Chapter 14

Forest Fragmentation In The Rocky Mountains

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Contents

Introduction

This laboratory exercise introduces students to the issue of forest fragmentation by guiding them through an exploration of the origin of forest fragmentation and the threats fragmentation poses to the integrity and sustainability of our land resources. The objectives of this exercise are to: (1) Understand the phenomenon of forest fragmentation and its relation to timber harvesting practices; (2) Understand the positive and negative perspectives of forest fragmentation; (3) Learn how clear-cutting practices have changed from decade to decade; (4) Recognize the extent and importance of timber harvesting in temperate forests; and (5) Explain the relationships between forest fragmentation and its effects on the landscape, including implications for water quality, habitat, sustainability, and biological diversity. This exercise is designed to be completed in two hours by freshman-level, non-major general biology students. Preparation time for the lab may range from 2-4 hours, depending on how in-depth the instructor wishes the lab to be. The lab is best done by dividing the class into four to five groups, each of which should do one of the exercises. If only four groups are used, the fourth group should do both exercises D and E.

Materials

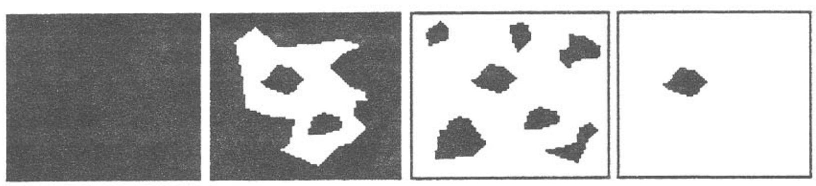
Photocopies of datasets provided	1 per student completing exercises
Clear acetate grid	1 per student completing exercise B
Erasable marking pen	1 per student completing exercise B
Calculator	2 each for exercises A, B, C, D, E
Ruler (30 cm)	1 per student completing exercise B

Planimeters (aka map measurers)	1 per student completing exercise C, E
Scratch paper	supply as needed for exercise C
Pens	1 per student completing exercise C

Student Outline

Forest fragmentation is a process by which large expanses of forest are increasingly divided into smaller, discontinuous units. These forest fragments are often created by forest cutting for agriculture, industry (e.g., timber, mining), or urban development. According to Harris and Silva-Lopez (1992):

> "...a fragmented forest refers to a landscape that was formerly forested but now consists of forested tracts that are segregated and sometimes isolated in a matrix of non-forest habitat. As the degree of fragmentation progresses, a **naturally patchy forest** is transformed into a **fragmented forest,** then to a number of **forest fragments**, and finally a single **insular tract** (or **forest patch**).



forested landscape | **fragmented forest** | **forest fragments** | **insular forest patch**

Figure 14.1. Progression of forest fragmentation.

Forest fragmentation is an issue of great concern worldwide because 1.) it results in habitat loss for all types of native forest species; 2.) it can increase the introduction of aggressive exotic species into sensitive habitats, 3.) it can alter the biogeochemical processes of forest ecosystems, and 4.) it often increases soil erosion and sediment load in streams, rivers, lakes, and other bodies of water, degrading water quality. Thus, fragmentation represents a serious threat to global **biological diversity** (or **biodiversity**) of both terrestrial and aquatic species. It may also be detrimental to human health, recreational opportunities, and economic well-being.

What is biological diversity? Why is it considered important? The media has focused our attention on forest fragmentation in the tropics, where large tracts of land have been cleared for agriculture and timber production. Tropical deforestation and forest fragmentation are serious problems because (1) they are occurring at an extremely rapid rate, (2) tropical forests have greater species diversity than any other terrestrial habitat, and (3) tropical forests are important in regulation of global biogeochemical cycles, including water, oxygen, and carbon.

North American temperate forests, both public and privately owned, are heavily used and harvested each year. It has become more and more apparent that the clear-cutting which fragments these forests is a serious threat to water quality within the forest and downstream. Forest fragmentation is also a threat to forest species' habitat, biological diversity, and the sustainability of timber harvesting. We will examine the effects of clear-cutting on a portion of the Medicine Bow-Routt National Forest in the Sierra Madre Mountains, located 60 miles west of Laramie, Wyoming.

