field called 'Cum_Acres' (cumulative acres), 'Cum_Pct' (cumulative percent) and 'Brk_Pts' (class break points).



- b. Filter the worksheet and sort by LEGACY_TPA (low to high) and ACRES (high to low)

ACRES	LEGACY_TPA	Cum_Acres	Cum_Pct	Brk_Pts	LEGACY_NO_TREES
2737.1	0.0018				5
926.8	0.0100				10
199.2	0.0100				3
135.7	0.0100				3

Sort		
Column	Sort On	Order
Sort by LEGACY_TPA	Cell Values	Smallest to Largest
Then by ACRES	Cell Values	Largest to Smallest

- ❖ **Note:** In this procedure we are formatting the LEGACY_TPA field to display to the 4th decimal place. In the source dataset downloaded in step 1 this field only contains values rounded to no more than 2 decimal places. However, in step 4 we calculated TPA for polygons that only had tree counts and introduced non-rounded decimal numbers. Using 4 decimal point precision allows the analyst to see what TPAs were calculated from tree counts during this procedure and can be useful for assigning features to an appropriate bin if rounding to 2 decimal points causes a record to fall on a TPA bin range breakpoint.

- c. Calculate 'Cumulative Acres' for each row by adding the ACRES value from the previous row to the current row.
- d. Calculate a 'Cumulative Percent' for each record by dividing the 'Cumulative Acres' cell for each row by the cumulative acre total.

ACRES	LEGACY_TPA	Cum_Acres	Cum_pct	Brk_Pts
2737.1	0.0018	2,737	0.14%	
926.8	0.0100	3,664	0.19%	
199.2	0.0100	3,863	0.20%	
135.7	0.0100	3,999	0.21%	
80.4	0.0124	4,079	0.21%	
297.2	0.0100	4,377	0.23%	

- e. Use the 'Cum_Pct' filter to select the cumulative percent value(s) that most closely approximate the Percent Affected cumulative percent breakpoints from step 1.6 (see yellow highlighted row in table below)

Rating Description	Very Light	Light	Medium	Severe	Very Severe
Pct. Aff. range classes	1-3%	4-10%	11 -29%	30 - 50%	> 50%
Pct. Aff. range mid points	2%	7%	20%	40%	75%
Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606
% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%
Cum. % of Pct. Aff acres	30.13%	61.07%	87.38%	96.39%	100.00%



- f. From the 'Cum_Pct' filter, and for each class, select the LEGACY_TPA cumulative percent value(s) that most closely approximate the Percent Affected cumulative percent breakpoints and identify the LEGACY_TPA value(s) associated with the filtered record(s).

❖ **Note:** See the TPA_Pivot tab of the R10_Xwalk.xlsx for an alternative TPA bin breakpoint selection method than what is shown below in steps f- h below.

For example:

- i. For the 'Very Light' class, I select the Cum_Pct values closest to the Percent Affected cumulative percent breakpoint of 30.13%, (30.02% and 30.45%).

ACRES	LEGACY_TPA	Cum_Acres	Cum_pct
12	2.9900		
11.3	2.9900		
9.3	2.9900		
6.7	2.9900		
6.3	2.9900		
6.3	2.9900		
5.3	2.9900		
4	2.9900		
3.3	2.9900		
3.3	2.9900		
8254.6	3.0000		

ACRES	LEGACY_TPA	Cum_Acres	Cum_pct
6.3	2.9900	582,361	30.02%
6.3	2.9900	582,368	30.02%
5.3	2.9900	582,373	30.02%
4	2.9900	582,377	30.02%
3.3	2.9900	582,380	30.02%
3.3	2.9900	582,383	30.02%
8254.6	3.0000	590,638	30.45%

- ii. Because 30.02 % is the closest cumulative percent to our target of 30.12% and represents the upper bound of the cumulative percent range associated with TPA value 2.99, it is clear that 2.99 is the upper breakpoint for the 'Very Light' class. Flag this record by entering a "1" on this row in the Brk_Pts column.

