

Calculating Forest Values

Assessing forest recreation value

—by Glen Jordan

Introduction

Problem

How much recreation potential exists in a forest? Unlike timber valuation, it's virtually impossible to compute a dollar value for forest recreation. How, then, do you go about calculating recreation value in a forest?

Hunting, fishing, bird-watching, hiking, mountain biking, cross-country skiing, and snowmobiling are just a few examples of forest recreation activities. It becomes a question of determining what forest conditions best serve particular recreation activities, just as, from a timber assessment perspective, you might ascertain what conditions best serve harvest of a variety of timber products.

Large metropolitan areas often abut or even surround forested areas. Typically, though, forest owners make no attempt to promote or develop recreation potential. As metropolitan populations increase, and recreational demands increase, forest owners may want to take a more active role in developing and managing for recreation value.

Location

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

Time to complete the lab

Three hours

Keywords: social forest value; recreation value; characterizing with a single number; numerical distribution and a map; selecting features by thematic attribute; computing a slope raster; calculating neighborhood (focal) statistics; creating a raster using a feature class attribute field; reclassifying a raster; calculating continuous distance; calculating multiple raster statistics (local)

Prerequisites

A basic working knowledge of geographic information system (GIS) data, including use of a geodatabase, and ArcGIS® software in particular (Some experience with rasters and the Spatial Analyst extension is also beneficial. Familiarity with basic forest analysis techniques is important, while familiarity with forest inventory data and terminology is also helpful but not essential.)

Data used in this lab

- Feature classes and rasters for a forest 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

The Woodlot is surrounded by 300,000-plus residents. Pressure on the Woodlot for commercial development—that is, residential construction and big-box stores—is significant. Is the Woodlot worth saving, however, as a recreational property?

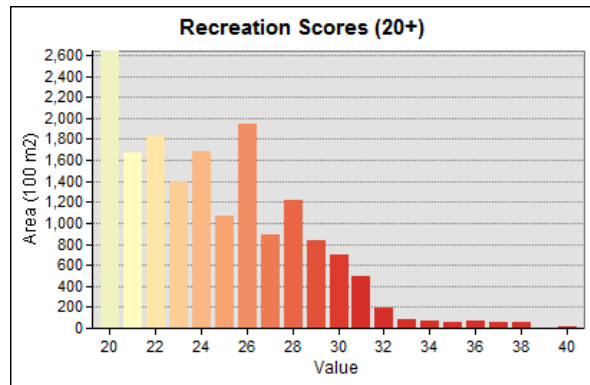
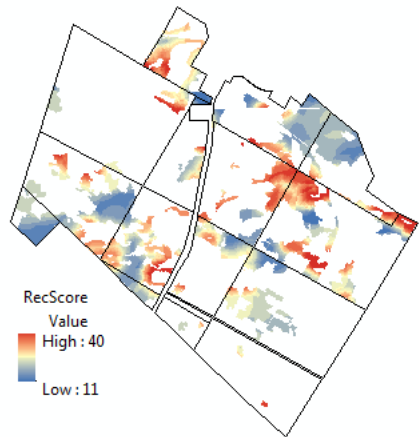
In this exercise, you'll assess the Woodlot for general recreation value, without zeroing in on a specific recreation activity. Generally, most forest recreation activities are best served where a variety of terrain conditions exist; where old-growth conditions occur; where streams, bogs, and wetlands are close by; and where easy access is available.

Building a suitability (or value) raster is one way of including all these factors in a recreation assessment. The suitability raster assigns each Woodlot area a score based on the forest conditions present, giving a high score where all the desirable conditions are present in abundance and a lower score otherwise.

You'll proceed by first computing a score raster for each factor: terrain diversity, stand age, and streams and wetlands proximity. You'll use a scoring scheme of 1 (worst) through 10 (best) in each case. Then, you'll combine these four into one final raster of recreation value. A final overlay of the Woodlot's road network will tell you if there are accessibility issues.

Results expected

A recreation score raster and a summary and chart of amounts



Data available

- Cover types feature class: *cover*
- Secondary roads feature class: *roads*
- Permanent streams feature class: *streams*
- Digital elevation model (DEM) raster: *DEM_Woodlot*
- Main road centerline feature class: *clines*
- Management compartment feature class: *compart*

Solution steps

1. Score terrain diversity.
2. Score stand age.
3. Score water proximity.
4. Compute recreation value.

SCORE TERRAIN DIVERSITY

Is the Woodlot characterized by rugged terrain—that is, significant variation in elevation and thus slope—or some other pattern? Regardless, how do you relate terrain diversity (slope) to recreation value?

Increasing slope diversity likely equates with increasing recreation value. But is the relationship strictly linear? Probably not. It's more likely similar to the graph in the figure.

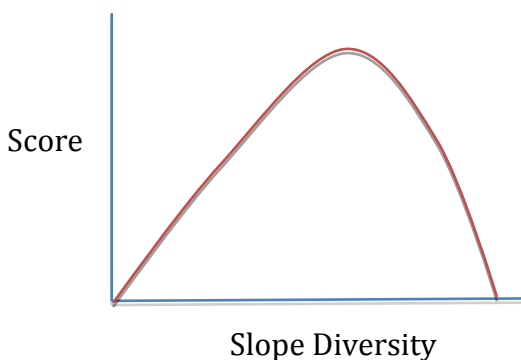


Figure 1. Recreation value (*Score*) as a function of slope diversity.