Fragmentation results in a change in the patterning of the forest landscape. These changes are detrimental to some species (for example, pine martens or brown creepers) which require interior forest habitat. Such changes on the landscape may be beneficial to other species, such as deer, which thrive near forest edges. In considering the implications of fragmentation and forest management practices now and in the future, we must take into account all of the effects of changes, both positive and negative, in the pattern of the landscape.

What are some other species that may be harmed or benefitted by forest fragmentation?

Objectives

The objectives of this exercise are to:

1. Understand the phenomenon of forest fragmentation and its relation to timber harvesting practices.
2. Understand the positive and negative perspectives of forest fragmentation.
3. Learn how clear-cutting practices have changed from decade to decade.
4. Recognize the extent and importance of timber harvesting in temperate forests.
5. Explain the relationships between forest fragmentation and its effects on the landscape, including implications for water quality, habitat, sustainability, and biological diversity.

Lab Exercises

During this lab, we look at several important factors related to clear-cut forest harvesting and forest fragmentation in a portion of the Hayden District of the Medicine Bow-Routt National Forest, WY (our "study area") during the period 1950-1993. Figure 2 shows the location of the study area within the state of Wyoming. One group will look at the progression of clear-cutting. The second group will look at changes in the size of clear-cuts over time. A third will examine the amount of edge habitat present on the landscape. A fourth will examine the changes in the area of the forest influenced by edges over time. The fifth group will examine the impact of roads on the forest landscape.

At the end of lab, each group presents their results to the class and we discuss the various impacts of forest fragmentation.

Useful Definitions

Fragmentation - the progressive division of large, comparatively homogeneous tracts of forest into a heterogeneous mixture of much smaller patches (Reed et al.1996).

Forest Edge - the boundary between forest and another type of land cover; for example, a clear cut, a road, or another type of vegetation (shrub steppe, grassland, meadow, etc.).

Depth of Edge Influence - A scientifically-defined area of forest which is affected by a forest edge. The influence begins at the edge and is contiguous with the forest interior. The area that is affected may have higher temperatures, more sunlight, less available moisture, and different plants and animals than the forest interior.

Insular Forest Patch - A fragment of forest that stands alone, somewhat like an island.

Old Growth Forest - Undisturbed, structurally complex, native forest which is characterized by trees of varying age and size, and contains a large amount of dead and downed wood in various states of decay.

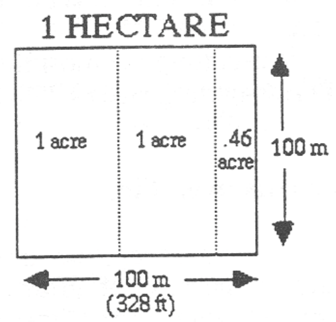
Biodiversity or Biological Diversity - The variety and variability among living organisms and the ecological complexes in which they occur (Harris and Silva-Lopez 1992).

Equivalents

You will use English units in this exercise, since that is the system with which you are probably most familiar. Occasionally, and hopefully more often in the future, you will hear metric units referred to in the press and will use them yourself. Therefore, included below are some equivalents between English and metric units for your information and reference.

square feet = ft^2
1 acre = 43,560 ft^2
1 hectare = 10,000 m^2 or 2.47 acres

square meter = m^2
1 meter = 3.28 ft
1 mile = 5,280 ft^2



Proportion = the comparative relation between two things (size, amount).

Percentage = a proportion multiplied by 100.

Rate = a change in a quantity measured over time. For example, the rate of clear-cutting over time is calculated as shown below:

$$\text{Rate} = \frac{\text{Amount of timber clear-cut, in acres or hectares}}{\text{The time period in which the timber was cut, in years}}$$

Total area of Hayden District = 372,796 acres.
Total area of our study area = 74,626 acres.

Exercise A: Rate of Clear-cutting in the Hayden District of the Medicine Bow-Routt National Forest, Wyoming

The rate of clear-cutting in the Medicine Bow-Routt National Forest has changed over the last few decades. This exercise shows the direction and rate of change in the **entire Hayden District** between 1950 and 1993.

Materials

Data Set for Exercise A

Procedure

This exercise will be completed by a group of 5 people. Each person should do parts 1 and 2 of the exercise for one of the time periods. When everyone is finished, each person should share their results with the others, and the group can complete part 3 together.

1. Using the data set provided, determine the total area, in acres, of clear-cuts in the Hayden District for each time period listed in Table A (this follows Data Set A). Enter these numbers into Table A.
2. Determine the number of acres cut/year for each time period.
3. Graph your results on a separate piece of paper.