ACRES	LEGACY_TPA	Cum_Acres	Cum_pct	Brk_Pts
6.3	2.9900	582,361	30.02%	
6.3	2.9900	582,368	30.02%	
5.3	2.9900	582,373	30.02%	
4	2.9900	582,377	30.02%	
3.3	2.9900	582,380	30.02%	
3.3	2.9900	582,383	30.02%	1
8254.6	3.0000	590,638	30.45%	

- iii. In most cases, it will require additional steps to determine these breakpoints. The example of the TPA range bin upper breakpoint for the "Light" class is a more typical example. The target from the Percent Affected acreage summary is 61.06%. The TPA associated with that cumulative percent in the TPA archive is 5.00.



Values Copied from TPA_gt_0_noBuf Brk_Pts											
LEGACY_TPA	Cum_Acres	Cum_pct	Brk_Pts		TPA range bins	< 3	3 - 5	> 5 & <= 10	> 10 & <= 29.98	>29.98	
2.9900	582,383	30.02%	1	➔	Sum of TPA acres	582,332	737,765	410,356	118,965	90,249	1,939,718
5.0000	1,320,149	68.06%	2		% of total TPA acres	30.02%	38.03%	21.16%	6.13%	4.65%	
10.0000	1,730,504	89.21%	3		Cum. % of TPA acres	30.02%	68.06%	89.21%	95.35%	100.00%	
29.9800	1,849,469	95.35%	4								
250.0000	1,939,718	100.00%	5								

Rating Description	Very Light	Light	Medium	Severe	Very Severe	Total Acres
Pct. Affected range	1-3%	4-10%	11 -29%	30 - 50%	> 50%	
Pct. Aff. Range mid-points	2%	7%	20%	40%	75%	
Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606	1,538,477
% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%	
Cum. % of Pct. Aff acres	30.13%	61.07%	87.38%	96.39%	100.00%	

TPA range bins	< 3	3 - 5	> 5 & <= 10	> 10 & <= 29.98	>29.98	
Sum of TPA acres	582,383	737,765	410,356	118,965	90,249	1,939,718
% of total TPA acres	30.02%	38.03%	21.16%	6.13%	4.65%	
Cum. % of TPA acres	30.02%	68.06%	89.21%	95.35%	100.00%	

2. Applying Crosswalk to Features in ArcMap

This portion of the procedure will:

- ❖ Assign crosswalk Percent Affected class mid-point to TPA-attributed features.
- ❖ Calculate the area weighted mean average TPA for each of the five TPA range bins.
- ❖ Assign the TPA bin average to Percent Affected mortality features
- ❖ Calculate tree counts (TPA_x_Acres) and 'Acres Of' (PctAff_MidPt * ACRES) using source and cross-walked values from both Percent Affected and TPA polygons

2.1. Assign crosswalk Percent Affected class mid-point to TPA-attributed features.

Using the crosswalk table from the previous step:

- a. Select non buffered TPA polygons for each class. Using the 'Very Light' bin as an example

DAMAGE_TYPE = 'Mortality' AND Buffered IS NULL AND (LEGACY_TPA > 0 AND LEGACY_TPA < 3)

- b. Add a Float field 'Est_PctAff_MidPt'

- c. Based on the selection set calculate the 'Est_PctAff_MidPt' field using the 'Very Light 1-3%' Percent Affected midpoint of 2%.



X_Walk_Polys								
	Circularity	Buffered	no_severity	LEGACY_TPA	TPA_x_Acres	PctAff_MidPt	Acres_Of	Est_PctAff_MidPt'
	0.342821	<Null>	<Null>	0.001827	5	<Null>	<Null>	0.02
	0.468482	<Null>	<Null>	0.01	1.357	<Null>	<Null>	0.02
	0.734419	<Null>	<Null>	0.01	9.268	<Null>	<Null>	0.02
	0.671439	<Null>	<Null>	0.01	1.992	<Null>	<Null>	0.02
	0.593404	<Null>	<Null>	0.012438	1	<Null>	<Null>	0.02
	0.769675	<Null>	<Null>	0.02	3.486	<Null>	<Null>	0.02
	0.655555	<Null>	<Null>	0.02	1.000	<Null>	<Null>	0.02

d. Repeat these steps for the remaining TPA bin ranges

2.2. Calculating area weighted, mean TPA values for each class.

❖ **Note:** There are options for calculating an average TPA value for the five TPA bin ranges (median, mode, non-weighted mean, etc.) but this procedure recommends using an area weighted mean. This average TPA value can be applied to Percent Affected polygons in the same way that Percent Affected mid points are crosswalked to legacy TPA attributed features.