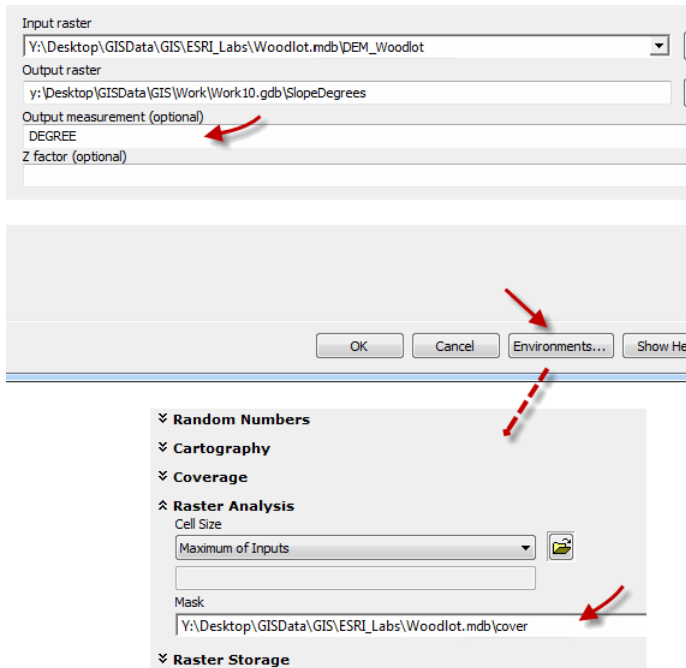
The graph indicates that the recreation value increases linearly until higher diversity values occur, at which point there is a sharp drop-off in recreation value. In other words, rugged terrain is desirable, but only to a point.

You can use that relationship as a basis for scoring terrain diversity in the Woodlot.

RELATED CONCEPT: RECLASSIFY USING LOCATIONAL ATTRIBUTES TO QUANTIFY

Obviously, you'll first need to calculate slope values across the Woodlot before you can score its terrain diversity. Slope values are easily derived from a DEM.

- 1 Start ArcMap™ and, if you haven't already done so, use *Environment Settings* to establish your Woodlot geodatabase as both your *Current Workspace* and *Scratch Workspace*.
- 2 Use the *Slope* tool (*Spatial Analyst Tools* » *Surface*) and the *DEM_Woodlot* raster as input to calculate slope values in degrees. Confine the output to the boundaries of the Woodlot using the *cover* feature class as an environment *mask*. Name the output raster *SlopeDegrees*.



The cover mask ensures that the output slope raster is limited by Woodlot property boundaries, including those that define the highway right-of-way that cuts through the Woodlot.

Figure 2. Calculating a slope raster for the Woodlot property.

If you zoom in, you can see that the Woodlot occupies fairly flat terrain, with steeper slopes mostly concentrated in the eastern corner. There is, however, some diversity of slope values across the Woodlot.

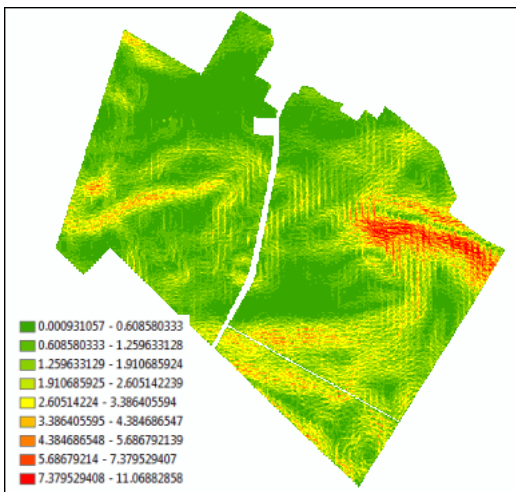


Figure 3. Slope (degrees) raster for the Woodlot.

How can you quantify the diversity of slope values you can see?

You can use a neighborhood analysis technique available in the Spatial Analyst extension whereby slope values are characterized within a search area of specified size at each location across the Woodlot.

- 3 Enable the Spatial Analyst extension (*Customize » Extensions*) if it isn't already.

- Use the *Focal Statistics* tool (*Spatial Analyst Tools » Neighborhood*) to compute the range of slope values that occur within a 200-meter (m) radius at each cell location across the *SlopeDegrees* raster. Name the output *SlopeDiversity*.

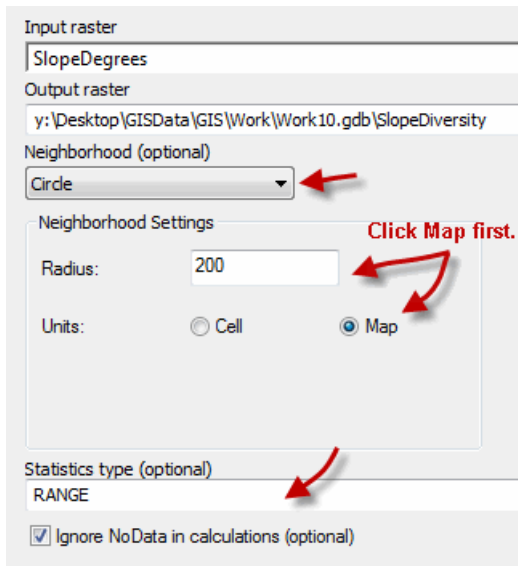


Figure 4. Calculating slope diversity (range) using a 200 m circular search neighborhood.

In the result, you can see the nature of slope diversity across the Woodlot—white (highest range) to black (lowest range). Not surprisingly, the most diversity occurs in the eastern corner.

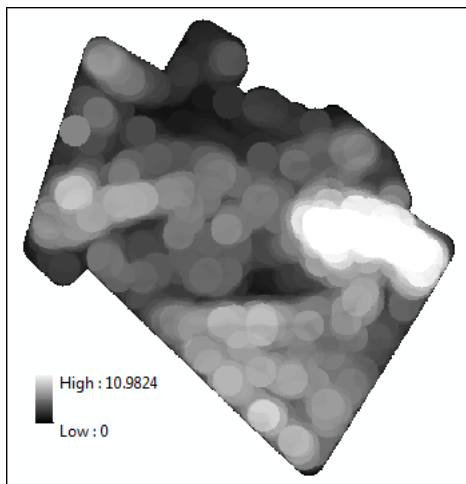


Figure 5. Slope diversity (low range, black; high range, white) across the Woodlot.

Recall the graph that illustrated recreation value as a function of slope diversity. You can use it to assign specific recreation scores to the slope diversity values. Here’s how.

- Use the following graph-derived table as a guide and the *Reclassify* tool (*Spatial Analyst Tools » Reclass*) to classify *SlopeDiversity* values into classes of width 1 and assign scores (new values) accordingly. Name the output raster *SlopeScore*.

