May 2006

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Integrating Ecological Forestry into Plantation Systems

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Note: 1 hectare = 2.47 acres

Foreword

Wildlife habitat, timber and pulp production, watershed protection, recreational opportunities, carbon sequestration, wilderness, spiritual fulfillment…we rely on our forestlands, public and private, to fill all of these services and values every day.

Many forests "multi-task," meeting several of these objectives simultaneously. It is often assumed that an intensively-managed, industrial plantation can not meet production goals while providing meaningful habitat quality. As this publication illustrates, however, there *are* forest product companies that are striving to meet this dual bottom-line in plantation management; they are successful, profitable enterprises *while* valuing the conservation of fish and wildlife on their plantation forestlands. Unfortunately, these examples are more the exception than the rule in plantation forestry in the United States today.

This report seeks to show the innovation underway in many parts of the world to better integrate wildlife and biodiversity needs within plantation systems. Some of these examples are from the United States. We hope this promotes a more vigorous conversation about what is possible in plantation forestry in this country and elsewhere.

The National Wildlife Federation has a long history of working with private and public landowners to encourage resource stewardship that integrates the needs of wildlife. Forest management strategies for plantations and natural forested stands have changed dramatically in the past few decades. This reflects in part our ability to measure the effects of management in more precise ways and our growing understanding of the web of ecological relationships supported by healthy forests.

Healthy forested ecosystems are critical to assuring a wildlife legacy for our children's future. So are healthy forest products-based industries that provide sustainable products and livelihoods in rural areas. We believe it is possible for plantations to do better in meeting their production goals while supporting diverse wildlife communities and helping change the forecast for climate change. We look forward to working with landowners and forest managers to realize this vision across our forested landscape.

Larry J. Schweiger

President and CEO
National Wildlife Federation

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Executive Summary

The Possibility of Plantations:
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Forests provide critical and irreplaceable habitat for wildlife, as well as opportunities for recreation and spiritual enrichment. Forest products are also a critical economic engine in the global economy via the opportunity for harvesting, processing, and manufacturing jobs and the provision of a wide array of consumer products.

Landowners choosing to manage their forests for timber production must decide generally whether to use natural forest or a plantation management system. Plantations generally yield more product in less time than natural forests, yet they often result in a simplified ecosystem. Wildlife species have varying habitat requirements for food, water, shelter, and breeding areas that cover a range of forest succession types, from very young to very mature forests. Habitat diversity at the landscape level generally offers better opportunities to meet wildlife needs rather than striving to protect all diversity components within each stand or management unit.

During the decade spanning 1993-2003, the global forest plantation area increased by an estimated 32 million hectares, while the area of natural forests declined by 126 million hectares. This trend is expected to continue. As plantation systems represent an increasing proportion of our forested landscape, the need to incorporate biodiversity has become more urgent.

Can forest and plantation managers do a better job of integrating biodiversity and non-timber values into plantation systems? Yes! The National Wildlife Federation (NWF) has found there are many examples from around the world where plantation managers are actively experimenting with, if not directly implementing, key biodiversity measures in their plantation systems. However, these "greener" plantation systems have not been broadly recognized nor have their techniques been sufficiently mainstreamed into plantation management at the level and pace of new plantation establishment.

Strategies to Integrate Biodiversity

As plantations systems are more widely adopted, NWF believes that techniques which transcend the historically narrow and intensive focus on productivity need to be more vigorously explored and encouraged. These complex plantation models would help to protect and retain the ecological resilience and economic productivity of our plantation landscapes.

Scientific research and management experience have revealed a variety of strategies for incorporating biodiversity considerations into plantation management systems. NWF's report profiles the use of several techniques, including those which emphasize the following:

Maintenance of landscape connectivity. Habitat fragmentation creates barriers and gaps which inhibit the ability of fish and wildlife to meet their habitat needs. An area with high connectivity allows species to move through the landscape and readily fulfill their habitat needs. Supporting strategies include the establishment of corridors and stepping stones, the retention of biological legacies, and careful consideration of road network placement.

Maintenance of landscape diversity. Wildlife species have varying habitat requirements, and diversity at the landscape scale is generally the best way to meet these needs. Strategies include varying the size and shape of plantation stands, planting a variety of species including native species as possible, establishing mixed stands, retaining areas of native forest, and using prescribed or controlled fire as appropriate.

Maintenance of structural complexity at the stand level. Managing for complexity and diversity within forest stands meets different species habitat needs and contributes to diversity at the landscape scale. Strategies include varying the spacing between trees, or widening the spacing, when planting occurs, retaining patches of native ground cover, thinning, incorporating biological legacies – leave trees, coarse woody debris, tall stumps - and extending harvest rotations.

As a supporter of incentive-based systems for improving forest management, NWF hopes that the case studies and discussion in this report will help nudge the process of plantation innovation and experimentation towards systems that provide higher returns to biodiversity and wildlife.

Maintenance of integrity and protection of aquatic ecosystems and riparian zones. Lakes, streams, wetlands and other aquatic ecosystems support much of the biodiversity in forested landscapes. The establishment of streamside or riparian management zones, protected wetlands and water bodies, and the rehabilitation of degraded waterways will support water quality, water flow, and decrease the likelihood of soil erosion.

Variability in management actions. Applying different strategies across an ownership allows landowners to pursue the best fit for a specific situation in terms of productivity and biodiversity. Implementing a variety of strategies also diversifies a landowners risk if negative or sub-optimal responses result from a strategy. Variability is explicitly recognized in variable retention harvesting, variable density thinning and forestland zoning programs, but can also be the aggregate sum of many different strategies (such as those listed above).

As in any forest management operation, the specific context and objectives of a plantation system must be considered in order to identify appropriate biodiversity strategies. Not all strategies are appropriate on all units. Ecologically progressive plantation management operations already incorporate strategies to support biodiversity conservation.

While the primary objective of owning and managing industrial forest plantations is the production of timber and pulp, this does not preclude management which supports both productivity **and** biodiversity. Case studies have highlighted several examples from around the world where plantation managers are actively experimenting with and implementing many of these strategies. The results are companies that are financially profitable **while** valuing the conservation of wildlife and ecosystem services. Of course these companies must continuously monitor the effectiveness of different strategies and adapt their management to incorporate lessons learned.

Carbon Sequestration – The Role of Plantations

Natural carbon sequestration is the absorption and storage of carbon from the atmosphere in plants, soils, and other organic matter. It naturally occurs when trees are growing and forests are maturing. Total carbon stocks vary considerably among forest and vegetation types. Industrial plantation owners and forest managers can structure their management activities to generate net positive carbon sequestration through their operations. However, growing trees for income and carbon uptake alone is insufficient for maintaining biodiversity in many areas of the world.

Linking Plantations with Offsite Biodiversity Mitigation

The possibility that plantations can *relieve* pressure on natural forests and enhance biodiversity through "biodiversity exchanges" or "offsets" has been widely suggested. Theoretically, increasing the output of wood fiber per unit of land can release forestland for other conservation purposes. Such exchanges, properly constructed, could create a win-win solution between wildlife and biodiversity, and the benefits of continued forest product output and local employment. These issues are examined, and a rough taxonomy for how such landscape level bargains between plantation management and conservation zones might go forward is explored.

Meeting the Needs of People and Wildlife

On the whole, plantation systems *can do better* in terms of managing for core wildlife and biodiversity values. However, there are already many individual examples from around the world that demonstrate the possibility for plantations to be designed and managed in a more ecological manner. Such practices can be implemented while maintaining economic returns. As a supporter of incentive-based systems for improving forest management, NWF hopes that the case studies and discussion in this report will help nudge the process of plantation innovation and experimentation towards systems that provide higher returns to biodiversity and wildlife. Our interest is to see both the wildlife and the people who depend on forests thrive together.

The complex plantation forestry model, while still being relatively intensive, attempts to include other land uses and values within plantation boundaries and aims to produce goods and services in addition to wood products.

Chapter 1

Introduction

Forests provide critical and irreplaceable habitat for wildlife. Forests also provide wood and paper products that support national economies, jobs that support local economies, and opportunities for recreation and spiritual enrichment. Forest owners can manage for multiple uses on the same forested acres making trade-offs as necessary, or they may allocate uses across forestlands to optimize certain values, for example, wilderness, timber production, wildlife habitat areas, or recreational uses.

Forestland owners choosing to manage their resource for timber production must decide whether to follow natural forest management or plantation systems. Natural forest management systems tend to model management activities on natural forest dynamics and attempt to retain compositional and structural heterogeneity in a forest stand and across the landscape. Plantation systems are designed for maximum productivity, efficiency, and predictability that often result in a simplified ecosystem, homogeneity in forest composition and structure, truncated succession patterns, and unnatural scales.

