Forest Analysis Techniques

Determining insect vulnerability

—by Glen Jordan

Introduction

Problem

What makes forest stands vulnerable, and how can you identify these stands?

Forests are affected by a host of natural disturbances, including windstorms, fires, diseases, and insects, on an ongoing basis. In fact, these disturbances contribute to the long-term ecological well-being of forests.

From a human perspective, though, these events seem destructive. After all, they destroy timber and nontimber commodities that we value highly. For this reason, society often protects its forests from these destructive events.

A good example is the long-standing battle against the spruce budworm (*Choristoneura fumiferana*). This insect has a long history of periodic outbreaks and defoliation of softwood-dominated forests in northeastern North America.

Outbreaks of varying severity and length have occurred on at least five occasions since the early 1700s. The most recent outbreak occurred in the late 1970s through the early 1980s and affected large areas of forest. It's just a matter of time before another outbreak occurs.

Typically, during outbreaks, efforts are made to target protection activities toward stands that are most vulnerable to tree mortality and, thus, significant timber and nontimber losses.

Location

A small, 1,400-hectare (ha) woodlot in the Acadian-New England forest region of North America

Keywords: forest protection; vulnerability to insects; reclassifying forest features aspatially and spatially; characterizing with a numerical distribution and a map; selecting features by attribute; using Python in the Field Calculator; using a VB code block in the Field Calculator; spatially joining features; dissolving features; summarizing an attribute

Time to complete the lab

Three hours

Prerequisites

A basic working knowledge of geographic information system (GIS) data, including the geodatabase, and ArcGIS® in particular; familiarity with forest inventory data also helpful but not essential

Data used in this lab

- Feature classes and rasters for a small woodlot (personal geodatabase)
- Geographic coordinate system: NAD 1983 CSRS New Brunswick Stereographic
- Datum: NAD83
- Projection: New Brunswick Double Stereographic Grid (unless otherwise stated)

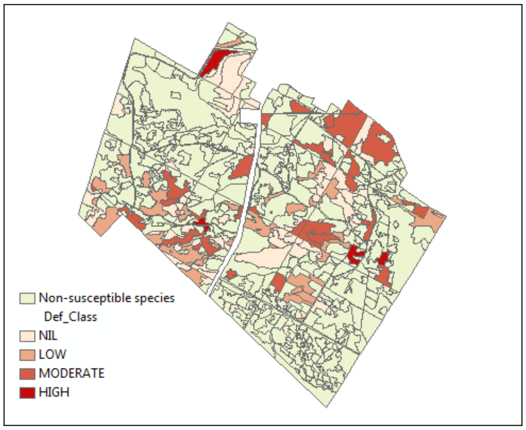
Student activity

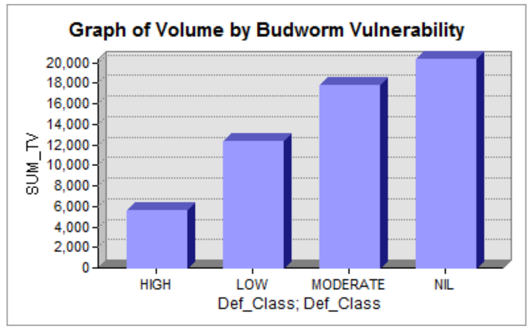
In this exercise, you'll analyze the Woodlot's overall vulnerability should a spruce budworm outbreak occur. In its present state, is the Woodlot particularly vulnerable to mortality losses, or is there little to worry about? How much timber volume, for example, is at risk?

You'll attempt to find an answer by first calculating budworm vulnerability index values for stands as a function of their spruce and fir species composition, age, and isolation. This will allow you to then map and summarize timber volume amounts by defoliation classes.

Results expected

Location and timber volume of vulnerable stands in the Woodlot (see below)





Data available

- Cover types feature class: *cover*
- Stand volumes table: *volumes*

Solution steps

1. Calculate spruce and fir volume content rating.
2. Calculate mature balsam fir content rating.
3. Identify hardwood patches.
4. Calculate isolation rating.
5. Calculate vulnerability index and defoliation classes.
6. Summarize defoliation classes.
7. Map defoliation classes.

CALCULATE SPRUCE AND FIR VOLUME CONTENT RATING

A stand's vulnerability to tree mortality during a budworm outbreak is determined by several factors:

The first is the amount of susceptible species present. The volume content of spruce (*Picea* species) and balsam fir (*Abies balsamea*) is critical.

A second factor is the amount of mature balsam fir present. Balsam fir is a relatively short-lived species and is particularly vulnerable to mortality from defoliation, even at a relatively young age.

The last factor that influences a stand's vulnerability is its degree of isolation. Here, the extent to which a stand of susceptible species is surrounded by nonsusceptible ones, like hardwoods, is important.