a. Select non buffered TPA polygons

DAMAGE_TYPE = 'Mortality' AND Buffered IS NULL AND LEGACY_TPA > 0

b. Calculate the percentage of mortality acreage in each of the five Percent-Affected classes. These are the class proportions based on acreage that you will attempt to match when defining TPA bin breakpoints in the steps below.

i. Right-click the 'Est_PctAff_MidPt' field heading and select the 'Summarize' tool

ii. Summarize on the selected records based on Sum of ACRES and Sum of 'TPA_x_Acres' (optionally AVERAGE of LEGACY_TPA)

iii. Save the output to a comma delimited text (*.csv) or dbf file



iv. Copy & Paste the values from csv or dbf file to the Output tab in the R10_Xwalk.xlsx

v. Calculate the weighted average TPA (Sum_TPA_x_Acres / Sum_Acres)

Values Copied from 'Est_Pct_Aff_MidPt' summarization						
Est_PctAff	Cnt_Est_Pct	Sum_ACRES	Ave_LEGACY_TPA	Sum_TPA_x_Acres	WghtAvg_TPA	
0.02	6173	582383.4	1.265514852	835277.1819	=AT3/AR3	
0.07	7129	737765.37	4.144020199	3200059.449	4.337502924	
0.20	2762	410355.71	9.487437876	3988578.672	9.7198079	
0.40	1094	118964.74	17.80543374	2195445.02	18.45458595	
0.75	349	90249.17	42.8630659	3746819.05	41.51638237	

Add the weighted average TPA values to complete the crosswalk table

Rating Description	Very Light	Light	Medium	Severe	Very Severe	Total Acres
Pct. Affected range	1-3%	4-10%	11 -29%	30 - 50%	> 50%	
Sum of Pct. Aff acres	463,584	475,892	404,771	138,623	55,606	1,538,477
% of total Pct. Aff Acres	30.13%	30.93%	26.31%	9.01%	3.61%	
Cum. % of Pct. Aff acres	30.13%	61.07%	87.38%	96.39%	100.00%	

TPA range bins	< 3	3 - 5	> 5 & <= 10	> 10 & <= 29.98	>29.98	
Sum of TPA acres	582,383	737,765	410,356	118,965	90,249	1,939,718
% of total TPA acres	30.02%	38.03%	21.16%	6.13%	4.65%	
Cum. % of TPA acres	30.02%	68.06%	89.21%	95.35%	100.00%	
Area weighted Avg. TPA	1.43	4.34	9.72	18.45	41.52	

2.3. Assign the TPA bin average to Percent Affected mortality features

Using the area weighted average TPAs from the previous step:

- a.** Select non buffered Percent Affected mortality polygons for each class. Using the 'Very Light' bin as an example

DAMAGE_TYPE = 'Mortality' AND Buffered IS NULL AND PERCENT_AFFECTED_CODE = 1

- b.** Add a Float field 'Est_TPA_Avg'

- c.** Based on the selection set calculate the 'Est_TPA_Avg' field using the 'Very Light' area weighted average TPA of 1.43

X_Walk_Polys								
PERCENT_AFFECTED_CODE	PERCENT_AFFECTED	ACRES	LEGACY_TPA	TPA_x_Acres	PctAff_MidPt	Acres_Of	Est_PctAff_MidPt	Est_TPA_Avg
1	Very Light (1-3%)	1.76	<Null>	<Null>	0.02	0.0352	<Null>	1.43
1	Very Light (1-3%)	1.22	<Null>	<Null>	0.02	0.0244	<Null>	1.43
1	Very Light (1-3%)	1.88	<Null>	<Null>	0.02	0.0376	<Null>	1.43
1	Very Light (1-3%)	1.64	<Null>	<Null>	0.02	0.0328	<Null>	1.43
1	Very Light (1-3%)	1.26	<Null>	<Null>	0.02	0.0252	<Null>	1.43
1	Very Light (1-3%)	1.94	<Null>	<Null>	0.02	0.0388	<Null>	1.43
1	Very Light (1-3%)	1.38	<Null>	<Null>	0.02	0.0276	<Null>	1.43

- d.** Repeat these steps for the remaining Percent Affected classes.