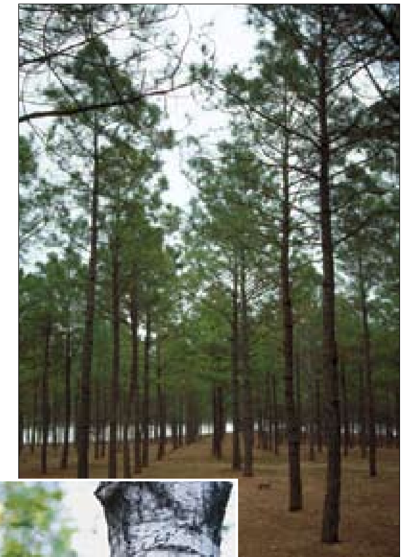
Plantations may be established for afforestation, reforestation, or conservation reasons. The Center for International Forestry Research (CIFOR) developed the following plantation typology: [1]

– *industrial plantations* (timber, biomass, food, and other)
– *home and farm plantations* (fuelwood, timber fodder, orchards, forest gardens, and other)
– *agroforestry plantations*
– *environmental plantations* (windbreaks, erosion control, game/wildlife management, site reclamation or amenity)
– *managed secondary forests with planting*

Given the scope covered by the typology, it is easy to see why many different definitions have been offered for plantations. These definitions often rely on distinctions in intensity of management, regeneration method, productivity, variety of species, scale, rotation length, silvicultural methods, and stand structure.

This report will focus largely on the category that CIFOR calls *industrial plantations* because the scale and intensity of these systems poses the biggest threat to wildlife habitat and other biodiversity values. Industrial plantations are defined as

> *….intensively managed forest stands established to provide material for sale locally or outside the immediate region, by planting or/and seeding in the process of afforestation or reforestation. Individual stands or compartments are usually with even age class and regular spacing… and of introduced species (all planted stands) and/or of one or two indigenous species.* [They are] *usually either large-scale or contributing to one of a few large-scale industrial enterprises in the landscape.*



This report will focus largely on the category that CIFOR calls "industrial plantations" because the scale and intensity of these systems poses the biggest threat to wildlife habitat and other biodiversity values.

Within industrial plantations there is a continuum of intensity and complexity that has been described by Peter Kanowski's simple and complex plantation forestry models.[2] Simple plantation forestry has a narrow and intensive management focus on producing a forest crop for a limited array of purposes. The complex plantation forestry model, while still being relatively intensive, attempts to include other land uses and values within plantation boundaries and aims to produce goods and services in addition to wood products.

As plantations systems are more widely adopted, the National Wildlife Federation (NWF) believes that complex plantation models need to be more vigorously explored and encouraged. The premise of this report is twofold:

1. Plantation systems on the whole can do better in terms of managing for core wildlife and biodiversity values.
2. There are already many individual examples throughout the world – some large, some small – that we can learn from where plantations are being designed and managed in an ecological manner while maintaining economic viability.

This report is offered as a tool to raise awareness among forestland owners, forest managers, and policy makers about the opportunities for incorporating biodiversity into plantation management. As a supporter of incentive-based systems for improving forest management, NWF hopes the case studies contained here will help nudge the process of innovation and experimentation towards complex plantation systems that provide higher biodiversity and wildlife benefits. We believe that forestland owners can conduct financially profitable and socially beneficial enterprises while valuing the conservation of biodiversity on their plantation forestlands.

Growth in Plantation Acres

The need to integrate biodiversity considerations into plantation management has become more critical as plantations systems influence an increasing proportion of our forested landscape. During the decade spanning 1993-2003, the global forest plantation area increased by an estimated 32 million hectares, while the area of natural forests declined by 126 million hectares.[3] Plantation forests are highly concentrated (60%) in several countries – China, India, the Russian Federation, and the United States – with climates, as well as government and business environments, supportive of this growth.[4] The most commonly used tree species on plantations are from the pine and eucalyptus genera.

According to the United Nations Food and Agriculture Organization (FAO) in 2001, industrial plantations accounted for 48% of the global plantation estate, while 26% of plantations were established on non-industrial forests for fuelwood, soil and water conservation or wind protection purposes. The other 26% were established for unspecified purposes.[5] Plantation forests currently contribute approximately one-third of the world's industrial wood supply and are expected to contribute nearly half by 2040.[6]

Within the United States (U.S.), the South represents the area of greatest growth in plantation establishment and management. The South now produces 15.8% of world timber production – more than any country except the U.S. as a whole.[7] A great deal of this production comes from planted pine. In 1953 there were 809,000 hectares of planted pine in this region. By 1999 there were 13 million hectares of planted pine. In 2040, there are expected to be 22 million hectares of planted pine.[8] It is estimated that high-intensity management has increased southern timber yields as much as 65% over standard site preparation and planting, and 100% over naturally regenerated forests.[9]

This dramatic growth in pine plantations is happening in the region of highest terrestrial biodiversity in the United States. The Southern Appalachians, Atlantic and Eastern Gulf Flatwoods, Gulf Coast Marsh and Prairie, and Peninsular Florida are all areas with high concentrations of endemic species. The South is the center of amphibian biodiversity in North America, including 19 critically imperiled species and 54 species of concern. [10, 11]

It is important to recognize that while most forest plantations result in simplified ecosystem structure and composition, they also often contain more biodiversity than the competing land uses of development and agricultural crops. While the threat of conversion is very real in many regions, it is occasionally held up as a justification for any kind of plantation forestry. NWF strongly supports tax and policy mechanisms that discourage forest fragmentation and conversion. While the first goal is to "keep forests as forests," NWF does not believe that the threat of conversion should be an excuse for not trying to improve the ecological quality of plantation systems.

Industrial Plantations

Industrial plantations generally have significantly higher yields (5-30 m^3/hectare/yr) than natural forests (1-m^3/hectare/yr), but they also often resemble the simple plantation model with low structural, functional, genetic, and species diversity. Achieving a higher yield requires substantial early investments in planting, thinning, understory suppression, and other stand management activities that will contribute to the goal of producing wood of a fairly uniform size and quality (the most efficient for transportation and mill utilization) on a predictable schedule. Genetic research contributes to selection of faster growth characteristics in the nursery leading to shortened rotations and a minimization of risk to the forestland investment through a faster realization of income. Recent research estimates that exotic plantations in North and South America have an internal rate of return (IRR) ranging from 10-24%, while native species plantations have an IRR between 4-10%, and managed natural stands will produce an IRR between 4-8%. [12]

The product of industrial plantations, primarily pulp and timber, is a commodity that competes on a global market. Cost minimization is imperative to stay competitive. This pressure will increase in the future as the so-called "Wall of Wood" enters the marketplace. Huge volumes of wood from vast plantations established in China and South America, and new areas opened for harvesting in the former Soviet Union, could potentially depress market prices. Economies of scale in management activities and standardization of management practices will add momentum towards a move to simpler plantation forestry models. Because it is significantly cheaper to grow pulp and construction timber in plantations than it is to grow it in sustainably harvested natural forests, there will be interest in shifting toward greater plantation production.

Context

The context in which a plantation is established, namely the management objectives and management systems, will determine the ecological impact of the plantation and opportunities to improve biodiversity. Issues related to this include:

- Was native forest or a rare natural community converted to create the plantation? Are there native forest areas left on the site?
- If not, is there natural forest in a proximity to the plantation such that linkages could be created between native forest areas?
- Are species native and appropriately sited?
- What is the scale of the operation?
- Are biological legacy trees, both alive and dead, allowed to persist within the plantation?
- Was the plantation matrix carefully designed to encourage structural and functional diversity through varying block sizes, shapes, and patterns?
- If not, can this be altered over time?
- Are riparian protection zones included within the protected areas?

Plantation growth is often represented by national or regional statistics, perhaps because the economic impact is often at this scale. From an ecological perspective, however, it is important to consider the landscape level impacts of plantation management. The local consequences of losing natural forestlands or converting natural forests to less complex plantations can be significant. While there has been little net change in forest areas in the Southern U.S. since the 1940s, there has been a great deal of change as forests were converted to urban and agricultural uses, or, conversely, as agricultural land became forests. Most forest loss has occurred in the eastern part of the South, while most conversion to forests has occurred in the western part of the South. [13] These changes have particularly strong implications for areas with rare forest types, or imperiled species, or in focal areas of rapid change. [14]

Wildlife species have varying habitat requirements for food, water, cover and breeding areas that involve the whole range of forest succession. From a biodiversity standpoint habitat is typically viewed at both the landscape and stand levels. "Stand" refers to a distinct forest management unit at the local level. Compositional, structural and functional diversity at the landscape level generally offers the best opportunity to meet wildlife needs.

In some cases, though, management choices may be tailored at the stand level to create habitat for a specific species, for example, the wiregrass community of a longleaf pine plantation for bob-white quail. Each diversity component is important at a landscape level, although at the stand level the forest may not contain all of these components. Thus the goal for conservation biologists is spatial diversity that includes both stand and landscape habitat components, rather than striving to meet each component within each stand. In practice this means there is room for intensive plantation forestry, provided that landscape biodiversity needs are met by adjoining lands. Or it may mean that a more complex plantation model is needed because important values are missing at both the stand and landscape level.