Slope Diversity	Score
0-1	1
1-2	2
2-3	4
3-4	6
4-5	8
5-6	10
6-7	9
7-8	8
8-9	6
9-10	4
10-11	1

Table 1. Scoring recreation value 1-10 (from worst to best) as a function of slope diversity

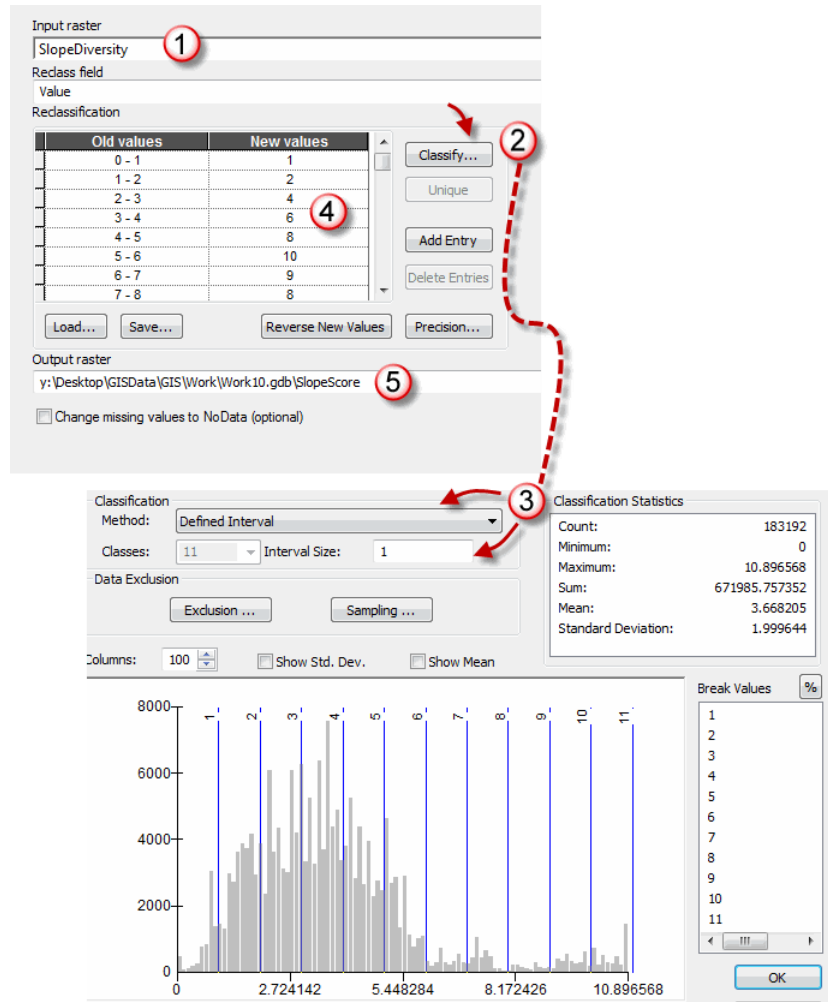


Figure 6. Assigning scores (1-10) to 1-degree slope diversity classes.

The result indicates that there is plenty of rugged terrain in the Woodlot, at least according to the scoring scheme used. The northeast and southeast corners stand out in that regard, while the northwest doesn't show much promise for recreation.

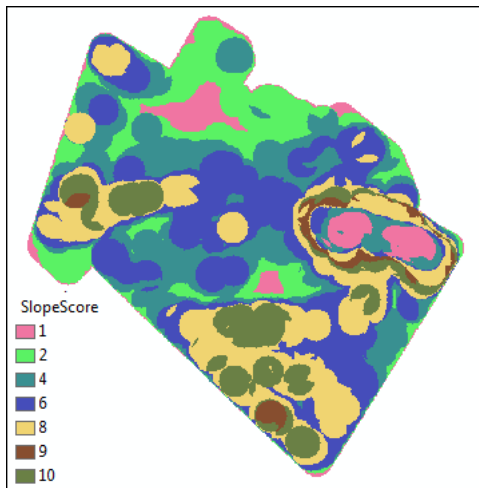


Figure 7. Slope diversity scores 1–10 (from worst to best) across the Woodlot.

Next, you can tackle the stand age factor. How will the Woodlot score for recreation on that count? You should be able to use a procedure similar to that just used for assessing terrain diversity.

SCORE STAND AGE

The relationship between stand age and recreation value is quite different from that of terrain diversity and recreation value.

Generally, forest recreation activities occur in mature, older stands, as opposed to recent cutovers or regenerating or immature stands. Yet very old or diseased and dying stands would not be desirable. This definition tells you that there is a relatively narrow range of ages where stands have recreation value. The following graph captures that relationship:

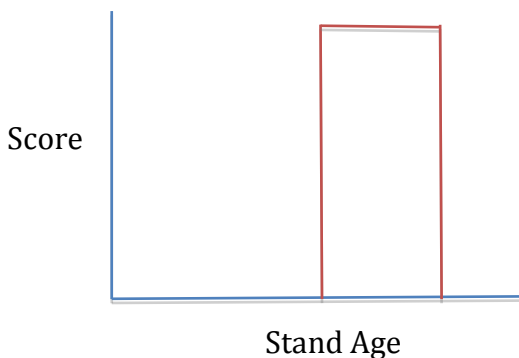


Figure 8. Recreation value (Score) as a function of stand maturity.

Given the lifespan of tree species that occur in the Woodlot, you might define this stand age window for recreation as age 60 to 100. Using your 1–10 scoring scheme, it means simply assigning all stands ages 60–100 a score of 10 and all others a no-score.

RELATED CONCEPT: RECLASSIFY USING THEMATIC ATTRIBUTES TO QUANTIFY

- 1 Add the cover types feature class (*cover*), and then use *Definition Query* (right-click *Cover Types* » *Layer Properties* » *Definition Query*) to limit its features to just stands from age 60 to 100, but excluding treed bogs, using the expression:

```
[TYPE] <> 'BG' AND [AGE] >=60 AND [AGE] <=100
```

If you turn off the slope layers, you can see that there is a good distribution of older, high-value recreation stands scattered across the Woodlot.