2.4. Calculate tree counts and 'Acres Of' using both source and cross-walked values from Percent Affected and TPA polygons

a. Add two additional Float fields 'Est_TPA_x_Acres' and 'Est_Acres_Of'.

- i.** The 'Est_TPA_x_Acres' field will store both recorded number of dead trees from TPA polygons and cross-walked tree counts from Percent Affected polygons.
- ii.** The 'Est_Acres_Of' field will store both recorded Acres Of values from Percent Affected polygons and cross-walked Acres Of from TPA polygons.

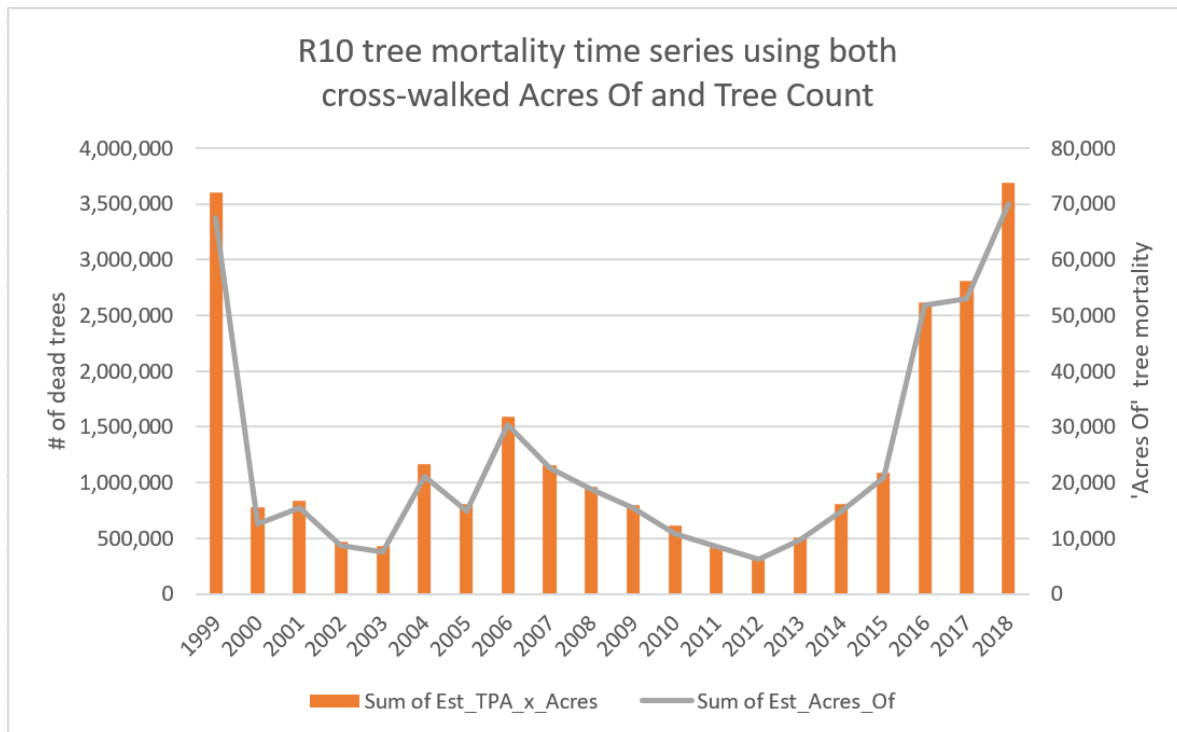
These fields can be used to chart time series or calculate cumulative mortality for datasets that span use of TPA and Percent Affected

b. Select non-buffered Percent Affected mortality polygons and calculate the 'Est_TPA_x_Acres' and 'Est_Acres_Of' fields:

- i.** $\text{Est_TPA_x_Acres} = \text{ACRES} * \text{Est_TPA_Avg}$
- ii.** $\text{Est_Acres_Of} = \text{Acres_Of}$

c. Select non-buffered TPA mortality polygons and calculate the 'Est_TPA_x_Acres' and 'Est_Acres_Of' fields:

- i.** $\text{Est_TPA_x_Acres} = \text{TPA_x_Acres}$
- ii.** $\text{Est_Acres_Of} = \text{ACRES} * \text{Est_PctAff_MidPt}$