How, though, does one combine these three factors into one vulnerability measure?

The following table illustrates one possibility, in which a vulnerability index is calculated by multiplying individual factor ratings as described above—spruce and balsam fir content, mature balsam fir content, and isolation among nonsusceptible hardwood stands:

Spruce and balsam fir (m3/ha)	Vulnerability rating	Mature balsam fir (%)	Vulnerability rating	Adjacent hardwood patch size (ha)	Vulnerability rating
0	0	0	0	<10	1.00
>0–7	1	>0–20	1	=10	1.10
>7–14	2	>20–40	2	>10	1.20
>14–21	3	>40	3		
>21–28	4				
>28–35	5				
>35–42	6				
>42–49	7				
>49–56	8				
>56–63	9				
>63	10				

Table 1. Stand budworm vulnerability index

Your first task, then, is to compile a vulnerability rating for each Woodlot stand based on spruce and balsam fir content as shown in the table.

RELATED CONCEPT: RECLASSIFY USING THEMATIC ATTRIBUTES TO QUANTIFY

1 Start ArcMap, add the *cover* feature class, and set your Current and Scratch Workspaces to your *Woodlot* geodatabase using *Environment Settings* (*Geoprocessing » Environments » Workspace*).

The *Cover Types* attribute table does not provide any details about species composition, but as you may recall, the *volumes* table does. It records species volume amounts in cubic meters

(m^3)/ha by three product types: pulpwood, sawlog, and veneer. A stand's volume content for a species, like spruce, is determined by adding fields *S_P* + *S_S* + *S_V*.

2 Join *volumes* to *Cover Types* via their shared stand numbers, *STAND_ID* and *Stand#*, respectively.

You now have access to spruce and balsam fir volume yields (m^3/ha) for each stand and can calculate a vulnerability rating. You need a new attribute field to do that.

3 Open the *Cover Types* attribute table and add a short integer field, *SpBF_Rate*.

Now you can populate the field with rating values, *0* through *10*, as follows:

Condition	Rating
S_P+S_S+S_V+BF_P+BF_S+BF_V = 0	0
S_P+S_S+S_V+BF_P+BF_S+BF_V > 0 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 7	1
S_P+S_S+S_V+BF_P+BF_S+BF_V > 7 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 14	2
S_P+S_S+S_V+BF_P+BF_S+BF_V > 14 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 21	3
S_P+S_S+S_V+BF_P+BF_S+BF_V > 21 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 28	4
S_P+S_S+S_V+BF_P+BF_S+BF_V > 28 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 35	5
S_P+S_S+S_V+BF_P+BF_S+BF_V > 35 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 42	6
S_P+S_S+S_V+BF_P+BF_S+BF_V > 42 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 49	7
S_P+S_S+S_V+BF_P+BF_S+BF_V > 49 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 56	8
S_P+S_S+S_V+BF_P+BF_S+BF_V > 56 AND S_P+S_S+S_V+BF_P+BF_S+BF_V <= 63	9
S_P+S_S+S_V+BF_P+BF_S+BF_V > 63	10

Table 2. A method for rating stands (0–10) based on their spruce and balsam fir content.

4 Calculate vulnerability ratings associated with spruce and balsam fir volume content, as indicated in the table above, using the following Python formula in *Field Calculator*:

```
SpBF_Rating = round((volumes.S_P + volumes.S_S + volumes.S_V +
   volumes.BF_P + volumes.BF_S + volumes.BF_V) / 7 + 0.499)
```

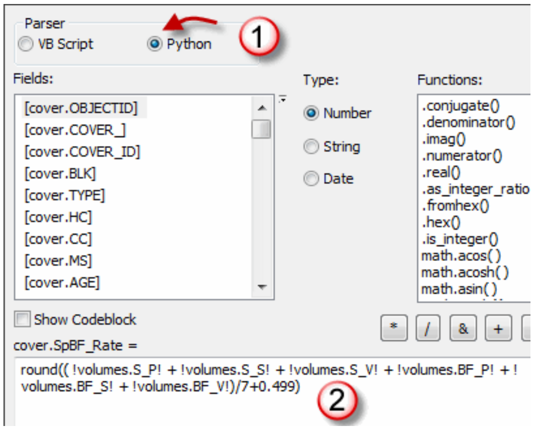


Figure 1. Use the Python *round* function to calculate spruce and balsam fir content ratings.

You could try Visual Basic (VB) here instead of Python, but VB has trouble handling Null values in expressions, in this case, volumes for nonstand features. However, you could have excluded the nonstand features when you joined the volumes *table earlier by clearing the* Keep All *option.*

Efficient calculation method

The formula is a very efficient way to calculate a defined interval series when compared with the alternative—in other words, a series of *Select By Attributes* and *Field Calculator* operations. The general form of the formula is `round(infield / interval + 0.49)`. To correctly handle input values that lie on interval boundaries, though, you will have to change 0.49 to 0.499 or 0.4999, and so on, depending on how many decimal places are involved in the input field. Warning: If the inputs are whole numbers, add a decimal to `interval` to avoid truncating when dividing.