The challenges for plantation owners and managers are of course not limited to biodiversity concerns. Economic constraints, social conflicts, and other ecological challenges related to hydrology, soil issues, pesticides/pests, and genetically modified organisms are just a few of the other considerations. Advances in science will help address some of these concerns, but others involve the balancing of less objective realms of public expectations, regulations, and the evolution of best practices.

Chapter 2 discusses a number of the many techniques and management strategies that can help to increase biodiversity at the landscape and stand levels. Chapter 3 focuses on case studies from the U.S. and abroad and offers illustrative examples of forest management practices that integrate biodiversity conservation into industrial plantation management. Each case study will focus primarily on two or three management strategies. Chapter 4 will explore the potential role and considerations of carbon sequestration in plantation management. The concept of linking high-intensity plantation management with biodiversity offsets is explored in Chapter 5.

Chapter 2

Incorporating Plantation Management Strategies that Support Biodiversity

There are a wide variety of management strategies that forestland owners and managers can contemplate as they look at integrating biodiversity into their plantation management systems. Each strategy must be viewed within the specific context of a plantation management unit: the surrounding landscape and land uses, native wildlife and plant species and their habitat needs, natural disturbance systems and patterns, regulatory and public expectations, and management objectives. The brief description of each strategy provided in this chapter is meant to be a starting point for considering whether a strategy could be effective or appropriate given the specific context of the plantation management.

When considering the strategies, landowners should think beyond the boundaries of their own forestland. They may or may not be able to influence management decisions made by those who own adjacent lands, but they should be aware that decisions made by other landowners can affect their forestlands – to their benefit or to their detriment. There may be opportunities to work together with neighboring landowners to pursue management strategies more efficiently and effectively as a group. See page 10 sidebar.

David Lindenmayer and Jerry Franklin in *Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach* provide five principles that contribute to biodiversity conservation[1] in plantation landscapes. The management strategies suggested in this chapter are based on these principles:

– the maintenance of connectivity
– the maintenance of landscape heterogeneity
– the maintenance of stand structural complexity
– the maintenance of the integrity of aquatic systems
– risk spreading by implementing a range of strategies at different scales

Each strategy must be viewed within the specific context of a plantation management unit…

Maintaining or Establishing Connectivity

A landscape with high connectivity allows a species to move through the landscape and readily meet their habitat needs. These needs will vary widely by species. Ideally, the maintenance of connectivity across the landscape would first be considered when establishing a plantation through the incorporation of features such as corridors and small patches of non-contiguous, native remnant vegetation embedded within a non-native landscape called "stepping stones," the retention of biological legacies on a harvested site, and careful consideration of road network placement.

Retaining continuous cover through a corridor – strips of trees or shrubs connecting patches of suitable habitat – can facilitate movement between preferred habitats, or it can provide the habitat in and of itself.[2,3] The effectiveness of wildlife corridors (measured by abundance and/or species richness of birds, mammals, and invertebrates) is thought to co-vary with corridor width, corridor length, habitat continuity, habitat quality, and topographic position in the landscape.[4]

Riparian or stream management zones are a common corridor feature on managed forestlands in the U.S. as they are often required by mandatory, or sometimes voluntary, state-level best management practices. (See "Protecting Aquatic Ecosystems" on page 13.)

Stepping stones are a connectivity alternative that doesn't require continuous cover but allows the movement of some bird and arboreal marsupial species. [5]

Retaining coarse, woody debris after a regeneration harvest can also serve a connectivity function as the presence of fallen logs, branches or debris may enable species to move through the plantation.

Supporting Complexity at a Landscape Scale

Every forested acre doesn't need to contain compositional, functional, and structural diversity, but it is important that each of these components be met at the landscape scale. Complexity at the landscape scale, sometimes known as the landscape mosaic approach, systematically includes different forest types, intensities of management (including protected areas with no management), harvest cycles, cutting patterns, and/or forest objectives and values. Landowners with management authority over large-scale forestlands may have an opportunity to incorporate a landscape mosaic objective into their approach. Landowners with smaller forestland holdings can make important landscape diversity and complexity contributions.

Familiarity with the forest resources is necessary at both a landscape and stand level to effectively support biodiversity. To accomplish this, a landscape-scale inventory should be compiled. An inventory would include information such as: forest types and age-classes; topography; soils; riparian zones; wetlands; archaeological sites; cultural and customary use areas; locations of, and habitats for, rare, threatened and endangered species; roads; property boundaries; and critical wildlife breeding or wintering areas. Global and U.S. databases list rare, threatened, and endangered species and communities. In the U.S. many states have Natural Heritage Programs that provide information on native species and habitats, emphasizing those of conservation concern. Once the

Greater Okefenokee Association of Landowners (GOAL)

The Greater Okefenokee Ecosystem is a mosaic of swamp and forest that encompasses over 400,000 contiguous hectares in southeast Georgia and northeast Florida, with the Okefenokee National Wildlife Refuge at its center. Fire is essential to the landscape-level ecological functioning of the Okefenokee Swamp, but uncontrolled fires can pose a threat to adjacent timber interests. To balance these considerations, the Greater Okefenokee Association of Landowners (GOAL) was formed. This innovative partnership includes industrial and private forest landowners, federal and state agencies, and other landowners adjacent to the Okefenokee Swamp; together these landowners and forestland managers represent over 809,389 hectares. They cooperate on fire-related issues and road and bridge maintenance, and they have supported research on the Florida black bear in this productive and beautiful landscape. [45]

www.srs.fs.usda.gov/r8/goal/

inventory data has been collected it may suggest the need for additional protection of, for example, locally or regionally rare, threatened, and endangered species; forest community types; or even restoration of a species valuable culturally, for wildlife food and cover, or for conservation purposes.

The size and shape of plantation stands relative to native forest remnants will influence the effect plantations have on wildlife and biodiversity values.[6] Research has indicated that, in general, larger patches of retained native vegetation within plantations support more vertebrate species than smaller patches. However, areas as small as 0.5–1 hectare have been found to be valuable for forest birds, reptiles, frogs, mammals, and invertebrates.[7]

The shape of a patch determines the edge to interior ratio. This ratio recognizes that the edge of a patch has a different microclimate than the interior forest. The external patch may be more exposed to wind, light, invasive pests, pesticide applications, etc., which will change its habitat desirability for some species.[8]

Increasing the diversity of species grown in a plantation and selecting native species will provide greater structural and functional complexity and thus more varied habitat possibilities for wildlife. Use of species native to the region and site are preferred as they often provide mast, fruit, nectar, or cavities upon which indigenous wildlife and endemic species depend for food and cover needs.[9] When non-native species are chosen for large-scale planting, there can be great significance in leaving remnant native species or interplanting native species within exotic plantations to meet wildlife food and cover needs.[10, 11]

Mixed species plantations could give biodiversity a boost at a landscape scale. Research regarding mixed species plantations, in particular the identification of species that may be most complementary for growth and biodiversity gains, is ongoing. Potential benefits for mixed species systems include greater vertical and horizontal diversity; more efficient nutrient use allowing trees to grow bigger faster; and the availability of nurse species that may provide a stand structure that is beneficial to primary production species.[12, 13, 14] Furthermore markets for wood products can change dramatically between the time of planting and harvest, and mixed species plantations, as opposed to single species, can provide an economic hedge for landowners.

When appropriate, landowners should consider the use of prescribed fire for controlling understory vegetation and for creating and maintaining quality wildlife habitat, as well as growth conditions, within specific species of pine plantations (for example, longleaf pine). According to the Virginia Department of Game & Inland Fisheries, "where fire can be safely used [in pine stands], it is the single best tool available to landowners seeking to improve the quality of habitat on their property."[15]

Enhancing or Maintaining Structural Complexity at the Stand Level

Simple plantation systems are often fairly uniform in their composition, so landowners who are trying to support biodiversity conservation must look for ways to enhance structural diversity and complexity at the stand level.[16] Structural complexity refers to a diversity of vertical and horizontal layers of vegetation; the presence of cliffs, caves, meadows, remnant patches of late-successional forest, vernal pools and other habitat features; and the incorporation of biological legacies into regeneration harvest prescriptions.

Structural diversity can be integrated into the establishment of a new stand through planting techniques that vary the spacing between trees (within rows and between rows) and use a wider initial spacing to delay the shading effects of the tree canopy.[17, 18] Increasing the amount of light reaching the forest floor and reducing the intensity of site preparation stimulates native plant growth and diversity, especially of fruiting and forage species such as blackberries.[19]

Retaining native ground cover by leaving patches untreated during site preparation can enhance surface micro-habitat variation. The quantity of ground cover is highly correlated to the presence and abundance of a range of species of small mammals. Understory trees are a key food source for several species of mammals, and they act as foraging substrates for birds and bats.[20] Shrubs can be very important for migrating neotropical birds. Some landowners are experimenting with the creation of shrub hotspots and intentionally leaving patches of the desired shrubs during harvesting.[21]

Thinning enhances structural diversity by creating small gaps and openings that allow an understory and shrub layer to persist. It can provide an opportunity for a mid-story of shade-tolerant trees that is often lacking on managed stands. Direct links have been made between thinning and wildlife abundance on managed stands. Some species that benefit include white-tailed deer, quail, small mammals, turkeys, nuthatches, and other birds.[22] For landowners, thinning can provide an immediate financial return as well. Through an extension of the mean annual increment, thinning provides an opportunity to maximize growth on remaining trees and potentially produce a higher value product in less time.