Questions

1. What percentage of the total area of the Hayden District was clear-cut from 1950-1993? (The total area of the Hayden District is 372,796 acres).
2. During which time period was the rate of clear-cutting the most rapid?
3. What can you conclude about the rate of clear-cutting from 1950-1993?

Exercise B: Changes in the Size of Clear-cuts over Time

The size of clear-cuts on the landscape can have profound implications for the degree of forest fragmentation and its progression. Changes in the size of clear-cuts represent changes in forest management practices over time, and also reflect changes in natural resource management policies. Today we will examine the change in clear-cut size since 1950 in subsamples of our study area.

Materials

Map Set: 5 maps, one for each time period
Clear acetate grid
Erasable marking pen

Procedure

This exercise will be completed by two groups of 5 people each. One group will do steps 1-8 of the exercise for the eastern subsample of the study area, and the other group will do steps 1-8 for the western subsample of the study area. In each group, one person should be responsible for completing steps 1-8 of the exercise for each map. After everyone is finished, you should exchange results so that you can proceed to steps 9 and 10 and finish the exercise.

1. Place the clear acetate grid over the map. Trace the outline of the map on the grid. Count the number of grid squares that the entire map occupies, and record this number under the "your data" heading that appears before Table B1.
2. Determine the area in $in.^2$ for the map. Record this under "your data.".
3. Using the erasable marking pen, put a dot in each grid square occupied by a clear-cut or part of a clear-cut. When you are finished, count the total number of dotted grid squares and record this number under "your data."
4. Determine the percentage of the map occupied by clear-cuts by dividing the total number of grid squares occupied by clear-cuts by the total number of grid squares in the map. Record the percentage under "your data".

5. Use this percentage to determine the total area of the clear-cuts (in in.^{2}) for this map, and record your result in Table B1.
6. Repeat steps 2-4 for each map in the set.
7. For each map, convert the total area of the clear-cuts in in.^{2} on the map to total area of the clear-cuts in acres on the ground using the relationship: 1 in.^{2} on the map = 1572 acres on the ground. Record these results in Table B1.
8. Determine the mean clear-cut size on the landscape by dividing the total area of clear-cuts on the ground by the total number of clear-cuts, and record these results in Table B1.
9. Determine the cumulative effects over time since 1950 by summing the results from all previous decades as you record data in Table B2.
10 Graph the individual time period and cumulative results for your subsample of the study area on a separate piece of paper. Use a different color or symbol for each of the two lines.

Your Data

1. Total number of grid squares in the entire map: _______
2. Area of the map: _______ in.^{2}
3. Total number of grid squares occupied by all the clear-cut patches: ______
4. Percentage of the map occupied by clear-cuts: _____ %

Lab Exercise C: Amount of Edge

Quantifying the amount of edge habitat in the forest is crucial to understanding the impacts of timber harvesting on the forest ecosystem and its component plants and animals. *Why would this be so?*

Today, we will measure the change in the amount of edge in a subsample of our study area since 1950. We will use maps derived from on-going research in this part of the forest.

Materials

Map Set: 5 maps, one for each time period
Planimeters

Procedure

This exercise will be completed by a group of 5 people. Each person should do parts 1 and 2 of the exercise for one of the time periods. When everyone is finished, each person should share their results with the others, and the group can complete parts 3 and 4 together.

1. For each map in the map set, use a planimeter to measure the amount of edge (in inches) around each clearcut on the map. Add up the length of edge from all the clear-cuts, and record the sum in Table C1.
2. Convert your map measurements to ground measurements in Table C1. One inch on the map = 1.55 miles on the ground.
3. In Table C2, for each time period, sum the results from each time period plus all the previous time periods, so that you can look at the cumulative effects over time since 1950.
4. Graph your cumulative results from Table C2 on a separate piece of paper.

Questions

1. How would you describe the cumulative increase in forest edge during the period between 1950 and 1993?
2. What effects could the creation of forest edge have on the plants and animals of the forest?

Exercise D: Areas of Edge Influence in the Forest

Clear-cuts in forests cause changes in the species of plants and animals present along the edges of the cuts. Researchers have shown that the habitats available in forests that have experienced clear-cutting are very different from uncut forests. There are differences in temperature, light, humidity, soil moisture availability, and the amount of vegetative cover along forest edges. All of these affect the species composition of the forest.