The *SpBF_Rate* field should now show ratings ranging from 0 to some maximum. The maximum depends on the stand with the greatest spruce and fir volume content.

You only need to make one adjustment to these calculated ratings—recalculate anything above 10 to *10*.

5 Select all stands with *SpBF_Rate* values greater than 10 and recalculate SpBF_Rate = 10.

You should end up recalculating 59 *SpBF_Rate* values.

That's spruce and balsam fir volume content ratings calculated.

If you summarized the *SPBF_Rate* field by area (*Shape_Area*) sum, you will discover that a relatively small area of the Woodlot rates a 10 (approximately 188 ha). Try it if you wish. (Don't forget to clear selected features first.)

OID	SpBF_Rate	Count_SpBF_Rate	Sum_Shape_Area
0	0	153	3274666.33381
1	1	70	3313859.70931
2	2	45	1056428.36488
3	3	30	594857.088454
4	4	37	1082042.83916
5	5	32	735991.903345
6	6	28	748648.538567
7	7	26	684513.184443
8	8	15	294153.56581
9	9	18	303702.474616
10	10	79	1884449.21396

Figure 2. Summary of spruce and balsam fir ratings (1–10) by area (m^2).

Rating stands by their mature balsam fir content is next.

Calculate mature balsam fir content rating

The amount of mature balsam fir in a stand also contributes to its vulnerability to mortality losses during a budworm outbreak. Balsam fir trees are the budworm's preferred food source and are particularly vulnerable at maturity and beyond. For balsam fir, maturity occurs at about 60 years of age.

The *BF_* field in *volumes* provides percentage estimates of balsam fir content. No indication of balsam fir maturity, however, is recorded. Therefore, in calculating your vulnerability ratings, you'll have to assume that stand age (*AGE* field) is a good estimate of the age of all the species in a stand.

Related Concept: Reclassify using thematic attributes to quantify

1 Add a short integer field named *MatureBF_Rate*.

Using the following as a guide, you can use *MatureBF_Rate* to calculate vulnerability ratings for Woodlot stands:

Mature balsam fir (%)	Vulnerability rating
0	0
>0–20	1
>20–40	2
>40	3

Table 3. A method for calculating mature balsam fir content ratings (0–3)

2 First, select just the mature stands (age 60 or more) using the *AGE* field.

You'll find 150 mature stands.

3 Then, for the 150 mature stands, calculate vulnerability ratings using the following Python formula in *Field Calculator*:

```
round(volumes.BF_ / 20.0 + 0.499)
```

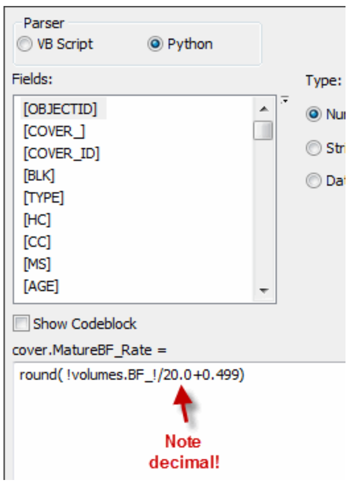


Figure 3. Use the Python Round function
to calculate mature balsam fir content ratings.

The formula makes it easy. It's worth remembering.

Question 1: *What would happen if you didn't divide by 20.0 but rather by 20?*

4 Terminate the ratings at 3—in other words, reassign all *MatureBF_Rate* values greater than 3 to 3.

You'll find that zero mature stands in the Woodlot have a rating greater than 3. That means there are no mature stands with more than 40 percent balsam fir content. That tells you that mature balsam fir content isn't going to be a big factor in vulnerability levels in the Woodlot.

That leaves the last vulnerability factor to calculate—stand isolation. To what extent do patches of nonsusceptible hardwood stands surround susceptible stands in the Woodlot? Figuring that out is next.

IDENTIFY HARDWOOD PATCHES

Susceptible stands that are isolated by patches of hardwoods are more vulnerable. With little opportunity to spread, the budworm remains concentrated in an isolated stand, leading to higher levels of defoliation and tree mortality.

Your first task in calculating an isolation rating for susceptible stands, then, is identifying hardwood patches.

That's easy enough. First, identify hardwood-dominated stands. Second, using the *Dissolve* tool, remove boundaries between hardwood stands that are adjacent.

RELATED CONCEPT: RECLASSIFY SPATIALLY

1 Add another short integer field, this time named *HWD*. Then use it to assign all hardwood-dominated stands `(HW_ >= 70)` a value of *1*.