While thinning is often fairly uniform across a stand, a variation called "variable density thinning" has been implemented in some regions. In North America this practice is most common in the Pacific Northwest and involves varying the thinning intensity across an ecologically appropriate scale (such as 1/10 to 1/2 hectare in Pacific Northwest Douglas fir forests) to produce a mosaic of unthinned, moderately thinned, and heavily thinned patches.[23, 24, 25] Variable density thinning helps to create more complex ecosystem structures by promoting tree growth at different rates.[26]

Incorporating biological legacies into regeneration harvest prescriptions is critical to enhancement of stand structural diversity. Biological legacies have been described as "the organisms, organic matter (including structures), and biologically created patterns that persist from the pre-disturbance ecosystem and influence recovery processes in the post-disturbance ecosystem."[27] Leave trees, snags, and coarse, woody debris are all biological legacies that retain critical wildlife habitat within the stand.

Leave trees may be individual trees or groups of trees that are identified for their value as a seed source for regeneration, as a food or cover source for wildlife, or as an important patch of remnant native vegetation in a plantation landscape. Leaving hardwood stands or individual trees can be particularly important in a plantation context for the food source (nuts, acorns, etc.) they offer to wildlife, as well as for the foraging substrate and habitat structure, which will help break up the uniformity of the future stand. Large living trees provide perching and roosting sites for birds.

Over time leave trees may evolve toward late-successional and old growth characteristics or hollow out to become cavity or den trees for wildlife ranging from the endangered red-cockaded woodpeckers to the more common bear or raccoon. Managers should seek to not only protect existing cavity trees for the wildlife that will use them, but also to recruit for future cavity trees by maintaining leave trees that are on a developmental path to becoming such trees.[28]

Snag trees and fallen trees, branches or bark on the forest floor are another important category of biological legacy known as coarse, woody debris; they are important for wildlife as cover, nesting and foraging sites, and as a nursery site for ferns and mosses. Coarse woody debris is especially important to the life cycle requirements of reptiles and amphibians.[29,30] John Hayes of Oregon State University has performed research on snags that demonstrates that the density of total snags in an unmanaged forest is up to five times greater than in a managed scenario.[31] Decomposing snags provide nutrients for insects, microorganisms and a variety of plants and fungi, which in turn attract

other species that need these organisms. Snags are so important for wildlife that in some areas where they are lacking forest managers are intentionally leaving a few tall stumps (created at 10 feet off the ground by a mechanical harvester or other techniques) after harvesting. [32]

Some wildlife species require habitat from mid-to-late successional forests. In landscapes dominated by relatively short-rotation plantations, this habitat may not exist. The concept of extending a rotation, in combination with some of the other elements listed above, can greatly enhance structural diversity on the landscape level. Longer time increments between regeneration harvests allows the possibility for greater age distribution across the stand; less frequent disturbances to soil, water, wildlife, and ecosystem components; and fewer truncated or even eliminated stages of stand development.[33, 34] Lindenmayer's research in Australia shows that as the age of the stand increased within a conifer plantation landscape, the bird species diversity improved as well. [35]

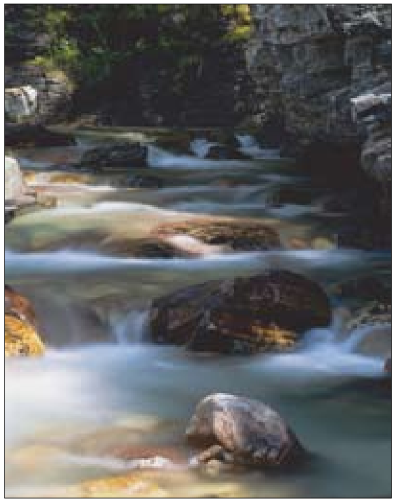
Extending the rotation for a forest stand often proves to be a win-win situation for enhanced biodiversity and for landowners. Longer rotations, especially when combined with thinnings discussed above, may involve a change in product mixes produced (for example, pulp to sawtimber) and result in higher quality wood. Both changes are likely to bring greater revenue to the landowner. The benefits of carbon sequestration are enhanced by longer rotations as well. (See Chapter 4, "Potential Role of Carbon Sequestration in Plantations")

Protecting Aquatic Ecosystems

The protection of waterways within plantation systems is critical as aquatic ecosystems support much of the biodiversity in forest landscapes. Streamside or riparian management zones (SMZs or RMZs) provide stream, river, or wetland protection from erosion by leaving buffer strips within which there is either no harvesting or lighter harvesting than in adjacent cutting units**.** SMZs not only protect the water quality and aquatic species, but also provide important cover, water and travel corridors for terrestrial wildlife.[36] On forestlands dominated by softwood species, SMZs often contain the largest, oldest, and perhaps only remnant, native hardwoods that often provide important food sources for terrestrial wildlife. In the United States, as mentioned above, individual states often require SMZs in their Best Management Practices.

Isolated, forested wetlands play an important role in the life cycle of reptiles and amphibians by providing perfect breeding habitat. They also provide rookeries for colonial wading birds and improve the habitat structure of adjacent forest stands for many bird species. [37]

Variability in Management Actions



Some of the strategies suggested above have been implemented in forests for centuries, while others are the result of more recent fieldwork and research. Just as a thorough landscape, forestland, and stand inventory is necessary before active management in the forest commences, monitoring changes in the landscape and stand biodiversity after the management activities occur is critical. Monitoring allows forest managers to judge the effectiveness of different strategies. Adaptive management incorporates lessons learned, through monitoring, into revised strategies that might more adeptly meet management goals. Each parcel of forestland has its own context and the influence and the impact of shifting management practices can not always be accurately predicted since different stands respond differently to similar practices.

Lindenmayer and Franklin suggest that the "Adoption of multiple strategies at multiple spatial scales is important because it increases the chances that suitable connectivity, heterogeneity, stand complexity and aquatic ecosystem integrity will be provided for most taxa in at least some parts of a landscape."[38] This is a risk-spreading adaptation and creates a situation very different from the traditional plantation establishment goal of reducing variability. Increased heterogeneity on the landscape implies management practices that are not uniformly applied but that are responsive to opportunities at a variety of spatial scales.

Forestland zoning is one method landowners have adapted to meet their multiple objectives across one forest management unit. This zoning is internally driven, voluntary, and flexible, although there may be overlap with regulatory requirements for riparian protection, threatened, and endangered species, etc. One college's forest management plan is organized around four landscape-scale themes: short-rotation wood production with a high return on investment; high quality, growth maximizing timber production; visually sensitive, even-aged forest; and structurally diverse forest.[39] Another landowner underscores the value of the zoning approach by noting that "attempting to maintain the entire range of biological diversity with a uniform approach to forest management has the effect of simultaneously reducing both habitat for biological diversity and economic opportunities or contributions."[40]

Variability in management actions includes varying the way specific management actions are implemented within a stand or among them. Variable density thinning involves varying the thinning intensity across a stand (see pg 12). Variable retention harvesting is a specific harvesting technique that requires retention of some portion of a stand; the retained portion is distributed such that the influence of forest or residual trees is maintained over most of the area.[41] This practice creates a multi-aged stand and creates patchiness at a stand level.

Carefully planned harvest schedules can create a diverse landscape with recently harvested stands abutting relatively older forests, and variations in rotation length.[42, 43] Using a variety of harvest patterns also adds to the mix with dispersed or concentrated logging activities, different harvest area sizes and shapes, the use of different types of equipment with varying influences on the residual forest, and road networks cutting through it all. Variability in management actions can be applied to almost any area of plantation management systems.

Moving Strategies into Practice

What creates the impetus for a shift from traditional management systems that met production objectives to a more complicated system that sometimes starts with as many questions as answers? Sometimes it is the pressure of changing public expectations or the recognition that greater scientific knowledge has opened up new options. For broad, large-scale change within a company or organization it often takes the visible and vocal support and commitment of that company's leader to create opportunities for the change.

A wildlife biologist at a company that experienced this shift explains how this happened:

> *It took a visionary CEO to shake the lethargy, energize people, and challenge them to have a new vision. He empowered people to think differently and announced new goals. The question became not if we could do it, but how…. As people became more committed to the system, they also saw the potential for win-wins. For example, loggers don't want to cut standing dead trees for safety reasons. Wildlife loves dead standing trees. Leaving dead standing trees after a harvest can be a win-win.*[44]

Some of these management strategies, especially on a stand-by-stand level, involve small and incremental changes. Other shifts involve dramatic refiguring of an entire system of management. Some of the shifts have economic repercussions (cost increases or revenue decreases) in the short-term, but over the long-term it is not clear what the financial impact of management changes will be. The value for wildlife and biodiversity conservation to some of these strategies is much more clear, although difficult to assign an economic value. Forest plantation management can have a dual bottom-line: it can be both economically viable **and** ecologically responsible. In the next chapter, case studies highlight the strategies chosen by a handful of pioneering companies as they integrate ecological forestry into their plantation management systems.