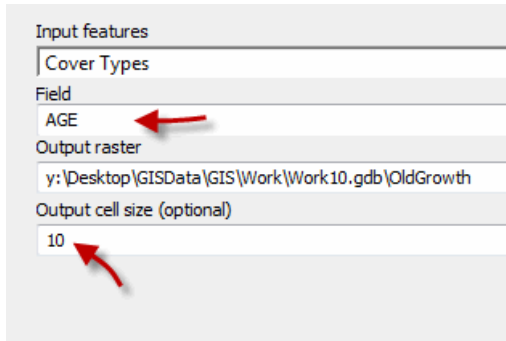
Figure 9. Mature and older stands (age 60–100) in the Woodlot.

These 133 stands, however, confine further recreation assessment to the areas they encompass. Areas outside are of little or no recreation value. Unfortunately, this excludes much of the rugged terrain in the southeast corner of the Woodlot.

This constraining effect happens when goodness is measured in a discrete, yes-no fashion, rather than using a continuous scale as you did in scoring terrain diversity. You'd want to be comfortable with the stand age window you're using and agree that stand age is an important contributor to recreation value.

To proceed with scoring stand age as you did with slope diversity, you'll first have to create a stand age raster. That's simple.

- 2 Use the *Feature to Raster* tool (*Conversion Tools* » *To Raster*) to create a raster of the 133 selected stands in the *Cover Types* layer using its *Age* field. Name the output *OldGrowth*.



Question 1: Why is a cell size of 10 used for the Stand Age raster?

Figure 10. Creating a stand age raster.

Turn off *Cover Types*. You’ve created a raster with specific stand age values assigned to each cell.

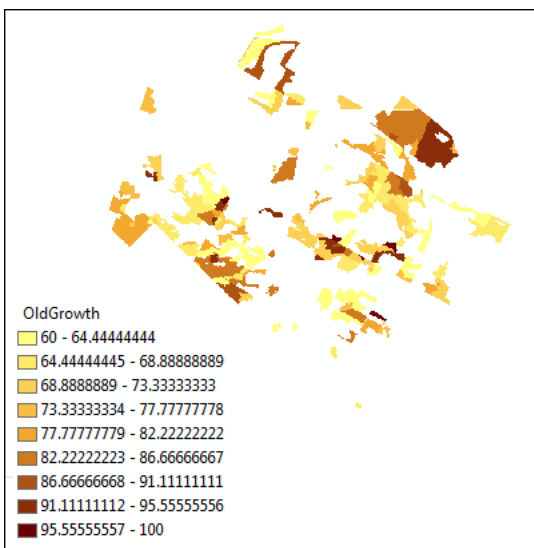


Figure 11. The *OldGrowth* raster maps the distribution of ages (60–100) in the recreation window.

Now, as you did for *SlopeDiversity*, you can reclassify the *OldGrowth* raster to create a raster that scores recreation value.

- 3 Use the *Reclassify* tool again to assign all *OldGrowth* areas a value of 10. Name the output *AgeScore*.

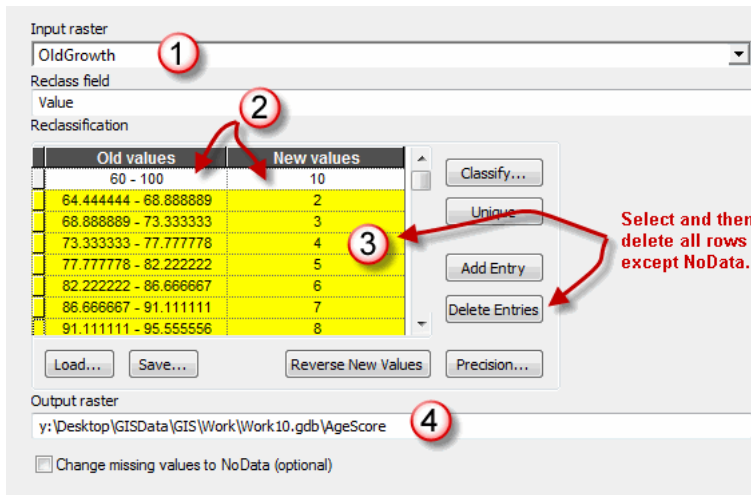


Figure 12. Assigning stand cells with age 60–100 a score of 10.



Figure 13. Areas scoring recreation values of 10 based on maturity (age 60–100).

Now you have recreation score rasters for terrain diversity and stand age. What about the third and last factor—proximity to streams and other water bodies? Dealing with that is next.

SCORE WATER PROXIMITY

Many forest recreation activities depend on the presence of, or at least close proximity to, water features. The Woodlot has many such features in the form of streams, ponds, marshes, and bogs. How might you score this water factor?

Again, as with terrain and stand age, it’s a matter of establishing a relationship between water and recreation value. The following graph is a possibility:

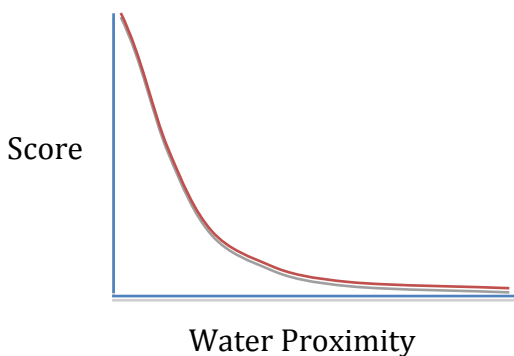


Figure 14. Recreation value (*Score*) as a function of water proximity.

The graph tells you that the presence of water of any type, or its immediate proximity, scores a high recreation value. Value declines very rapidly, however, with increasing distance.

Developing a water proximity score raster should be straightforward: identify all the Woodlot's water features; incrementally measure distances around them up to some maximum, say 200 m; and then use the graph as a guide to develop a score raster.

RELATED CONCEPT: RECLASSIFY USING LOCATIONAL AND THEMATIC ATTRIBUTES TO QUANTIFY

- 1 Turn *Cover Types* back on, and then use *Definition Query* to isolate wetlands—ponds, marshes, and bogs—with the expression `[TYPE] = 'BG' OR [TYPE] = 'DU' OR [TYPE] = 'PD'`. Rename the layer *Wetlands*.