Now, dissolve boundaries between any of the 78 hardwood stands that are adjacent.

2 With the hardwood stands still selected, use the *Dissolve* tool (*Data Management Tools » Generalization*) to dissolve the *HWD* field and create a new feature class named *HWD_Patches* in your geodatabase. Disable multipart features.

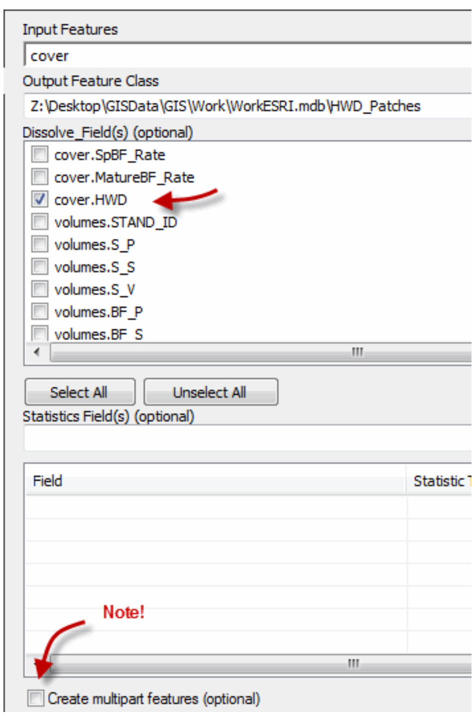


Figure 4. Use the Dissolve tool to create hardwood patches.

Question 2: *When forming forest patches, why is it critical to disable multipart features in the* Dissolve *tool?*

If you turn the *Cover Types* layer off, the new *HWD_Patches* feature class becomes apparent.

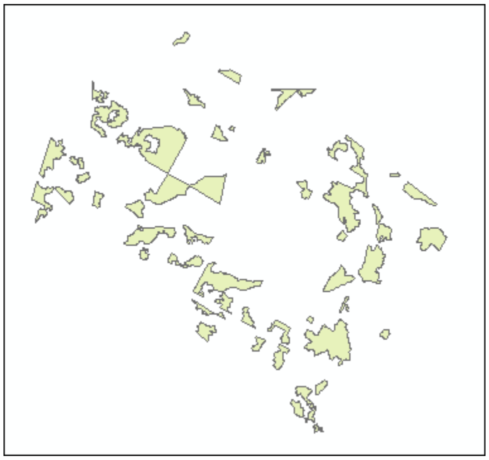


Figure 5. Hardwood patches in the Woodlot.

If you open the attribute table, you'll see 50 records, representing 50 hardwood patches. You've gone from 78 stands to 50 patches. So 14 hardwood stands were adjacent.

Conveniently, patch areas have been calculated in the *Shape_Area* field.

With hardwood patches identified and their sizes calculated, you can now determine which budworm-susceptible stands have one or more patches adjacent.

CALCULATE ISOLATION RATING

Isolation is the third and last factor in your spruce budworm vulnerability index calculation.

It's estimated that susceptible stands isolated by adjacent hardwood patches may see mortality increases of 10 to 20 percent, depending on the size of adjacent patches of nonsusceptible species. Appropriate isolation rating values thus might be calculated as follows.

Adjacent hardwood patch size (ha)	Vulnerability rating
<10	1.00
=10	1.10
>10	1.20

Table 4. A method for calculating isolation ratings

When used in calculating vulnerability index values *(spruce-fir content rating * mature balsam fir content rating * isolation rating*), the isolation ratings have the effect of adjusting the index upward by either 10 or 20 percent.

You've identified hardwood patches and calculated their areas. All you need to do is find the area of hardwood patches adjacent to susceptible stands. A spatial join is the easiest way to do this.

RELATED CONCEPT: RECLASSIFY USING LOCATIONAL ATTRIBUTES TO QUANTIFY

1 Remove the *volumes* join from *Cover Types*, and then, using the *Sum* option, join features in *HWD_Patches* that are adjacent (intersect) to those in *Cover Types* (*right-click » Joins and Relates).* Name the new feature class *cover_HWD_Patches.*

Removing the joined *volumes* table is optional. It will, however, improve the efficiency of subsequent operations.

