ASPI
Appalachia-Science in the Public Interest
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ASPI TECHNICAL SERIES TP 33

THE PRACTICE OF ECOFORESTRY

PART 2. ECOLOGICAL RESTORATION

Introduction

The term **ecological restoration** refers to activities aimed at repairing human-caused injuries to forest ecosystems, and restoring natural levels of ecosystem health and integrity. As noted in the introduction to Part 1, restoration and protection of native ecosystems are the transcendent goals of ecoforestry. This paper considers some practical activities that further these goals. Part 3 of this series ("Tending and Harvest") then considers how people may obtain wood products within the overriding constraint that restoration and protection of forest health and integrity comes first.

Basic Principles

The health and sustainability of human communities are dependent on the health of the natural ecosystems in which the communities exist. The health of forest ecosystems, in turn, is dependent on the integrity of the **web of life** : all aspects of natural **biodiversity**, ecological relationships and interactions. Biodiversity includes diversity in the **species** that form the living part of the ecosystem; diversity in the **structure** (how the parts of the ecosystem are arranged both vertically and horizontally) of the living and non-living components; diversity in the **functions** that occur; and diversity in the underlying **gene pool.** High levels of structural diversity are associated with high levels of both species and functional diversity. Similarly, high levels of plant species diversity are associated with high levels of animal species diversity. Although ecosystems are variable over time and space, high levels of biodiversity buffer fluctuations. Compared to degraded ecosystems, ecosystems with undiminished levels of biodiversity would be expected to resist drastic and abrupt alterations of their natural properties, processes, and dynamics, including their natural directions and rates of change in space and time. We must begin now to undo our past mistakes, by restoring and protecting natural ecosystems, if we want to provide future generations of people with the opportunity to live healthy and dignified lifestyles.

The following recommendations emphasize observation, measurement, and manipulation of plants as an approach to the restoration and protection of entire ecosystems. This is a reasonable approach since plants are more easily observed and manipulated that animals or other ecosystem components, and since green plants are the basis for all life on Earth. Restoration programs based primarily on the manipulation of plants will result in restoration of the overall ecosystem.

Importance and Diversity Measures

A number of quantitative indices may be used as measures of the **importance** of individual species, and of the diversity of all the species on an area of land. **Relative density** and **relative basal area**, or the average of the two, are often used as measures of the importance of individual species (Example 1).

EXAMPLE 1

Total density = 400 stems/ac and basal area = 100 sq.ft/ac.
Red Oak density = 80 stems/ac and basal area = 50 sq.ft/ac.
Red Oak importance (density) = 20% [(80 ÷ 400) X 100]
Red Oak importance (basal area) = 50% [(50 ÷ 100) X 100]
Red oak importance (average) = 35% [(20 + 50) ÷ 2]

Species richness (the total number of species) is the simplest measure of species diversity for an area. A more complicated index is called **C** (**diversity index**):

$$C = 1 - (\text{SUM } p_i^2)$$

Where:
p_i = the importance of species "I", expressed as a decimal fraction

The importance value for each species is squared, then all of the squared importance values are summed together and subtracted from one. This index considers not only the total number but also the importance of the individual species, and increases as the number of species increases and as species become more uniform in importance.

EXAMPLE 2

STAND 1		STAND 2	
Total basal area = 100 sq.ft/ac.		Total basal area = 100 sq.ft/ac	
Red Oak basal area = 25 sq.ft/ac	& Importance = 0.25	Red Oak basal area = 10 sq.ft/ac.	& Importance = 0.10
Yellow-poplar basal area = 25 sq.ft/ac	& Importance = 0.25	Yellow-poplar basal area = 70 sq.ft/ac	& Importance = 0.70
Basswood basal area = 20 sq.ft/ac	& Importance = 0.20	Basswood basal area = 10 sq.ft/ac	& Importance = 0.10
Ash basal area = 30 sq.ft/ac	& Importance = 0.30	Ash basal area = 10 sq.ft/ac	& Importance = 0.10
Species Richness, S = 4		Species Richness, S = 4	
Diversity Index, C = 0.74		Diversity Index, C = 0.48	

Restoration and Protection

Snags, Logs, And Windthrow Mounds-and-Pits. **Snags** (standing dead trees), **logs** (fallen dead trees) , and **windthrow mounds-and-pits** (small hillocks and pits that form when a tree uproots) are the **biological legacy** that one generation of trees bequeaths to the next generation. All three types of biological legacy provide unique habitats for organisms and increase the structural diversity of the forest. It is estimated that as many as 20% of all forest animals may rely on dead wood at some stage of their life-cycles. The biological legacy, to a large degree, distinguishes natural forests, and especially old-growth forests, from young managed forests and plantations.