Chapter 3

Case Studies

The case studies in this chapter were chosen to highlight on-the-ground examples from around the world where plantation managers are actively implementing strategies which integrate biodiversity into plantation management systems. The National Wildlife Federation recognizes the leadership of these companies in advancing the practice of plantation management that considers wildlife and biodiversity conservation. We are not, however, endorsing all management activities undertaken by these companies.

In many parts of the world plantations have been sources of friction around issues such as indigenous people's rights, community's use of the forest, forest conversion, and appropriate land uses. These case studies, and the overall report, have focused on silvicultural management techniques that support the conservation of wildlife and ecosystem services. The social impacts of plantations on local communities are mainly beyond the scope of this report.

The National Wildlife Federation recognizes the leadership of these companies in advancing the practice of plantation management that considers wildlife and biodiversity conservation.




Case Study #1

Cascadia Forest Products, Coast Forest Strategy Canada

Management Objective: [The] production of high quality wood products within a framework of sustainability, world-class safety and leading environmental standards.

Species: Douglas fir, hemlock, western red cedar, amabilis fir, yellow cedar, Sitka spruce

Forestland Hectares under Management: 800,000

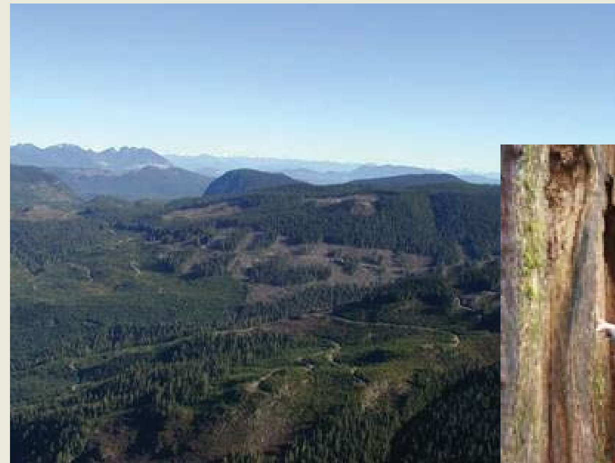
Web Site: http://www.forestbiodiversityinbc.ca/forest_strategy/default.htm

Variable Retention Harvesting, Stewardship Zoning and Adaptive Management

In 1998 MacMillan Bloedel announced a dramatic shift in their forest management practices on 800,000 hectares of publicly-owned coastal forestland to an ecologically-based approach involving variable retention, stewardship zoning and adaptive management. The change was stimulated by public concerns regarding clearcutting, old growth, and biological diversity, and by the leadership of a visionary CEO. Weyerhaeuser purchased the Tree Farm License (TFL)/cutting rights in 1999, and sold them in 2005 to Brascan Timberland Investments which then created Cascadia Forest Products. The management approach initiated by MacMillan Bloedel has been implemented throughout the changes in ownership. This initiative is known as the Coast Forest Strategy (CFS).

Variable Retention

As defined in British Columbia, a "retention" silvicultural system requires standing trees to remain for at least one rotation and be distributed throughout a cut-block so that forest or residual tree influence is maintained over most of the area. The retention of structure within harvest areas is intended to provide future forest stands that more closely resemble conditions following natural disturbances. Variable retention means that the long-term retention will involve different amounts of individual trees, groups of trees or patches of the original forest in various combinations.



CFS forest planners have created site-specific resource management plans. They use structural features, equipment and transportation requirements, and spatial guidelines to create each harvest plan. Key structural features and compositional characteristics targeted for retention include: a range of tree sizes, coniferous and deciduous species, and multiple canopy layers; areas of undisturbed understory vegetation and forest floor; snags, decay features, and coarse woody debris; riparian areas, and rock outcrops; nests, and bear dens; gullies, seeps, and unique flora or terrain features.

MacMillan Bloedel's *A Forest Management Strategy for the 21st Century – Silviculture* explained in 1998 "We will choose the most appropriate harvesting and silvicultural system based on site characteristics. The goals for structural retention within a landscape unit will be matched to the sites that benefit most from a habitat, regeneration, slope stability, or visual standpoint. When faced with equal biological rationale for partial cutting one of several sites, we will choose the most economical site and system to meet our objectives."

Variable retention can be implemented with a wide range of harvesting methods and can be combined with traditional silvicultural systems, such as shelter-wood or selection, to meet forest regeneration objectives. A range of retention levels (5% to 60%), patterns (group, dispersed or mixed) and cutting cycles (single-pass, multi-pass) have been implemented. CFS management practices have intentionally concentrated retention at the lower end of the retention range in order to maintain structural attributes while attempting to minimize an expected reduction in growth and yield. That said, the average retention level across all three zones was 21% in 2004 – with 91% of CFS harvested area using variable retention. This is a tremendous change from 1998 when clear cutting was used for 93% of all harvesting.

Stewardship Zones

CFS planners assigned different goals to different areas of their forestland by applying one of three stewardship zones: timber zone (65%), habitat zone (25%), and old growth zone (10%). The zone concept was applied in recognition that "attempting to maintain the entire range of biological diversity with a uniform approach to forest management has the effect of simultaneously reducing both habitat for biological diversity and economic opportunities or contributions."

In the **Timber Zone**, the objective is to emphasize commercial timber production, while protecting water quality, soil productivity and conserving areas of critical wildlife habitat.

In the **Habitat Zone**, the management objective is to emphasize conservation of biodiversity and wildlife habitat with low intensity harvesting.

In the **Old Growth Zone**, the management objective is to conserve the larger contiguous old-growth areas on CFS tenures, and restore old-growth attributes on previously logged areas within the landscape unit, allowing minimal harvesting.

Stewardship Zones

Management emphasis	Timber: Commercial timber production	Habitat: Wildlife habitat conservation	Old Growth: Maintain late-successional forest conditions
Proportion of company managed landbase in each zone	65%	25%	10%
Average proportion of productive forest area in reserves	28%	40%	70%
Long-term retention in each cutblock (minimum)	Dispersed: 5% Group: 10%	Dispersed or group: 15%	Dispersed or group: 20%
Primary silvicultural systems	Retention shelterwood	Retention, shelterwood, selection	Selection, irregular shelterwood

The allocation of stewardship zones was responsive to economic realities as well as ecological goals. As the CFS land base has shrunk over time through the government's withdrawal and redistribution of 20% of the TFL agreements, the proportion of forestland allocated to each zone may need to be revisited.

Adaptive Management

The Adaptive Management (AM) program provides a structure and process for examining whether the CFS is implementing the planned management activities and, more importantly, whether these activities are indeed leading to the desired end result - maintaining the forest attributes necessary to sustain biodiversity and essential ecosystem functions. Feedback loops and semi-annual meetings and workshops with CFS staff and scientific advisors support the ongoing role of AM.

The AM framework considers three levels of ecological indicators related to the goal of maintaining species:

1. **Habitat representation.** Ecologically distinct ecosystem types are represented in the unharvested land base to maintain lesser know species and ecological functions.
2. **Habitat structure.** The amount, distribution and heterogeneity of stand and forest structures important to sustain biological richness are maintained over time.
3. **Indicator species.** Productive populations of species are well distributed within the company's land base.

CFS staff and affiliated researchers have monitored forest structural attributes and completed pilot studies for a variety of species groups (amphibians, birds, carabid beetles, mycorrhizal fungi and others) as well as monitored the impacts of variable retention on forest growth and yield, wind throw, and small streams. (See sidebar for example of research.) Nine experimental areas have been established to compare the biological and economic impacts of variable retention in its different patterns and levels of retention. Initial results for most species groups indicate that group retention is generally better than dispersed retention for maintaining habitat (within the 0% to 30% range tested) although different species respond differently to the harvesting.

Variable retention seems to show the potential for maintaining species from the original forest that would not otherwise be present in a clear-cut. Public surveys indicate, however, that the group retention pattern is perceived as being very similar to a clear-cut, and thus dispersed retention is publicly more acceptable when no further information or education is provided.

Do Birds Use Group Retention Patches? Study Results from 2000–2004

As part of the Adaptive Management program, the CFS team has worked with Michael Preston at Simon Fraser University to monitor the use of group retention patches by forest-dependent songbird species after harvesting. Results showed that all of the 18 most frequently detected species occurring in uncut stands were represented in group retention stands, but most (66%) occurred in lower abundance. He also found that abundance, richness and diversity of species increased with the size of the patch retained; this result is based on 33 patches ranging from 0.25 to 3.2 hectares. Habitat features such as the density of trees > 50 cm in diameter at breast height (1.6 m), and percent canopy cover, were also important factors for species presence.