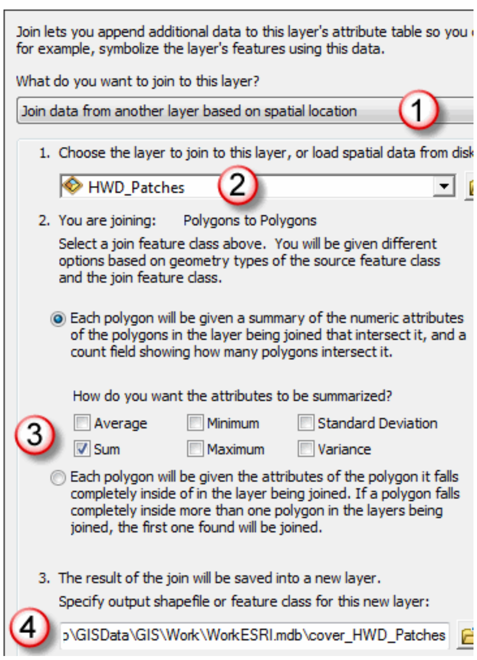
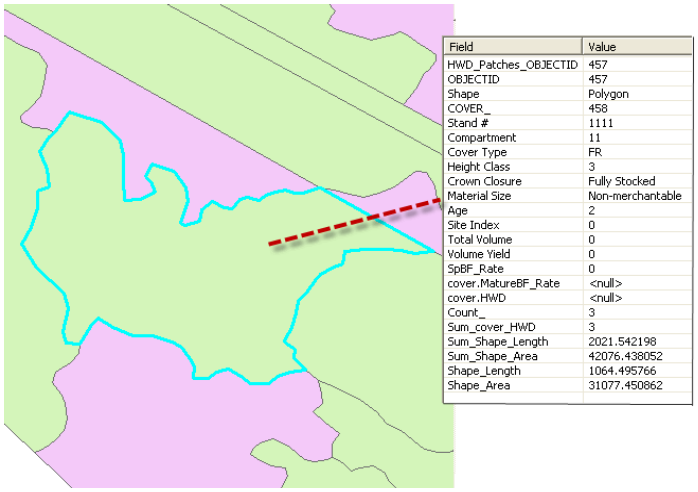


Figure 6. Spatially joining adjacent hardwood patches to Woodlot stands.

You may want to take a closer look at the result to appreciate what you've accomplished in this case.

2 Select stand 1111 (*COVER_ID* or *Stand#*) in *cover_HWD_Patches*, and then zoom in on it.



Field	Value
HWD_patches_OBJECTID	457
OBJECTID	457
Shape	Polygon
COVER_	458
Stand#	1111
Compartment	11
Cover Type	Forested area
Height Class	3
Crown Closure	fully stocked
Material Size	non-merchantable
AGE	2
SI	0
Total Volume	0
Volume Yield	0
cover.spBF_Rate	0
cover.matureBF_Rate	<null>
cover.HWD	<null>
Count_	3
Sum_cover_HWD	3
Sum_Shape_Length	2021.542198
Sum_Shape_Area	42076.438052
Shape_Length	1064.495766
Shape_Area	31077.450862

Figure 7. Stand 1111 selected, showing a summary of its adjacent hardwood patches. Note: If you have inadvertently directed the spatial join output to a shapefile, as opposed to a feature class in your Woodlot geodatabase, you will see different field naming. For example, Sum_Shape_Area may appear as Sum_Shap_1.

For stand 1111 (highlighted), the spatial join has identified three adjacent hardwood patches (`Count_ = 3`) and then appended a summary of their numeric attributes—*Sum_cover_HWD*, *Sum_Shape_Length*, and so forth. Most importantly, the area of the three patches is recorded as 4.2 ha (*Sum_Shape_Area*). You can verify this amount by identifying each of the three adjacent patches and manually adding their *Shape_Area* values.

You can also see that stand 1111 is not particularly vulnerable. Its spruce-fir content is negligible (`SPBF_Rate = 0`), and it has no mature fir content (`MatureBF_Rate = <null>`). Its *Age* of *2* tells you it's a recent cutover.

So, for each stand in the Woodlot, you now have the area of adjacent hardwood patches. Using this information, you can calculate isolation-rating values of *1.00*, *1.10*, or *1.20*, depending on patch size. Here's how.

3 Add a float field in *cover_HWD_Patches* named *Isolation_Rate.*

Now you want to calculate *Isolation_Rate* values, depending on the size of adjacent hardwood patches.

Adjacent hardwood patch size (ha)	**Vulnerability rating**
<10	1.00
=10	1.10
>10	1.20

Table 5. A method for calculating isolation ratings

This looks like a query/calculator problem.

First, you'd select nonhardwood stands in *cover_HWD_Patches*. From that set, you'd select those with adjacent patches totaling less than 10 (`Sum_Shape_Area / 10000`). Then you'd assign those stands an *Isolation_Rate* value of 1.10. Next, you'd repeat the whole process for patch areas equal to 10 ha, and then again for those greater than 10 ha.

While the query/calculator approach would work fine, there is a more efficient way if you know a little VB.

Here, you'll enter several lines of VB code that will essentially automate the query/calculate process described above.

4 Using *VBScript* and *Show Codeblock* options in *Field Calculator*, enter the following VB code and then calculate `Isolation_Rate = Rate`.