The natural abundance of snags in hardwood stands ranges from 1 to 10/ ac. Your inventory estimates of the number of snags per acre in various height and DBH classes (see Part 1 of this series) may be "scored" (Table 1) and then used to compare snag density on your land to the "target" densities found in natural stands. For example, the target score of 100 for snags could be achieved with approximately 25 snags/ac that are 10 inch DBH and 30 feet tall; with 3 snags/ac that are 20 inches DBH and 60 feet tall; or with 1 snag/ac that is 30 inches DBH and 60 feet tall (Table 1).

	HEIGHT (ft)					
	30		60		90	
DBH(in)	Logs	Snags	Logs	Snags	Logs	Snags
10	15	4	20	10	30	17
15	-----	-----	50	20	70	35
20	-----	-----	80	35	120	55
25	-----	-----	120	60	200	90
30	-----	-----	200	100	300	100

Table 1. Scores for restoration of snags and logs. TO USE: Multiply the average number of logs (or snags) recorded per acre in each height and DBH class by the score for that class, then add the totals for all height and DBH classes together. To achieve the target values, snag scores should =100, and log scores should = 1000.

Approximately 10 tons/ac of wood naturally occurs as logs in older stands of eastern hardwoods. Although this seems like a lot, the mass of logs in our forests is small compared to the 250 tons/ac of logs that typically occur in old-growth coniferous forests of the Pacific Northwest. As with the evaluation of snag density, your inventory results may be used in conjunction with the scores in Table 1 to evaluate log density on your land relative to natural target values. In the case of logs, inventory estimates of the number of logs per acre in various height and DBH classes are converted to scores and compared to a target score of 1000. For example, the target is achieved with approximately 60 logs/ac that are 10 inches DBH and 30 feet long; with 8 logs/ac that are 20 inches DBH and 90 feet long; and with 3 logs/ac that are 30 inches DBH and 90 feet long. Note that height (or length) in this case refers to the total height (or length) of the snag (or of the fallen tree that formed the log) rather than only to the portion of the tree trunk that is normally considered a log.

The density of snags and logs may be increased by killing or cutting trees. Snags are formed by **girdling** trees (cutting through the bark and outer wood around the entire circumference), and logs are formed by cutting trees and leaving them lying in the woods. Theoretically, **cavity trees** (living trees that are hollow and used as dens by animals) may also be formed by partially girdling but not killing trees. Artificial production of snags and cavity trees is not recommended since girdled trees rot from the outside in, rather than from the inside out as occurs in cavity trees and snags. Rather than trying artificially to increase their numbers, you should protect all natural snags and cavity trees until their density approximates the target densities. This practice is contrary to the natural tendency to cut decayed, dying or dead trees first when harvesting trees for firewood or other products.

If substantial numbers of trees are cut and left as logs, it is usually advisable to cut the finer branches and spread them on the ground to prevent accumulation of fine, dry fuels that might increase the wildfire hazard. The felling of large trees must always be done with care to prevent breakage or wounding of surrounding trees.

In the Appalachians, the density of treethrow mounds-and-pits ranges from 20/ac to 50/ac. Densities are usually higher and individual mounds-and-pits are usually larger in coves and other moist sites than on dry sites such as ridge tops. Although there is no practical way to increase the density of mounds-and-pits, you should recognize that mounds-and-pits are part of the local **microtopography** (small scale irregularities in the land surface) that contributes to the overall structural diversity of the ecosystem. Mounds-and-pits should be monitored and protected from disturbance.

Old-Growth Forests. In eastern hardwoods, **old-growth** forest stands generally contain many **canopy layers** (distinct layers occupied by living branches with green foliage) ; a variety of tree species; a variety of tree heights and DBHs; a variety of tree ages (**uneven-aged structure**); some trees over 200 years old; and an abundance of cavity trees, snags, and logs. Due to past clearcut logging and to attempts to convert all stands to an **even-aged structure** (stands with trees that are all of approximately the same age), old-growth stands are now rare. All old-growth should be protected. In addition, attempts should be made to restore old-growth using the techniques discussed in this paper and in Part 3 ("Tending and Harvest") of this series.

Sensitive, Threatened and Endangered Habitats and Species. You should obtain federal and state lists of threatened and endangered species that may occur on your land. In order to foster and protect these species you should also become familiar with their habitats and special requirements. Cliff lines, caves, and **riparian zones** (the areas around streams or ponds) should be protected since they provide a variety of unique habitats and have high levels of natural biodiversity. In the Appalachians, threatened and endangered plants and animals such as White-Haired Goldenrod, the Allegheny Woodrat, the Virginia Big-Eared Bat, and the Green Salamander utilize caves and cliffs. "No-use zones" about twice the average mature height of the tallest tree species native to the site should be established to either side of cliff lines and streams, and surrounding cave entrances and natural ponds. Caves, in particular, are vulnerable to temperature changes and to air and water pollution. Care should be exercised in cutting trees near caves and in locating camps relative to cave entrances. Careless removal of even a few trees, especially trees shading south-facing caves and cliff lines, may increase sunlight and temperature enough to eliminate sensitive plants and animals. Smoke from fires may also be sucked into caves and adversely affect air quality for many years or decades as the smoke slowly circulates throughout the cave system.