Many of the characteristic species of late-seral stands in this region (for example, brown creeper, chestnut-backed chickadee, golden-crowned kinglet, Pacific-slope flycatcher, and varied thrush) were present in group retention stands. However, not all stands were occupied by each species or similar numbers. When comparing the frequency of occurrence of the ten most common bird species in uncut stands with their frequency in group retention stands, Preston found that group retention were more similar to uncut stands, than they were to clear-cuts.

Case Study #2

The Forestland Group
Eastern and Central United States

Management Goal: To seek competitive returns for investors while maintaining the productive capacity of the forest.

Species: loblolly pine, loblolly-pitch pine hybrid, red pine, white pine

Forestland Hectares under Management: 728,000 across 16 states, 38,380 hectares (5%) of which are plantations as of January 2006

Web Site: www.forestlandgroup.com

Enhancing Stand Diversity and Extending Rotations on Pine Plantations

The Forestland Group (TFG) is a timber investment management organization that pursues investments primarily in naturally regenerating hardwood and pine forests containing considerable volumes of intermediately aged, vigorous timber stands. Many of TFG's acquisitions have involved portfolios of forestlands and in this manner they have acquired approximately 38,380 hectares of conifer plantations. TFG aims to produce large, high-value hardwood and pine sawlogs.

Enhancing Diversity in Pine Stands

All of TFG's management plans are designed on a tract-by-tract basis; there is no standard operating procedure. They use an opportunistic approach to forest stand management; looking not only at what is currently growing on a site, but what the site could host most productively with the least intervention. TFG's foresters pay careful attention to each property's unique biological habitat and diversity. Their interest in using each site's natural advantages for appropriate species recruitment leads to productive sites in timber volumes and quality, as well as wildlife, diversity and ecosystem resilience.

When evaluating management options for planted pine, TFG considers whether the site is suitable for pine and whether there is an adequate seed source and regeneration. If pine is not the most suitable species, a conversion may take place involving a change of species or a conversion from planted pine to a naturally regenerated pine stand using a shelterwood silvicultural system – TFG's method of choice.

Many of the plantations that TFG has purchased were established through intense site preparation and dense plantings of loblolly pine seedlings until they dominated a site. Under the pine seedlings there are usually stored seed and residual roots of other species capable of sprouting, but lack of sunlight reduces their ability to do so. In these situations, TFG initiates thinning to both accelerate the growth of the remaining pines and provide sufficient sunlight and space to permit some residuals to develop. Depending upon stand density and site quality, there may be three thinnings before a final harvest. As the pine canopy is opened, seed blown in from adjacent natural stands germinates and begins to develop, as does the seed from the shade intolerant pines above. The thinnings accelerate the very natural process of plant succession, and increase the complexity and diversity of the stand. Ultimately as the last large pines are harvested there is a younger, more natural forest in place. The usual age of the stand at the time of the final removal cut will be 40 to 45 years. Upon occasion the last pines from the plantation will be left standing to be removed only when the new stand is ready for its first thinning. In addition to creating a more complex, diverse, wildlife-friendly stand, these thinnings provide a periodic cash flow for investors.

One example where the conversion is happening is in TFG's pitch pine-loblolly pine hybrid plantations. TFG does not feel that this species will produce high quality sawlogs. Following the harvest of these plantations, if there is inadequate advanced regeneration of acceptable hardwoods in the understory, the area will be planted at wide spacings to native white pine. This procedure will be followed for all other plantations. If there is adequate advanced regeneration of acceptable species, there will be no planting following harvest. Failing this, a site will be planted at wide spacing to a species native to the site.

Each plantation is different because of variations in soil, pine survival, adjacent stands and the effects of insects, disease and weather. The plan for the regeneration of each must take these differences into account. TFG's focus on natural regeneration requires that its managers work in concert with natural ecological forces to achieve their goals. Consider, for example, TFG's preference for oaks in its management. A dense pine plantation is an attractive place for blue jays and a number of species of rodents to stockpile acorns for future consumption and there are likely to be few acorn predators resident in these plantations. If there is a nearby forest of mature oaks the quantity of germinating acorns over time will increase, and TFG's foresters will capitalize on this opportunity. They will initiate a thinning operation to provide enough sun light to permit the survival of the oak seedlings. A prescribed fire will then kill much of the other woody vegetation while the oak seedlings sprout back with greater vigor. As the thinnings continue the oaks continue to grow and repeated prescribed fire will control other species until the final mature pines are removed leaving a young stand of mixed pine and oak is in place. Few forests provide habitat for as large a variety of wildlife.

Occasionally pine plantations are the only viable option, for example if an aggressive invasive is present or if the present stand is so degraded that recovery is unlikely in a reasonable time. In these cases, TFG may choose to undertake intensive site preparation and plant native pine, with the intention to recruit more native understory during the coming rotation. When replanting pine plantations, forest managers use widely spaced rows to achieve, ultimately, fully stocked mixed stands of pine and hardwood. Some hardwood will be maintained within loblolly plantation stands for stand diversity and habitat enhancement.

Extended Rotations

As a general practice, TFG will lengthen harvesting rotations on their plantation forestlands beyond the previous owners' harvesting schedule. While traditional rotations for loblolly pine are 25-30 years, TFG focuses on loblolly pine saw-timber production with a 40-45 year rotation. A lengthened rotation allows more time for a stand to develop vertical and horizontal structure including snags and other forms of coarse woody debris that provide habitat for many wildlife species. There is also likely to be a wider diversity of age-classes, tree sizes, and stand composition as shade-tolerant species are recruited into gaps occurring through natural processes or thinning. An extended rotation allows TFG to take advantage of the value accumulating in the larger stems and to possibly incorporate an additional thinning operation as they focus on the production target of high value sawtimber. Although extending the rotation adds some risk and time until returns are realized, the markets for pine sawlogs provide better returns than pulpwood.

Case Study #3

Global Forest Products
South Africa

Vision: Global Forest Products is a world class forest products company which delivers quality products and services for the benefit of our customers while managing our resources on a sustainable basis in order to be a worthy partner to all our stakeholders.

Species: Mexican weeping pine, slash pine, loblolly pine, shining gum, brown barrel eucalyptus

Hectares under management: 92,000, of which 64,000 hectares are plantations

Web Site: www.globalforestproducts.net/

Conservation Lands, Land Optimization, and Corrective Planning

Global Forest Products is an integrated forest products company that manages 64,000 hectares of plantation forestlands, 28,000 hectares of conservation land, three sawmills and a plywood plant. Many of Global's plantation areas were afforested in the early 1900s following the depletion of native forests during the South African gold rush due to the need for timber. The plantations were established on grasslands using exotic species which had much faster growth rates than native species. They have been managed in 25-28 year rotations for more than 50 years. Global is the largest supplier of solid wood products in South Africa and produces structural timber, appearance timber, industrial timber, veneers and plywood products.

A Commitment to Conservation Lands

Global actively manages nearly one third of their land holdings for conservation purposes; 1,000 hectares are indigenous forest, 2,000 hectares are wetland areas and 25,000 hectares are grasslands. These non-planted areas are managed to maximize biodiversity and water yield, and for non-timber products, while the planted areas are managed to maximize the yield and quality of timber products.

Global works closely with local conservation authorities to create baseline species data and to ensure that best practices are used on their managed lands. Over 60 rare, threatened and endangered species have been identified and of these certain key species are closely monitored on the conservation lands, while various native species are also known to use the managed lands. A fish species that was thought to be extinct, the Truer River barb, has been reintroduced on Global's property through close cooperation with the Mpumalanga Parks Board and Olifants River Forum. Some of the species on Global's managed lands are habitat specialists and prefer grasslands, native forests, wetlands or plantation areas, while others move through the mosaic of habitat using different areas to meet a variety of needs.

Seven Natural Heritage Sites have been recognized on Global's lands for their environmental or national significance by the South African Government. These sites include the Klipkraal Tree Fern Reserve (one of the largest concentration of tree ferns in the world), the Cycad Reserve (protected habitat for the humble cycad), and the habitat for the Truer River barb. Global has committed to protecting the values that distinguish these natural sites. For example, "Giep se Gat" is home to a unique dragonfly and

burning regimes require a patchwork mosaic in order to ensure suitable habitat at all times – this requirement is integrated into the area's fire protection plan.

In the years since the plantations' establishment the remaining grasslands and native forest areas on Global's land holdings have been recognized to be of high conservation value. These conservation areas will be protected from conversion as well as from the potential effects of plantation management activities at their edges such as alien vegetation infestations, the influences of harvest activities in adjacent plantation stands, or fires that burn at different seasons, intensities or in different directions than planned. Company policies, for example, explicitly discuss the importance of fire in sustaining wildlife habitat and productivity in grassland ecosystems, but also the critical nature of timing and controlling the path and patterns of fire within the managed lands.