Don't forget to clear the currently selected feature (stand 1111); otherwise, *Field Calculator* will see only that feature.

```
DIM Rate
' First, if it's a hardwood, or not a stand, set Rate = 0.
IF [HWD] = 1 OR [AGE] = -99 THEN
   Rate = 0
' If it's a stand, then if patch areas total 10 ha set Rate = 1.10
ELSEIF [Sum_Shape_Area] / 10000 = 10 THEN
   Rate = 1.10
' Failing that, then if patch areas total more than 10 ha, set Rate = 1.20
ELSEIF [Sum_Shape_Area] / 10000 > 10 THEN
   Rate = 1.20
' Last, if none of the above, i.e. patch areas total less than 10 ha, set Rate =
1.00
ELSEIF [Sum_Shape_Area] / 10000 < 10 THEN
   Rate = 1.00
END IF
```

Copying and pasting the code into *Field Calculator* won't work unless you build the code in Notepad.

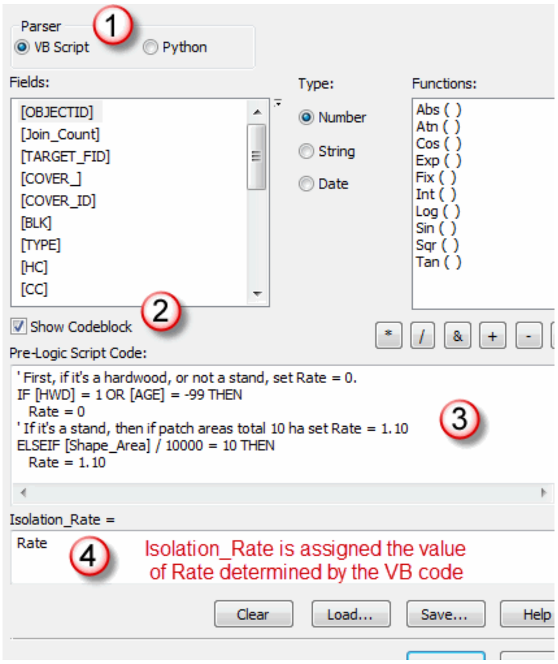


Figure 8. Use VB code to calculate isolation ratings.

Very quickly, *Field Calculator* compiles *Isolation_Rate* values. Now you have everything you need to calculate a budworm vulnerability index for each Woodlot stand.

CALCULATE VULNERABILITY INDEX AND DEFOLIATION CLASSES

Calculating a vulnerability index for Woodlot stands is simple at this point. It's calculated simply as the product of *SpBF_Rate* (spruce-fir content) * *MatureBF_Rate* (mature balsam fir content) * *Isolation_Rate* (isolation adjustment) for each stand.

However, to make assessing values at risk in the Woodlot easier, it's best to derive defoliation classes—Low, Moderate, High, and Extreme—from index values. The following table provides one possibility:

Budworm vulnerability index	Defoliation class
0	NIL
>0–7	LOW
>7–15	MODERATE
>15–24	HIGH
>24–28	EXTREME
>28	DEAD

Table 6. A method of assigning defoliation classes

RELATED CONCEPT: RECLASSIFY USING THEMATIC ATTRIBUTES TO RANK

1 Add a float field named *Vul_Index* to *cover_HWD_Patches.*

2 Calculate *Vul_Index* values as the product of `SpBF_Rate * MatureBF_Rate * Isolation_Rate`.

This calculates a *Vul_Index* value for each feature in *cover_HWD_Patches*.

Values will range from 0 for nonstand and nonsusceptible stands up to larger values for stands that have high spruce-balsam fir content, have significant mature balsam fir content, and are adjacent to large areas of hardwood.

The higher the index value, of course, the greater the amount of expected defoliation and therefore tree mortality and timber losses.

Now you can reclassify stands by their defoliation risk, using the ordinal ranking scheme—DEAD, EXTREME, HIGH, MODERATE, LOW, and NIL.

3 Add a new text field of length 8 named *Def_Class*.

Unfortunately, a Python shortcut formula won't work for computing your defoliation classes since the class interval is not constant. But you can adapt the VB script you used earlier for calculating *Isolation_Rate* values. Try that, or use the tried-and-true query/calculator approach.

4 Using the following VB code as a guide, label stands by defoliation class in *Def_Class*:

```
DIM Def
If [Vul_Index] = 0 Then
  Def= "NIL"
ElseIf [Vul_Index] > 0 AND [Vul_Index] <= 7 Then
  Def = "LOW"
ElseIf [Vul_Index] > 7 AND [Vul_Index] <= 15 Then
  Def = "MODERATE"
ElseIf [Vul_Index] > 15 AND [Vul_Index] <= 24 Then
  Def = "HIGH"
ElseIf [Vul_Index] > 24 AND [Vul_Index] <= 28 Then
  Def =" EXTREME"
ElseIf [Vul_Index] > 28
  Def = "DEAD"
Else
  Def = Null
End If
```

In *Field Calculator*, or in VB code, text strings are always entered with double quotation marks.