Exterminated and Declining Species . Native species that have been locally exterminated, or species that are in imminent danger of being locally exterminated, may be re-introduced or nurtured. It is easier to re-introduce plants than animals since plants are conveniently collected and transferred as cuttings, seeds, or seedlings. Re-introductions should always be made from a nearby population, since introductions of non-local genotypes may lead to the elimination of local genotypes. Species such as American Chestnut, Flowering Dogwood and Butternut, which are in decline due to human-induced degradation of ecosystems, should be nurtured and protected. As a starting point for this effort, up-to-date scientific information on symptoms and treatment of conditions such as Chestnut Blight, Dogwood Anthracnose, and Butternut Canker may be obtained from your county extension agent, from your state's division of forestry, from the forestry department of your state's land-grant university, from local offices of the U.S. Forest Service, or by computer from any of a growing number of sites on the Internet.

Elimination and Control

Roads. Road-building is perhaps the single most destructive human activity on forest lands. Roads are a form of **forest fragmentation** (breaking-up of extensive tracts of forests into relatively small patches separated by non-forested land) and contribute to many types of ecosystem degradation including: isolation of small populations of non-mobile organisms; alteration of forest climate; direct mortality due to road-kill; disruption of animal movements; disruption of water flow patterns; increased incidence of tree damage by wind, snow and ice; increases in soil erosion; introductions of exotic species; increases in numbers of opportunistic predators such as Raccoons and Cowbirds; increases in human disturbances due to noise, fire, litter, pets, poaching, gathering dead wood, trampling and compacting soil, off-road vehicle use, and cutting trees. Research has found a critical road density just under 1 mile of roads per square mile of land area. Above this critical density animal movements and other ecosystem processes and properties are severely and adversely affected. Any program of ecological restoration of forests should therefore aim to reduce road density below 1 mi/mi^2 using whatever effort and technology is required to first close and then to rehabilitate road beds. The box below describes a simple and accurate method for estimating road density on a map to determine if the existing density exceeds the critical value.

Line-Intersect Method of Estimating Road Length

1. Delineate the land area of interest on a map. Calculations are easiest if the area is some regular shape (square, rectangle, triangle, etc.) for which the land area may easily be calculated. Although not absolutely necessary, subsequent steps are easier if you darken the road system you are interested in with a pen.
2. Use the scale on the map to determine the area (in units of square miles) of the land that you have delineated.
3. Completely cover your delineated area with vertical and horizontal lines that form a square grid having a unit length of 1/4-inches. The grid may be drawn directly on a copy of your map, or, better yet, may be put on a piece of clear plastic that can be used repeatedly as a map overlay.
4. Randomly place the grid over your map. Follow each vertical line of the grid and record the number of times a road intersects a grid line (not a grid corner). Repeat this procedure for the horizontal grid lines. Add the two numbers together to get the total number of times roads intersected grid lines.
5. Multiply your total number of intersections by 0.2 to get an estimate of the number of inches of road on your delineated land area. Use the map scale to convert inches of road on the map to miles of road on the ground.

> On a standard USGS topographic map, the scale is 1:24,000. This means that 1 inch on the map represents 24,0000 inches = 2,000 feet = 0.4 miles on the ground.

>A square land area 3-3/4 inches on a side would be equivalent to: [(3.75 X 0.4) X (3.75 X 0.4)] = 2.25 square miles.

>A count of 27 road intersections with vertical grid lines and 25 intersections with horizontal grid lines = 52 total intersections.

>52 intersections X 0.2 = 10.4 inches of roads on your map.

>10.4 inches X 0.4 miles/inch = 4.2 miles of road in your delineated area.

>4.2 miles road ÷ 2.25 sq.miles land area = 1.8 miles road per square mile land area.

Exotic Species. Exotic plant and animal species are common in degraded ecosystems. Although exotic species such as Starlings and Dandelions may be here to stay, efforts at exotic species control should be part of all ecological restoration programs. Exotic plants may be eradicated by pulling or cutting when they are young, but control becomes more difficult once plants are established. Animals such as goats have been successfully used to eradicate Kudzu from pastures, but domestic animals need to be used with caution to prevent them from doing more harm than good to the forest ecosystem. **Prescribed fires** (fires that are intentionally set and controlled to achieve a specific objective) may also be effective in controlling exotic plants in certain situations. Chemical controls are never recommended since they almost always have unanticipated and negative effects on non-target organisms. Consult local sources of information concerning the occurrence and control of important exotic pest species in your area.

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