You should be able to see wetlands features superimposed on your *AgeScore* raster.

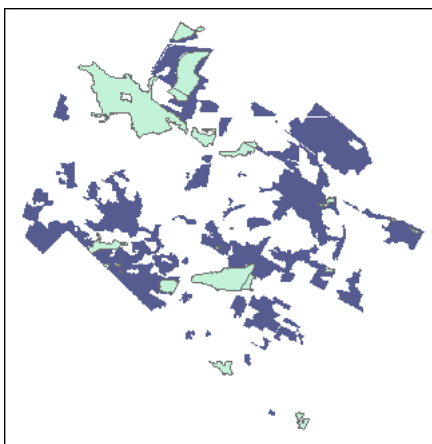


Figure 15. Wetlands features (green) over areas scoring recreation values of 10.

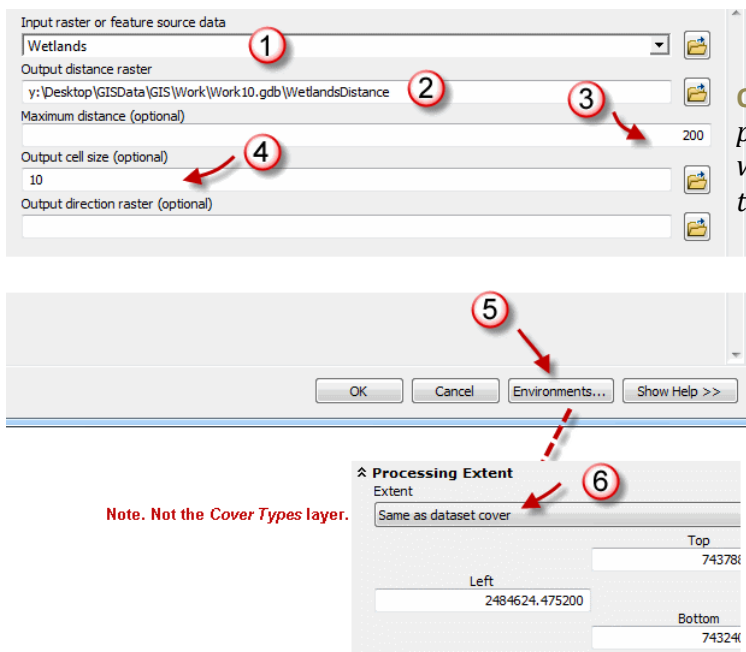
That's a rather small amount of wetlands, it seems, but don't forget about the Woodlot's extensive stream network stored in the *streams* feature class. How do you include that?

It becomes a bit more complicated than you might think. While intuition says you would simply merge the wetlands with streams, it's not possible. You can't easily combine linear features with polygon features using ArcGIS.

Given that, scoring streams and wetlands separately is your best plan. That approach also opens the opportunity to score the two differently, if you felt that their proximity does not contribute equally to recreation value. In this exercise, you'll treat them as contributing equally.

Continue by scoring wetlands proximity. After that, you can return to streams.

- 2 Use the *Euclidean Distance* tool (*Spatial Analyst Tools » Distance*) to compute distances around wetlands features to a maximum distance of 200 m. Set the processing extent to include the entire Woodlot using the *cover* feature class. Name the output *WetlandsDistance*.



Question 2: What would happen if a processing extent were not specified when using the Euclidean Distance tool?

Figure 16. Measuring 200 m around wetland features.

You might wonder why the *Buffer* tool wasn't used here. *Buffer* measures distance around features to a specified amount, such as 50 m. *Euclidian Distance*, on the other hand, measures distance amounts continuously away from features up to some maximum.

The result, displayed with default mapping symbolism, gives the appearance of distance contours placed around wetland features.

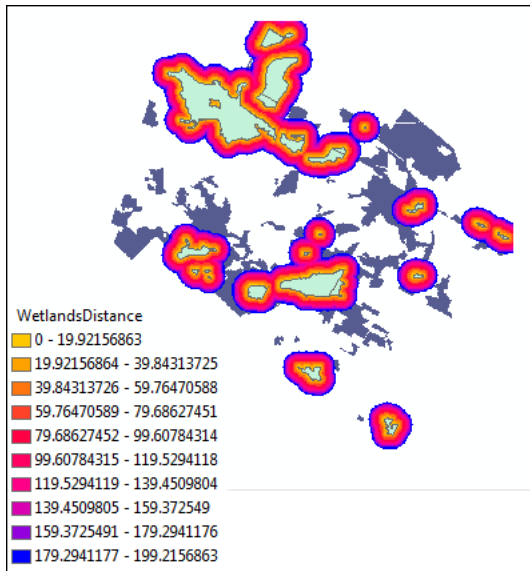


Figure 17. Incremental distance measurement up to 200 m around wetland features.

Now it should be a simple matter of reclassifying the distances using the relationship graph and its associated table.

- 3 Use the following graph-derived table as a guide and the *Reclassify* tool to classify *WetlandsDistance* values into classes 20 m wide and assign scores (new values) accordingly. Name the output raster *WetlandsScore*.

Water Proximity	Score
0–20	10
20–40	10
40–60	9
60–80	8
80–100	7
100–120	6
120–140	4
140–160	3
160–180	2
180–200	1
(NoData)	0

Table 2. Scoring recreation value 1–10 (from worst to best) as a function of water proximity