How much area is represented in each defoliation class, and how much timber value is at risk? That's next.

SUMMARIZE DEFOLIATION CLASSES

If there are significant amounts of Woodlot stands in the high and extreme defoliation classes, there is significant risk, and large timber losses are possible during an outbreak. Is there a problem in the Woodlot?

As you probably guessed, that's easily determined by summarizing the *Def_Class* field.

RELATED CONCEPT: CHARACTERIZE USING A NUMERIC DISTRIBUTION

1 Summarize the *Def_Class* field by both *Shape_Area* sum and *TV* (total volume) sum.

2 Name the result table *Sum_Defoliation* in your geodatabase.

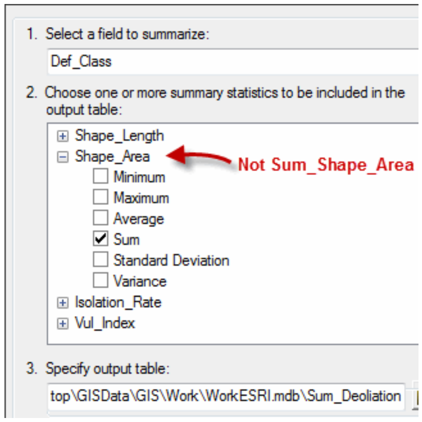


Figure 9. Summarizing defoliation classes (Def_Class) by area and volume (TV) totals.

The summary table tells the story.

OBJECTID *	Def_Class	FREQUENCY	SUM_Shape_Area	SUM_TV
1	<Null>	419	10261004.219511	35300.9
2	HIGH	5	153677.014929	5651.5
3	LOW	32	1052076.830297	12274.7
4	MODERATE	27	1220729.942653	17724.3
5	NIL	86	1711985.104638	20321.9

Figure 10. Summary table of defoliation classes by area (m^2) and volume totals (m^3).

You can also present these tabular results in a chart for clarity. Do so if you wish.

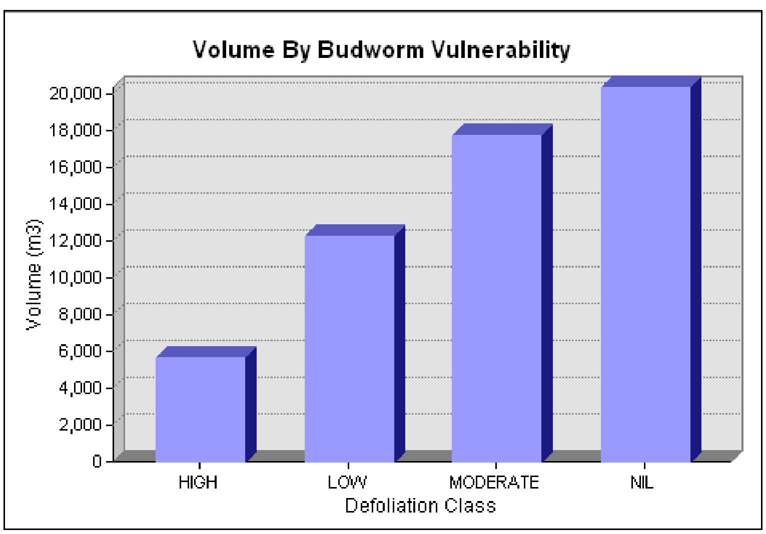


Figure 11. Histogram of timber volume amounts by defoliation classes in the Woodlot.

But where are the most vulnerable stands located? That's next.

Map defoliation classes

Mapping defoliation classes in the *Def_Class* field— is simple with the use of straightforward ArcMap™ mapping techniques.

Related Concept: Characterize using a map

1 Map the *Def_Class* field using shades of red, ranging from light for NIL to bright for HIGH.

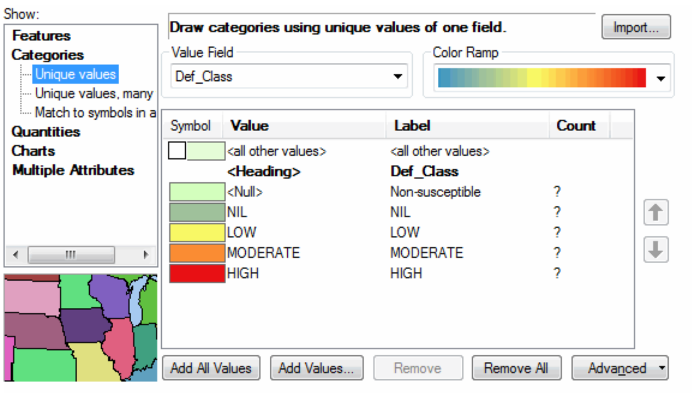


Figure 12. Map the *Def_Class* field using a graduated color ramp.