Because of the changes that occur in the habitats along the edges of clear-cuts, forest researchers have coined the terms "edge forest" (forest occurring along and impacted by an edge) and "interior forest" (forest not influenced by the presence of an edge). Certain species of plants and animals can survive only in the interior forest. Areas of edge influence around the clearcuts can be studied to determine the proportion of the forest that is "edge" and the proportion that is "interior". Today, we will examine the amount of clear-cutting in our study area and the amount of forest influenced by 164 ft. (50 m) and 328 ft. (100 m) depth of edge influences around the clear-cuts.

The **depth of edge influence** is the distance into the forest to which the effects of the presence of an edge extend. This distance can be defined scientifically based on a number of factors (e.g., temperature, moisture). For our study area, a 164 ft. depth of edge influence is a conservative estimate; for some effects, this distance is more likely at least 328 ft.

The depth of edge influence defines the **area of edge influence** -- the proportion of the forest area impacted by the presence of edge.

Materials

Data Set for Exercise D

Procedure

This exercise can be done by a small group of 2-4 people.

1. Using the data set provided, calculate the cumulative area of the forest clear-cut for each time period by summing the results from each time period plus those from the previous time periods. Record the results in Table D1.
2. Do the same for areas of edge influence defined by (1) a 164 ft. depth of edge influence and (2) a 328 ft. depth of edge influence. Record your results in Table D1.
3. Graph the results for each decade individually (data set) and the cumulative results (Table D1) on a separate sheet of paper. Use different colors or symbols for each line.

Things to know

Study area = 74,626 acres (30,213 hectares)

Questions

1. What percentage of the study area has been clear-cut since 1950?
2. What is the percentage of intact forest remaining in the study area?
3. What percentage of the remaining intact forest is contained within the 164 ft. areas of edge influence?
4. What percentage of the remaining intact forest is contained within the 328 ft. areas of edge influence?
5. What is the actual area of the unimpacted landscape when the 328 ft. areas of edge influence are deducted?
6. Why is it important to consider how much of the uncut area is influenced by edges?

Exercise E: Roads and Forest Areas Influenced by Road Edges

Timber cannot be harvested without access to the area in which the harvesting will take place. Therefore, another component of the effects of clear-cutting on the forest is that of roads. The impact of roads is quite significant, though few studies of fragmentation incorporate their full effects.

Roads create forest edge much as clear-cuts do. "Road edge" impacts the forest in unique ways, however, because there is often increased air pollution, higher concentrations of toxic metals, increased human traffic, and greater vehicular mortality of animals along roads. Therefore, it is useful to consider the proportion of forest affected by road edges in addition to considering the proportion affected by clear-cut edges.

Materials

Map of roads (Figure 14.4.)
Planimeters

Procedure

This exercise can be done by a small group of 2-4 people.

1. Use a planimeter to measure the total length of roads (in inches) in a subsample of the study area on the roads map. Record these results in Table 14.E1.
2. Convert the total length of roads in inches on the map to total length of roads in miles on the ground.
   1 in on the map = 1.55 miles on the ground. Record your results in Table 14.E1.
3. Convert your results to feet and record them in Table E1. (See equivalents.)
4. Assuming that the roads are 30 ft. wide, determine the total area of forest cleared to build roads. Record these results in Table 14.E1.
5. Convert the total area of forest cleared for roads from ft.^{2} to acres (see equivalents) and record in Table 14.E1.
6. Calculate the total area in acres of the forest encompassed by both 164 ft. and 328 ft. areas of edge influence along the roads. To do this, multiply the total length of the roads by the depth of the area of edge influence, and double the resulting figure (there are areas of edge influence on both sides of the roads). Record these results in Table E2. Convert your results from ft.^{2} to acres and record in Table 14.E2.

Questions

1. What happens to the total area of intact forest when you account for the area occupied by roads?
2. How do the areas of edge influence affect the total area that is impacted by roads?
3. Why are the areas of edge influence considered in situations where the forest is impacted by roads?
4. Do you think the areas of edge influence affect the forest organisms? If so, in what way?

Acknowledgments

We would like to thank the teaching assistants for non-majors General Biology at the University of Wyoming between the Fall of 1995 and the Spring of 1997 for their efforts in teaching this lab and making helpful comments for its improvement.