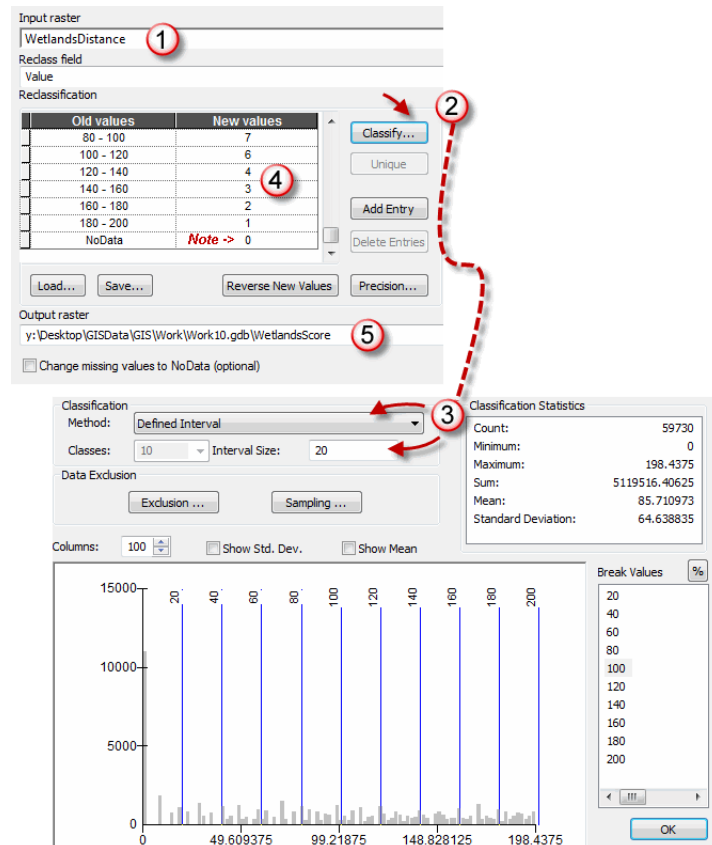


Figure 18. Assigning scores (1–10) to 20 m wetland distance classes.

By reassigning 0 to NoData values, you ensure that areas beyond 200 m will not be excluded from your final recreation analysis, unlike the AgeScore raster.

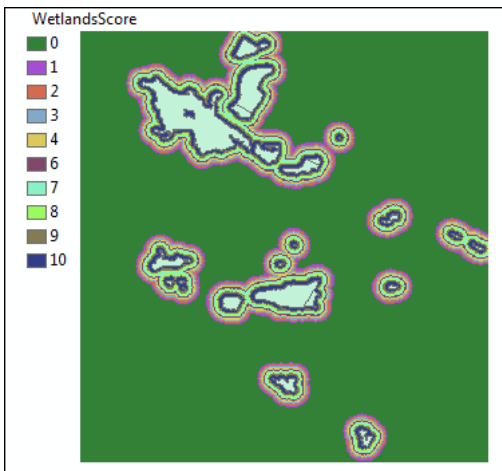


Figure 19. Recreation scores (0–10) based on wetlands proximity.

Now you need to execute a similar procedure for streams.

- 4 Use the *Euclidean Distance* tool to compute distances around stream features (*streams*) to a maximum distance of 200 m. Again, set the processing extent to include the entire Woodlot using the *cover* feature class. Name the output *StreamsDistance*.

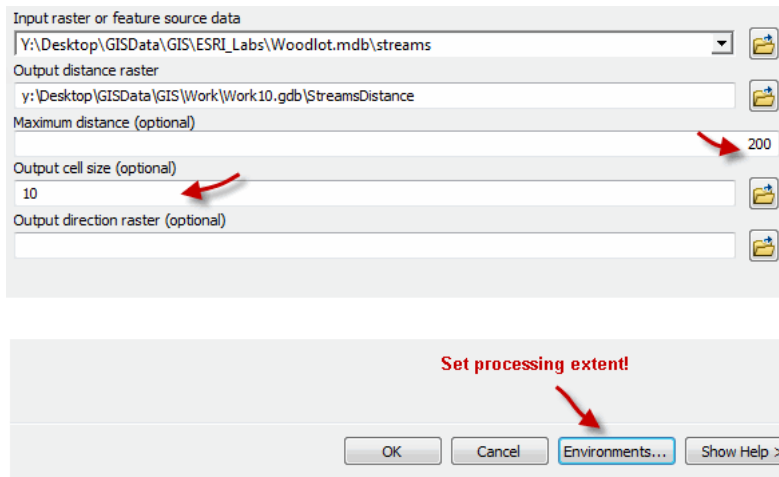


Figure 20. Measure distance up to 200 m around stream features.

If you turn all layers off but *StreamsDistance*, you'll see a raster of continuous distance values of up to 200 m around stream features.

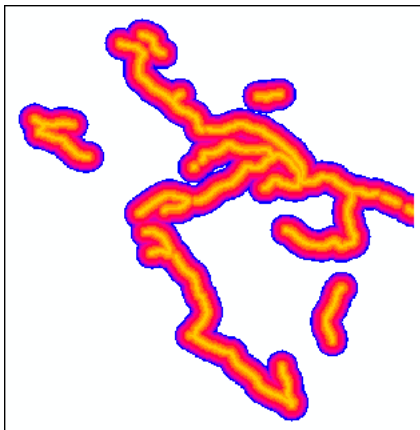


Figure 21. Incremental distance measurement up to 200 m around stream features.

- 5 Now, with the same scoring scheme you used in creating *WetlandsScore*, use the *Reclassify* tool to score *StreamsDistance*. Name the output *StreamsScore*.

Old values	New values
80 - 100	7
100 - 120	6
120 - 140	4
140 - 160	3
160 - 180	2
180 - 200	1
NoData	<i>Note -></i> 0

Figure 22. Assigning scores (0–10) to 20 m stream distance classes.

That provides the final piece of information you'll need to arrive at an assessment of recreation value in the Woodlot.

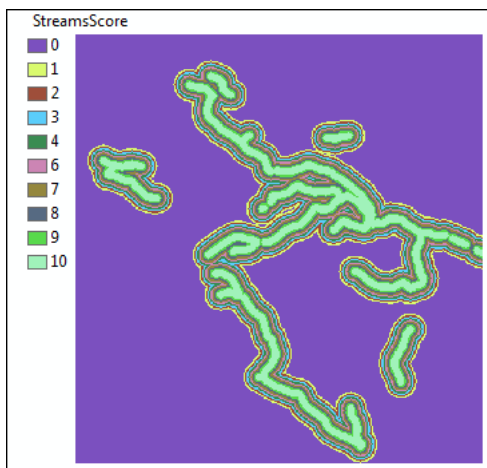


Figure 23. Recreation scores (0–10) based on stream proximity.