The map tells you exactly where stands of high and moderate defoliation risk are located. It would prove useful in planning protection activities should a budworm outbreak occur.

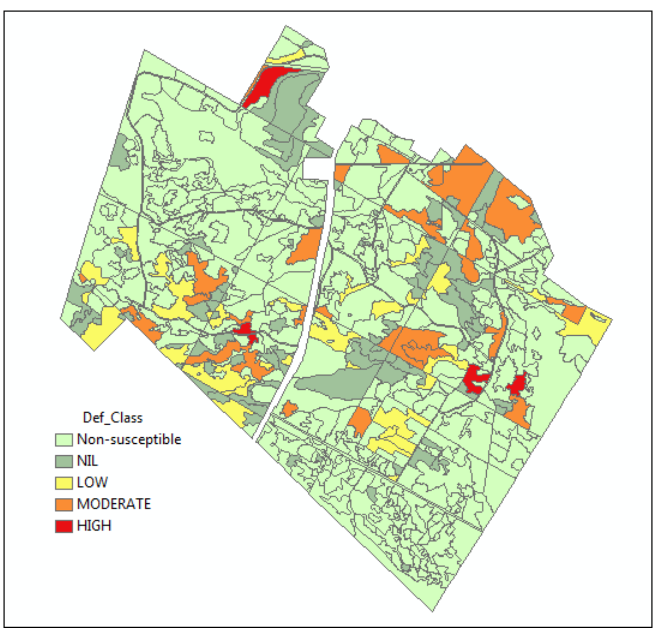


Figure 13. Woodlot map of budworm defoliation classes.

Conclusion

It would appear that the Woodlot has a budworm vulnerability issue. While the five stands at high defoliation risk represent a relatively small area of 15 ha, their timber volume totals more than 5,600 m^3. Add to that the 27 stands at moderate risk, covering 122 ha with a volume of almost 18,000 m^3, and you might conclude that these areas warrant protection in the event of a budworm outbreak.

You might want to explore changing some rating parameters—spruce-balsam fir content or mature balsam fir criteria, for example. Do these have a large influence on the result?

Submit your work

- A summary table, chart, and map of budworm vulnerability in the Woodlot
- A summary of the exercise, indicating where and how related reclassifying and characterizing concepts, as well as analysis techniques, are used (Your summary could take the form of a table that checks off each of these elements.)
- The lab procedure, or something similar, implemented for another insect or other forest disturbance
- Answers to the questions posed in the exercise:
  1. What would happen if you didn't divide by 20.0 but rather by 20?
  2. When forming forest patches, like the hardwood patches in this exercise, why is it critical to disable multipart features in the *Dissolve* tool?
- Explanation of the difference between *susceptible* and *vulnerable* when discussing forest insect problems

Credits

Sources of supplied data

Course Data

Data\cover, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\highway, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\newprop, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\tin, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management
Data\Woodlot.mdb, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Codes\Woodlot_Codes.xls, courtesy of University of New Brunswick UNB Faculty of Forestry and Environmental Management

Data\Coordinate Systems\ATS 1977 New Brunswick Stereographic.prj, courtesy of ESRI
Data\Coordinate Systems\NAD 1983 CSRS New Brunswick Stereographic.prj, courtesy of ESRI

Data\GPS\Knowledge.shp, courtesy of University of New Brunswick
Data\GPS\towers.xls, courtesy of University of New Brunswick Faculty of Forestry and Environmental Management

Data\Layer Files\Age Classes.lyr, courtesy of Glen Jordan
Data\Layer Files\Air Photo Centre Points.lyr, courtesy of Glen Jordan
Data\Layer Files\Main Roads.lyr, courtesy of Glen Jordan
Data\Layer Files\Mgt Compartments.lyr, courtesy of Glen Jordan
Data\Layer Files\Non-forested.lyr, courtesy of Glen Jordan
Data\Layer Files\Secondary Roads.lyr, courtesy of Glen Jordan
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Data\Mass Points\DTM.txt, courtesy of Service New Brunswick

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Data\Models\Forest Values.tbx, courtesy of Glen Jordan

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Lesson 2: Analysis data

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Data\Budworm\DiagStep2a.gif, courtesy of Glen Jordan
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Data\Budworm\DiagStep4b.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep6a.gif, courtesy of Glen Jordan
Data\Budworm\DiagStep7a.gif, courtesy of Glen Jordan
Data\Budworm\ResStep3a.gif, courtesy of Glen Jordan
Data\Budworm\ResStep6a.gif, courtesy of Glen Jordan
Data\Budworm\ResStep6b.gif, courtesy of Glen Jordan
Data\Budworm\ResStep7a.gif, courtesy of Glen Jordan

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