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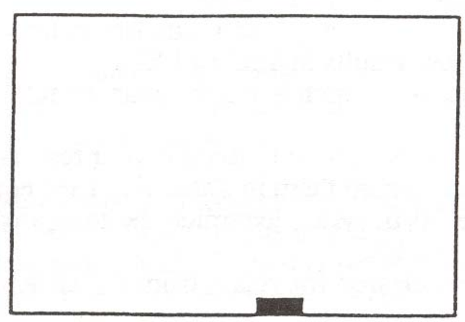

Figure 14.2. Location of the Hayden District of Medicine Bow-Routt National Forest in Wyoming.

Appendix 1: Data sets for Exercises A and D.
Data Set For Exercise A
(Modified for laboratory use)
Hayden District Past Timber Sales, 1955 to 1993

Timber Sale Name	# of Acres Clearcut	Sale Area	Harvest Time Span
Big Creek #1	403	2000	1955-59
Big Creek #2	1091	1916	1956-67
Big Creek #3	526	830	1961-67
Big Creek #4	580	1357	1964-69
Big Creek #5	538	3080	1967-69
Calf Creek	145	640	1955-58
Camp Creek	1086	3143	1956-64
Chippewa	350	350	1967-69
Heather Creek #1	400	1247	1960-63
Heather Creek #2	258	1485	1962-68
Henry Creek	61	61	1955-57
Phillips	7	7	1957
Six Mile Gap	0	263	1961-63
S. Miner Cr.	451	2841	1961-68
Weber Springs	10	10	1955
Willow Park	50	720	1965-66
Wood Mtn. #1	50	50	1966-68
Wood Mtn. #1	143	680	1968-69
Billie Creek	682	2899	1970-76
Blackhall Mtn.	167	1997	1975-79
Brady Creek	397	1920	1970-78
Bull Pine	0	35	1988
Camp Creek	220	3398	1980-85
Cascade Creek	63	1926	1980-82
Coon Creek	878	4000	1988-93
Cow Creek	3	500	1980-84
Divide Peak	242	710	1973-76
Dudley Creek	352	2577	1974-79
Dunkard Creek	27	91	1972-74
Green Mt.	8	650	1972-77
Green Mt. #2	105	3390	1980-93
Green Ridge	645	3247	1974-79
Green Ridge #2	248	1104	1977-79
Hell Creek	20	607	1980-84
Jack Creek #2	549	2260	1976-79
Jack Creek Mine	429	3100	1987-89
Jerry Park	689	6200	1990-93
Jones Creek	396	1159	1970-73
Mill Creek	303	2800	1990-93

Mowry Peak	525	5975	1981-86
McAnulty	245	4878	1980-88
No. Miner Cr.	200	1206	1970-74
North Savery	694	5700	1985-88
N. Spring Cr.	686	5850	1983-89
Nugget Creek	187	2621	1977-79
Nugget Cr. #2	349	2550	1989
Olson Creek	78	210	1972-74
Piedra Blance	8	33	1987
R-J-Whiskey W	424	3392	1990-93
Sandstone Div.	202	905	1976-79
Silverstone	224	13680	1982-89
S. Miner Cr.	14	143	1974-79
S. Spring Cr.	84	1305	1973-77
Stg. 2 Water	908	908	1982-87
Teddy Creek	736	7700	1984-89
Vulcan Mt.	31	1888	1980-85
Wood Mt.	411	4225	1989-93
Battle Highway Row	20	No Data	1990-91

Data Set For Exercise D

This table depicts (1) the area of forest clearcut, (2) the area of the forest influenced by the edges of clearcuts with a 164 ft. depth of edge influence, and (3) the area of the forest influenced by the edges of clearcuts with a 328 ft. depth of edge influence, for each decade between the years 1950 and 1993.

Time Period	**Clearcut Area (acres)**	**164 ft. Area of Edge Influence (acres)**	**328 ft. Area of Edge Influence (acres)**
1950-1959	**756**	**649**	**1321**
1960-1969	**1946**	**1086**	**2061**
1970-1979	**2277**	**1656**	**3364**
1980-1989	**852**	**861**	**1678**
1990-1993	**2240**	**2310**	**4027**

Appendix 2: Data sheets for all exercises.

Table 14.A: Clear-cuts in the Hayden District: acres and acres/year.