Land Optimization and Corrective Planning

Global's plantations are predominantly softwoods (57,000 hectares) but also include two species of eucalypts. The company's nursery produces nearly 10 million seeds annually that are supported by years of research and development for disease resistance and optimal fiber characteristics. To achieve the best yield and quality from the plantations, Global has instituted a land optimization planning process to match site characteristics with species qualities. As they have built up an extensive Environmental Conservation Database layering information about site characteristics and landscape features, the company has found some planted areas in need of corrective planning.

Prior planting decisions may have prioritized conveniently shaped boundaries (such as those created by square stands) over appropriate species and site matches, planted trees in wetland areas or built dikes to project water flow away from its natural course. Global is realigning these stand boundaries to match site characteristics, identifying excision areas where trees are to be permanently removed and areas restored to natural vegetation, and breaking dikes at intervals as appropriate to assist in the natural dispersion of water and reclamation of wetland vegetation.

Enhancing Water Quality and Natural Flow Patterns

Projects to restore and enhance water quality and quantity are central to corrective plantation design. Water is extremely scarce in this part of the world and is the limiting resource throughout Global's forested landscape; annual average rainfall is about 1300 mm in the upper catchments where plantations are established but decreases rapidly to an average rainfall of about 650 mm in the Lowveld where other land uses, industry and urbanization compete for the same water resources. Biodiversity is strongly driven by water resources, and in South Africa wetland ecosystems play a significant role in supporting wildlife biodiversity. There are national programs which require water quality bio-monitoring, stream flow regulation and payments for water use.

Global has integrated this ethic for water protection and conservation into their management philosophy and practices. They have created a wetland policy to identify and delineate saturated sites, leading to wetlands rehabilitation in some area. The company has created buffers around wetlands as well as indigenous forests and riparian zones. Incorrectly established planted trees are systematically removed and the habitat restored to natural vegetation through active management. These buffer zones help protect aquatic areas from the unintentional impact of plantation management, protect water quality and flow, and create corridors allowing wildlife movement through the planted mosaic.

The company has been a consistent supporter of the national Working for Wetlands and Working for Water programs which have multiple goals of rehabilitating wetlands, eradicating introduced invasive species, raising awareness and influencing behavior that impacts wetlands, and providing economic opportunity to unemployed youths. Forging a relationship with local communities in support of wetlands protection and thoughtful natural resource stewardship will have spillover benefits on the ongoing non-timber product harvesting that Global allows on their managed lands. The gathering of mushrooms, thatching grass for buildings, and firewood, as well as the grazing of cattle and beekeeping are all allowed in appropriate areas across the Global managed landscape.

Case Study #4

Klabin SA, Parana Unit
Brazil

Management Objective: To practice sustainable development to manage forestry activities, assuring the maintenance and improvement of environmental, social and economical aspects, according to Forest Stewardship Council (FSC) principles and criteria.

Species: loblolly pine, slash pine, flooded gum, Dunn's white gum, Sydney bluegum, eucalyptus hybrids, araucaria

Forestland Hectares under Management: 229,503 hectares

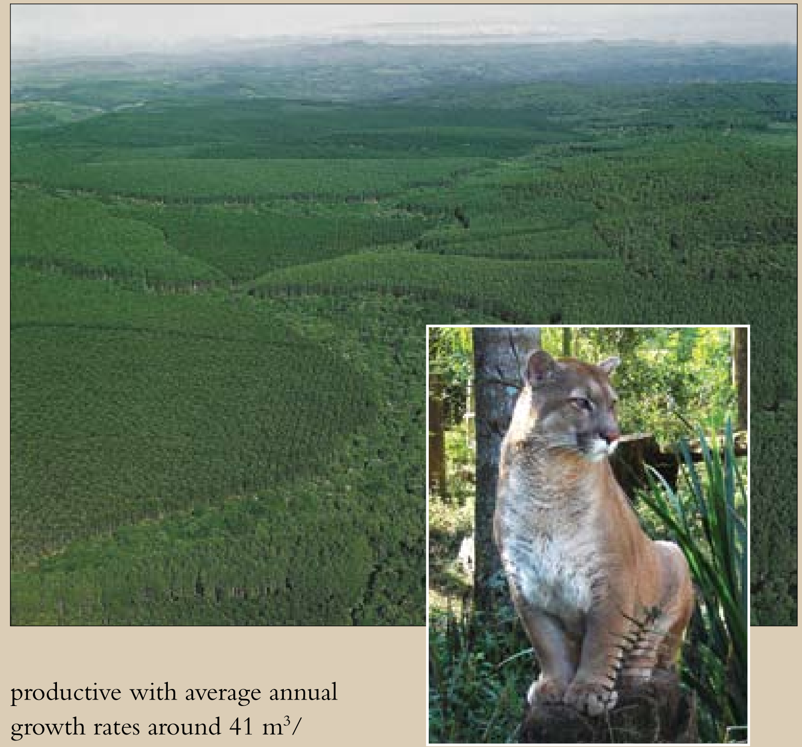
Web Site: www.klabin.com.br/en/go-76.htm

Landscape Mosaic and Non-timber Forest Products

Klabin has managed the Parana Unit plantations since 1943 when they were established (the land itself was bought in 1934). Although the company has experienced tremendous growth, they have strived to retain the principles with which they began - a respect for nature and a permanent commitment to manufacturing their products with a focus on sustainable development. On the landscape these principles are tangibly demonstrated through the landscape mosaic strategies that are at the foundation of Klabin's management system and their pioneering work integrating non-timber forest products into their forest management objectives.

Landscape Mosaic

The Parana Unit contains 85,000 hectares of native forest and 120,000 hectares of pine and eucalyptus plantations. In planted areas, careful planning creates a landscape mosaic of species (two pine, four eucalypt and the native araucaria), age classes, and management systems. Harvest cycles vary according to the species and product being produced. Eucalyptus rotations range from 6-21 years, pine rotations are 14 or 20-25 years, and araucaria rotations are about 40 years. The Parana Unit plantations are immensely



productive with average annual growth rates around 41 m^3/hectare/yr for eucalyptus, 28 m^3/hectare/yr for pine, and 13 m^3/hectare/yr for araucaria.

The native forests are intermingled within eucalyptus and pine plantations, and are well distributed throughout the landscape. Native forest areas are linked through ecological corridors to assure wildlife and plant species connectivity and to provide rich wildlife habitat. In the State of Parana, only 9% of the original native forest area has been preserved making the remaining native forest areas especially important for wildlife. Streams and rivers are considered ecological corridors and have permanent preservation areas of at least 30 meters on each side; thus many of the native forests are located along streams and rivers. There are also some larger blocks of native forest (41,000 hectares total) that have been protected through Legal Reserves; established to protect High Conservation Value Forest, which contains endangered species or important fragments of ecological habitat. For example, one Legal Reserve contains a high proportion of araucaria forests and several endangered species including the maned wolf, wild cats, and parrot species. There are guidelines for harvesting crews specifying that if a planted area is adjacent to native forest, the native forest area will be totally protected against any kind of damage.

Klabin's management systems permit the development of an understory in areas managed under an extended rotation (70% of the planted area); understory is important for protecting and supporting many of the wildlife species native to this area. Biological legacies, such as areas with birds' nests or critical frog reproduction areas, are integrated and protected within the mosaic. The Parana Unit is biologically rich with 354 plant species found, 397 bird species, 80 mammals species and 11 of 50 of Brazil's endangered species including the maned wolf, cougar and giant anteater.

Planting Species to Match Site Qualities

When deciding which species to plant on a specific site, soil type, nutrient supply, microclimate, adjacent species already planted and the protection of native forests will all be considered. Klabin has been clear that no native forest areas will be converted into plantations. As a general guideline pine has been planted in lower, less fertile locations as it is more resistant to frosts and less demanding from a nutritional perspective. Eucalypts are planted according to a zoning map on which the climatic and nutritional requirements of each species are noted. Klabin also has some planted araucaria areas. Studies on soil, fertilizers, silvicultural techniques, environmental management, and genetic improvement have supported the tremendous growth and yield on Klabin's plantation areas.

Non-timber Forest Products

In addition to pulp and sawlogs, the Parana Unit produces non-timber forest products of great value to local communities. In 1984 Klabin began a phytotherapy program focused on extracting herbs and other plant materials from the native forest areas to produce medicines and cosmetics. Currently the phytotherapy program benefits 20,000 people, employees and their families, in the area. Most of the synthetic drugs previously prescribed have been replaced by phytotherapic medication. Compared to synthetic products, the herbal medicines have proved to be 95% efficient at an average cost 4 times lower and an outstanding acceptance rate of 97%. Currently 40 species are cultivated in the phytotherapic lines, and further opportunities for food and cooking spices and scents are being explored.

Klabin offers several environmental education and recreation opportunities on the Parana Unit. There is a Center for the Interpretation of Nature, and the Fauna and Flora Museum to educate local communities about the wildlife and conservation opportunities in the region. The company also participates in a Wild Animals Scientific Breeding program to support efforts for reintroduction of wildlife species such as the Brazilian tapir, gray rhea, maned wolf, and the ocelot. The Ecologic Park program is based in the araucaria forests and focuses on developing research on wildlife, protecting primitive ecosystem samples and particular habitats of native wildlife, and safeguarding Nature's exceptional attributes. In 2005 there were 33,000 visitors to the Ecologic Park including students, local community members and Klabin's clients. The Harmonia Biking Track leads the local community to the Ecologic Park, and together with the Ecologic Track provides 6,000 meters of recreational trail with educational signs about flora and fauna along the trail.