Regardless of cross-walk metric, annual tree mortality trend lines are very similar

* To generate the charts shown in this document, the X_Walk_Polys attribute table was exported to the All noBuf withSeverity tab of R10_Xwalk.xlsx. Based on this data a pivot table was inserted for chart creation (see the All_Pivot & Charts tab)



- 2.5.** Another way to crosswalk the two severity metrics is to use the area weighted TPA bin averages for calculating dead tree counts instead of recorded LEGACY_TPA values. This is a parallel to converting TPA polygon dead tree counts to Acres Of but has the advantage of evaluating the quality of the crosswalk with the same dead tree count metric. To calculate:

Using the area weighted average TPAs from step 2.2

- a.** Select TPA mortality polygons for each bin range. Using the 'Very Light' bin as an example

$$\text{Est_PctAff_MidPt} = 0.02$$

- b.** Based on the selection set calculate the 'Est_TPA_Avg' field using the 'Very Light' area weighted average TPA of 1.43
- c.** Repeat these steps for the remaining TPA bins (Est_PctAff_MidPt's .07, .2, .4 and .75)
- d.** Select all non-buffered mortality features with valid recorded TPA or Percent Affected

DAMAGE_TYPE = 'Mortality' AND Buffered IS NULL AND
(PERCENT_AFFECTED_CODE > 0 OR LEGACY_TPA > 0)

- e.** Add a field 'BinAvg_TPA_x_Acres'

- f.** Based on the selection set calculate 'BinAvg_TPA_x_Acres': ACRES * Est_TPA_Avg

3. Options for points, buffered points and no severity features

- 3.1.** Calculate an overall mean Percent Affected value to be used for legacy features that have no TPA attribution; to calculate:

- a.** Using the DMSM mortality polygons with percent affected attribution. Multiply the acreage in each of the 5 classes by their respective Percent Affected range mid-points to calculate the "Acres-Of" for each class. For example, there were 463,584 acres (with) in R10 that were classed in the 1-3% category with a class mid-point of 2%. $463,584 * 0.02 = 9,272$ Acres-Of.
- b.** Sum the Acres-Of for all 5 categories and divide by the sum of Acres (with) to get the overall mean percent affected of 14%.

Rating Description	Very Light	Light	Medium	Severe	Very Severe	Total Acres
Pct. Affected range	1-3%	4-10%	11 -29%	30 - 50%	> 50%	
Pct. Aff. Range mid-points	2%	7%	20%	40%	75%	
Sum of Pct. Aff acres With	463,584	475,892	404,771	138,623	55,606	1,538,477
Sum of Pct. Aff acres Of	9,272	33,312	80,954	55,449	41,704	220,692
Average Percent Affected mid-point						14%

- ❖ **Note:** In many regional archives, there are very large mortality polygons with no TPA attribution as a way to identify broad regions of widely dispersed tree damage. If there is no historical knowledge to explain these very large polygons there is a risk that attributing these large polygons with a default estimated percent affected value could significantly overestimate actual damage. Consider whether to exclude these very large, no TPA



damage features from the analysis, count them as very light 1-3%, or take a feature-specific action based on DCA. In R10 there are 17 of these types of features greater than 1,000 acres in size with DCAs of fire, flooding and eastern larch beetle.

3.2. Calculate 'Acres Of' values for legacy buffered points and DMSM point features.

- a.** If there is a compelling interest to include legacy buffered points and DMSM point features when charting historical trends or calculating multi-year, cumulative mortality impacts one approach would be to use FHAAS's default acre assignment for DMSM point features (see table below). For example, if a legacy buffered point mortality feature cross-walked to one of the two lowest percent affected classes, its estimated acres of value would be calculated as .25 acres

DMSM Tree Count Classes	Estimated Point Acreage (Default)
1	0.25
2 - 5	
6 - 15	1
16 - 30	
31 - 99	2

Alternatively if using dead tree counts as opposed to 'Acres Of', DMSM point features could be attributed with their 'number of trees' class mid points and then combined with the 'TPA_x_Acres' tree counts for TPA polygons (buffered and not-buffered) and 'Est_TPA_x_Acres' tree counts for Percent Affected polygons (buffered and not-buffered).