Time Period	**Total Clear-cuts (acres)**	**Acres Cut/Year**
1950-1959		
1960-1969		
1970-1979		
1980-1989		
1990-1993		

Table 14.B1: Total Clear-cut Area on the Map and on the Ground and Mean Clear-cut Size.

Time Period	Total Clear-cut Area (in.^{2} on map)	Total Clear-cut Area (acres on ground)	Mean Clear-cut Size (acres)
1950-1959			
1960-1969			
1970-1979			
1980-1989			
1990-1993			

Table 14.B2. Cumulative Area of Clear-cuts on the Ground.

Time Period	**Total Clear-cut Area (acres)** (your subsample)	**Total Clear-cut Area (acres)** (other subsample)
1950-1959		
1950-1969		
1950-1979		
1950-1989		
1950-1993		

Table 14.C1. Forest edge in the study area from 1950-1993.

Time Period	Total Edge (inches on map)	Total Edge (miles on ground)
1950-1959		
1960-1969		
1970-1979		
1980-1989		
1990-1993		

Table 14.C2. Cumulative amounts of forest edge since 1950.

Time Period	Total Edge (miles on ground)
1950-1959	
1950-1969	
1950-1979	
1950-1989	
1950-1993	

Table 14.D1: Cumulative effects of clear-cuts and areas of edge influence.

Time Period	Clear-cut Area (acres)	Area of Edge Influence (acres)	
		164 ft. depth	328 ft. depth
1950-1959			
1950-1969			
1950-1979			
1950-1989			
1950-1993			

Table 14.E1: Total Length and Total Area of Roads.

Total Length (in. on map)	**Total Length (miles on ground)**	**Total Length (ft on ground)**	**Total Area (ft^2)**	**Total Area (acres)**

Table 14.E2: Total Areas of Edge Influence along Roads.

	Total Area (ft^2)	**Total Area (acres)**
164 ft. area of edge influence		
328 ft. area of edge influence		

Instructor's Notes: Forest Fragmentation Lab

1. Every student is given a copy of the entire lab.
2. The lab is designed to be completed by students in five lab groups. Four of the groups should have a m

Suggested Format:

Group 1 (5 people) does Exercise A.
Group 2 (5-6 people) does Exercise B with the *eastern* subsample of the study area maps.
Group 3 (5-6 people) does Exercise B with the *western* subsample of the study area maps.
Group 4 (5-6 people) does Exercise C on one or both subsamples of the study area, depending on the amount of time available.
Group 5 (minimum of 2 people, maximum of 5) does Exercises D and E, starting with Exercise D.

After they have completed Exercise D, they should borrow a planimeter from Group 4 and proceed with Exercise E.

1. You should make your students aware of the spatial context of the exercises, ideally using a map of Wyoming. Point out the location and boundaries of (1) the entire Hayden District of the Routt-Medicine Bow National Forest (the area for Exercise A), (2) the study area (the focus of Exercises D), and (3) the subsamples of the study area used in Exercises B, C, and E.

2. Graphing the cumulative results over time should give the students a feeling for the *rate* at which various landscape changes have occurred, which will give you the opportunity to emphasize the concept of rates.

3. It will be very important for you to make clear to the students the main points of the lab during the summary. A few short "take-home" messages would be very useful. Since each group will be doing something different, it is important for the students to discuss their results with the class at the end, so they can see the whole picture of the components and effects of fragmentation. You must tie in the parts and help them to understand the whole picture.

4. Overheads are available for the students' presentations at the end. Clear acetate grids can be used by students presenting Exercises A, B, C, and D to show their graphs. An overhead of the two tables from Exercise E are available for students presenting that exercise.

Prep Notes

1. Data set for Exercise A:
   a. If file is available, then make changes and print out.
   b. If file cannot be found, then retype with changes.
   c. Need 5 copies for the lab.
2. Data set for Exercise D:
   a. Need 3 copies for the lab.
3. Every table needs 5-6 sheets of graph paper for the students to graph their results from each exercise.
4. Overheads:
   a. These are needed for the group presentations at the end.
   b. 1-2 overheads with grid lines for group's graphs.
   c. 1 overhead with the tables for Exercise E.
5. Maps of clearcuts:
   a. Try this first: cut each map in 1/2 and blow up on the copy machine.
      If patches are large enough, blacken in the stipling and copy for the lab.
      2 copies of the maps are needed for each lab:
      1 to trace for Ex. C, 1 to be cut up for Ex. B
   b. If the patches are still too small, subset the map as noted in prep meeting,
      and blow up on the copy machine. Blacken in the stipling and copy for lab
      2 copies of the maps are needed for each lab:
      1 to trace for Ex. C, 1 to be cut up for Ex. B

After enlargement, recalculate the scale of the maps. [i.e., 1 inch = ? miles; 1 inch^2 = ? acres]

6. Map of roads:
   Blacken in stipling and copy for class. Each lab needs 2 copies of the map.
   Use the roads map for the entire study area.