How will you combine your score rasters, *SlopeScore*, *AgeScore*, *WetlandsScore*, and *StreamsScore*, into one composite that will allow some overall assessment of recreation value in the Woodlot?

That's next.

COMPUTE RECREATION VALUE

There are a number of ways you could compute recreation value. You could simply sum the rasters, cell by cell, to compute a total score raster. In that case, of course, areas with a high score would indicate favorable recreational conditions on all counts, while low scores, such as less than 20, would indicate otherwise.

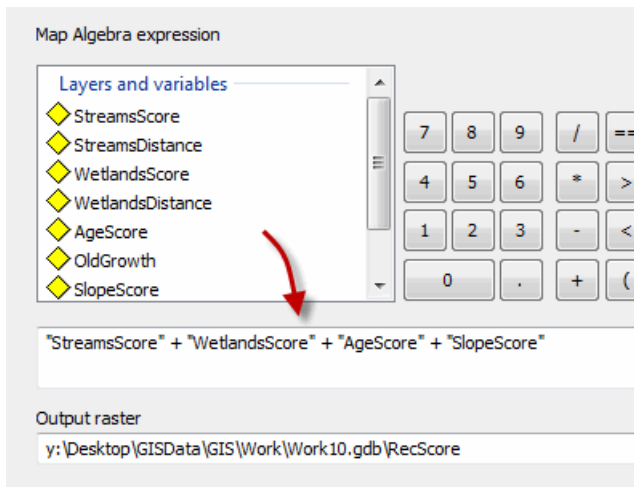
There is an array of other cell-by-cell statistics that you could use—minimum, maximum, majority (most frequently occurring), minority (least frequently occurring), mean, and range. For example, if you minimized the four rasters, the result would contain the lowest score in each area, and as a result, highlight high-value recreation areas. So, if you were to get lots of 8s, 9s, and 10s in an area, you'd know you had a high-value recreation location.

For this exercise, try summing the four rasters.

The resultant raster will show you how high- through low-scoring areas are distributed across the Woodlot and allow you to compute summary amounts by score.

RELATED CONCEPT: CHARACTERIZE USING NUMERICAL AND GEOGRAPHICAL DISTRIBUTIONS

- 1 Use the *Raster Calculator* tool (*Spatial Analyst Tools » Map Algebra*) to add your four score rasters—*SlopeScore*, *AgeScore*, *WetlandsScore*, and *StreamsScore*. Name the result *RecScore*.



You could also use the Cell Statistics tool here.

Figure 24. Adding the four recreation score rasters using *Raster Calculator*.

If you turn off all layers except *RecScore* and add the management compartments feature class (*compart*) with a hollow fill for spatial reference, you'll see high-value recreation areas in a light shade, progressing to dark for low value.

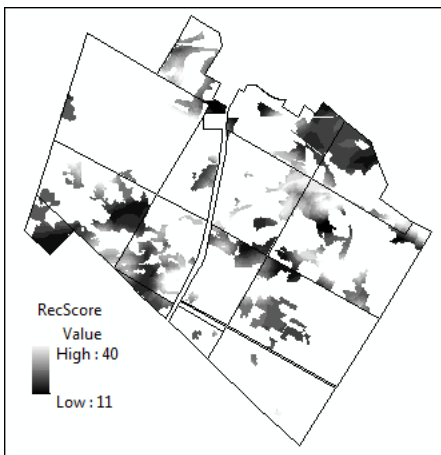


Figure 25. Raster of recreation scores (low value, dark; high value; light).

Unfortunately, the gray scale doesn't highlight results as well as a color scheme would. There's an easy fix for that.

- Adjust *RecScore* layer symbology using color ramp symbolism—blue to red.

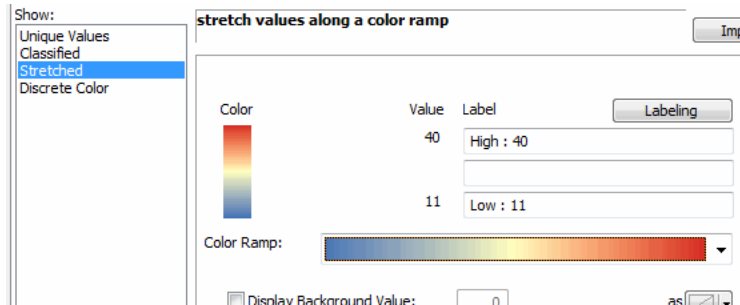


Figure 26. Assigning the *RecScore* raster a blue to red color ramp.

That's much better.

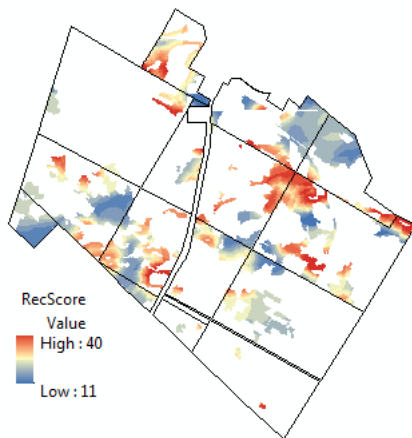


Figure 27. Raster of recreation scores (low value, blue; high value, red).

It's pretty obvious that there are some high-value recreation areas (yellow to red) in the Woodlot.

Where exactly, though, are the areas with scores of 20 or higher? How much area do they occupy? Are they easily accessible by road?

- Open the *RecScore* table and select records with *Value* amounts of 20–40.

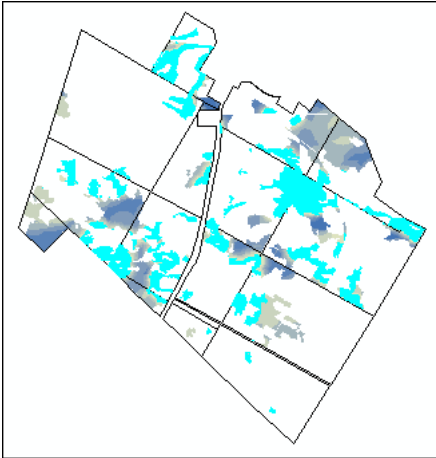


Figure 28. High-scoring (20–40) recreation areas selected.

It looks like high-scoring areas are well distributed across the Woodlot. How much area in total do they represent?

- 4 With the records still selected in *RecScore*, compute statistics (right-click) for the *Count* field.

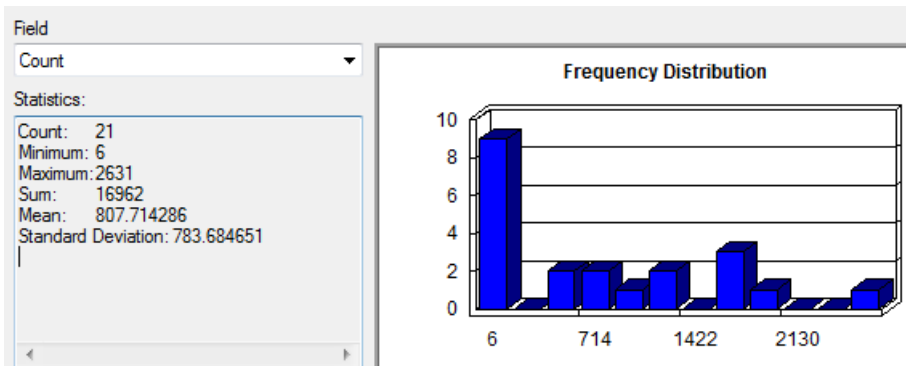


Figure 29. Statistics and frequency distribution for recreation amounts.

Recall that raster cells in this case are 10 by 10 m. That means each cell is 100 m², or 1/100th of a hectare.

So, the Woodlot has close to 170 ha of valuable recreation areas. How, though, is the total distributed across the range of scores 20 to 40?

- 5 Use the *Create Graph Wizard (Table Options » Create Graph)* to build a vertical bar chart of *Count* amounts by *Value* scores in *RecScore*.

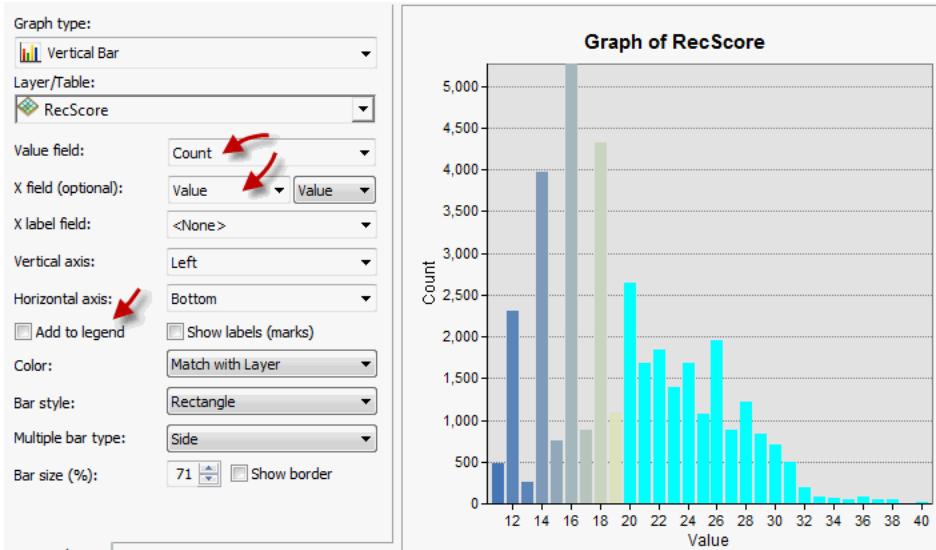


Figure 30. Tallying up amounts by recreation score.

It's apparent that the bulk of the Woodlot is in the lower half of the 20–40 recreation score range. Nonetheless, how accessible are these higher-valued areas?

- 6 Add the main road centerline (*clines*) and secondary roads (*roads*) feature classes as ArcMap layers.

If you clear selected records in *RecScore* and zoom in on one or more of the highly valued areas, you'll see that accessibility is not a problem.

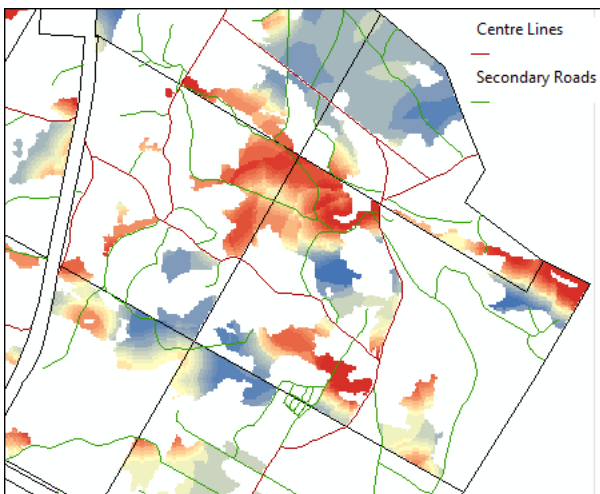


Figure 31. Zoomed in on a high-value recreation area with main and secondary roads added.

Conclusion

You've created a summary, chart, and map of recreation value in the Woodlot using various ArcGIS tools.

Based on your analysis results, what's your assessment of the recreation value of the Woodlot? Is it a significant social asset for the surrounding community, or would it be best to develop it commercially? Is there an opportunity for economic recreation development?

Submit your work

- A recreation score raster and tally and chart of recreation amounts by score
- Based on lab results, a paragraph detailing an assessment of value in the Woodlot, from an economic perspective (Is it good news or bad?)
- Answers to the questions posed in the exercise:
 1. Why was a cell size of 10 used for the Stand Age raster?
 2. What would happen if a processing extent were not specified when using the *Euclidean Distance* tool?
- A summary of the exercise, indicating where and how related reclassify and characterize concepts and analysis techniques are used (Your summary could take the form of a table that checks off each of these elements.)
- Calculation of recreation value in another forest property using techniques similar to those used in this exercise

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

Data\Layer Files\Streams.lyr, courtesy of Glen Jordan

Data\Mass Points\DTM.txt, courtesy of Service New Brunswick

Data\Models\Clearcutting.tbx, courtesy of Glen Jordan

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

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

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