Later Possibilities

For Exercise B, use clear grids with dots to measure clearcut size on each map, instead of having the students cut and weigh little pieces of paper.

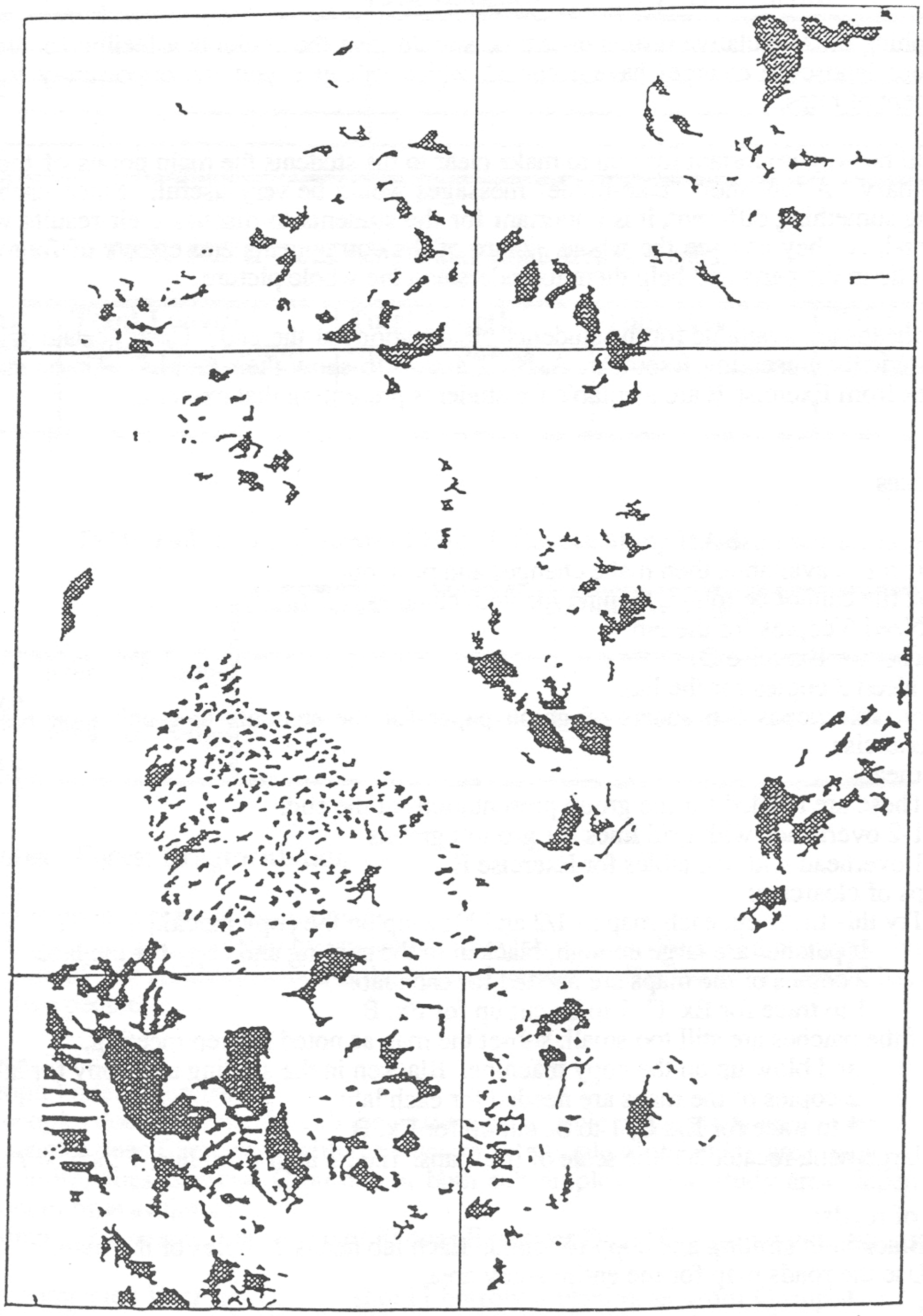

Figure 14.3. Cumulative cuts of the Hayden District 1950-1993. The entire study area is considered in exercise A; other exercises consider different areas, as indicated.

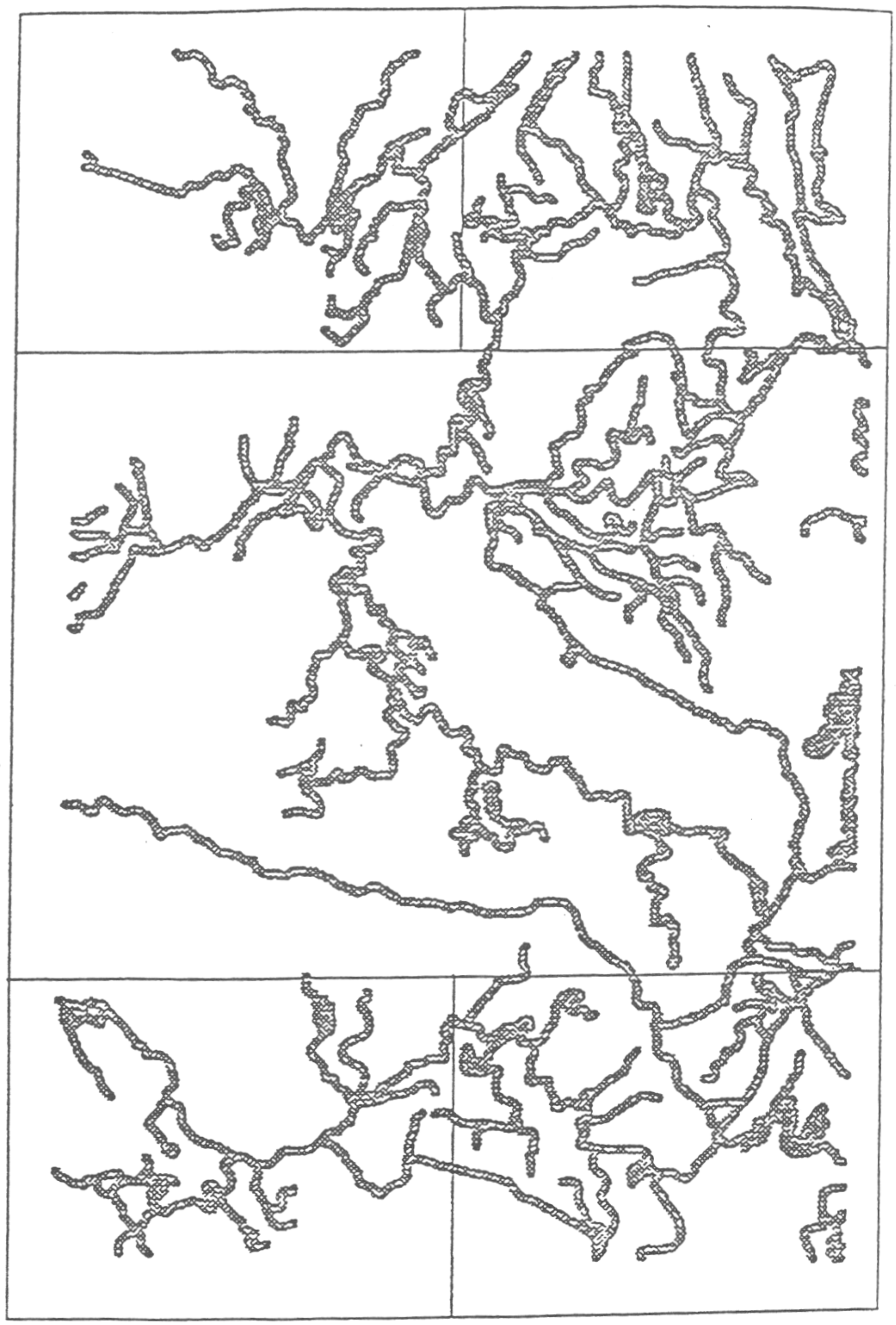

Figure 14.4. Roads of the Hayden District of the Medicine Bow National Forest.