In 2004, Klabin became the first Brazilian company to participate in the Chicago Climate Exchange, thus qualifying it to sell carbon credits to companies that need to take measures to reduce and control the greenhouse gases that cause global warming.

Case Study #5

MeadWestvaco
Southeastern United States

Forestry Division Vision: Our vision is to be a global leader in sustainable forest resource management: Optimizing forest productivity, while sustaining environmental and social values; Supplying our business partners with high quality forest products and services; Marketing to generate industry-leading financial returns.

Species: loblolly pine, longleaf pine, slash pine, sweet-gum, upland hardwood, bottomland hardwood

Forestland hectares under management: 485,633 hectares in five states

Web Site: www.meadwestvaco.com/forestry.nsf

Ecosystem-Based Forestry – Landscape, Intra-Stand, and Stand-level Planning

MeadWestvaco owns forestlands to generate revenue and supply their mills with a reliable source of low cost wood fiber. Their forestlands contain a mix of natural softwood or hardwood stands, softwood plantations, and non-forest areas. Company foresters and biologists manage portions of their landholdings for fiber production and many different forest values. In the 1990s the company created a system called Ecosystem-Based Forestry (EBF) which is applied across their entire ownership with some variation depending on landscape features and inherent diversity.

Implementing Ecosystem-Based Forestry

MeadWestvaco's team of foresters and biologists has classified its 485,633 hectares into one of six EBF zones. Each zone has a primary and numerous secondary functions. Zone classifications may shift over time if, for example, the team obtains new knowledge about site specific resource properties (i.e., soil), learns more about how zones interact or adjacent stand characteristics change.

Ecosystem-Based Forestry Zones

***Water Quality Zones (WQZ)* –** provide water quality protection that often exceeds state Best Management Practices for forestry. WQZs also provide additional habitat diversity through retention of older age-class hardwood species (riparian habitat).

***Special Areas* –** protect and enhance areas of unique historical, geological, and biological significance. Examples include historic sites, threatened, endangered, and globally imperiled species, and unique landscape features.

***Timber Management Zones (TMZ)* –** provide raw materials for wood and paper products. By applying the latest silviculture technology, TMZs are managed for maximum production of wood fiber while taking advantage of site specific habitat elements available (i.e. isolated forested wetlands, snags, mast producing trees). Thinning in TMZs also enhances habitat structure within pine plantations.

Habitat Diversity Zones (HDZ) – provide older age-class habitat structure and diversity of timber types, and are managed primarily for wildlife habitat. HDZs complement habitats found within TMZs by providing different habitat structure in natural stands and stands identified for multiple thinnings to encourage understory and mid-story species.

Visual Quality Zones – provide visual buffers along well-traveled roads and waterways to soften the visual impacts of forestry operations.

Non-Forest Zones – include facilities needed to conduct forestry operations as well as ponds, rice fields and power line right of ways. Non-forest zones add to habitat diversity.

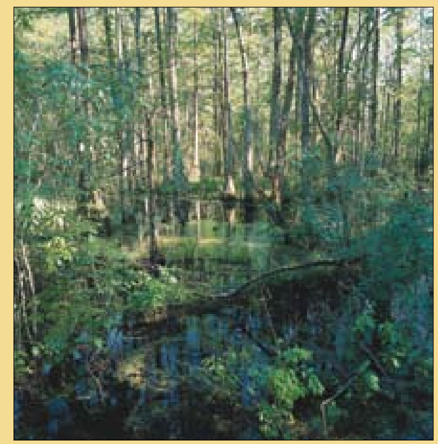
Landscape Considerations

Water Quality Zones generally exist as forested corridors of multiple stands that follow concave landforms. Habitat Diversity Zones also may exist as corridors or as individual timber stands. Both are managed to provide older age-class habitat structure, interior forest habitats and other varying levels of habitat growth that complement surrounding pine plantation habitats. Forest management practices in these corridors or stands are designed to protect water quality and promote biological diversity. Generally, harvesting methods include those that promote uneven age class timber with multiple canopy layers and increased vertical structure. These corridors and stands (HDZs) are well distributed across Timber Management Zones and across MeadWestvaco's ownership.

Within the Habitat Diversity Zones and Water Quality Zones are Timber Management Zones (TMZs) which contain a variety of planted pine plantations and naturally regenerated timber stands. In TMZs, foresters apply the most appropriate silvicultural techniques to produce the raw materials for wood and paper products. The complexity of the size, shape and age class of stands within TMZs is an important diversity consideration. Habitat interspersion between timber stands and Habitat Diversity Zones forms a diverse landscape mosaic.

While EBF zone placement provides a framework for long-term planning, MeadWestvaco's foresters and biologists have developed a comprehensive site specific planning process that further addresses a number of habitat considerations associated with forest management operations at the individual timber stand level.

Stand-Level Considerations



Each pine plantation or timber stand in a Timber Management Zone is evaluated prior to, and during, any treatment such as timber harvesting or site preparation to determine habitat features that need to be considered. Varying management practices and identifying different features to retain helps to ensure a wide range of wildlife species on the MeadWestvaco land base.
For example:

- Foresters may retain isolated forested wetlands to provide added age class and tree species diversity at the stand and landscape levels. These wetlands play an important role in the life cycle of amphibians and reptiles.

– Snags may be retained within harvested areas to provide appropriate structure for cavity-nesting birds, mammals, and roosting sites for forest roosting bats.
– Single mast-producing green trees, or groups of them, may be identified for retention during a timber harvest. An example would be a large oak tree or a group of oaks within a pine plantation.
– Cavity trees may be maintained in groups or as individual trees; this can include mast producers or any species including pine.
– Coarse woody debris may be scattered across the stand or consolidated in small piles to provide microhabitat and organic nutrients for microorganisms, detritus feeders, invertebrates, fungi, lichens, and mosses.
– MeadWestvaco foresters and biologists frequently work with recreational leasing customers to establish wildlife food plots along company roads, logging decks, skid trails, and fire lines. Openings in the forest which are a result of active forest management can be valuable to a number of game and non-game species.

Because maintaining biodiversity is a significant focus of Ecosystem Based Forestry, foresters consider not only where to place zones and how the zones work together across the landscape, but also how habitat components can work together within a specific forested stand. The consideration of biodiversity at three spatial scales (landscape, between stand and stand level) along with the extensive deployment of Habitat Diversity Zones and Water Quality Zones as part of the framework of EBF, are a comprehensive method of providing substantial age class distribution, aesthetic considerations, and biological diversity.

Adaptive Management – Programs to Monitor Impacts and Benefits of EBF

EBF is a dynamic management system, changing and adapting with forest technology, economics and science to continue to provide the multiple use functions of MeadWestvaco forests.

To monitor and improve upon this program, the company has co-operated with conservation partners, such as The Nature Conservancy, and on wildlife studies with various universities in the Southeast. The company maintains a 3,240 hectare working Ecosystem Research Forest in West Virginia. See sidebar below for an example of Avifauna research. Cooperative projects are generally designed to answer questions related to operations in Timber Management Zones and overall implementation of Ecosystem-Based Forestry. Data from this cooperative research helps ensure that MeadWestvaco meets its objectives of providing the necessary wood products people need **and** maintaining and enhancing biodiversity on their forest lands.

The Effects of Corridors on Breeding Land Birds within Intensively Managed Forest Landscapes – Study Results from 1994–2003

The study documented over 100 bird species on MeadWestvaco's forested landscape in South Carolina. Forty-five of those species are neo-tropical migrants. Of the twenty most abundant species documented, 60% are neo-tropical migrants. Eleven bird species are considered species of concern by Partners in Flight.

The study results indicated that: loblolly pine stands aged 6–10 years function as transitional starting and ending points, supporting early successional bird species as well as those requiring a broadleaf understory and mid-story component; the understory and mid-story components found within the pine stands are vital to many of these nesting birds; mid-rotation thinnings improve vegetation structure and the hardwood component within pine stands improves breeding habitats for a number of neo-tropical migratory birds and others; and territorial mapping and nest searching data of the acadian flycatcher and hooded warbler revealed that corridors are as productive as larger stands in supporting breeding bird habitat.

Research Partners: North Carolina State University, NCASI, North Carolina State Museum of Natural Sciences

Case Study #6

Potlatch Forest Holdings, Inc.
Arkansas Region, United States

Mission: Creating exceptional value for our investors and customers through active management of the forest property portfolio and by providing high quality products and services in ways that are environmentally, socially and economically responsible.

Species: loblolly pine, short-leaf pine, cherry bark oak, water oak, willow oak, white oak, sweet gum.

Forestland hectares under management in Arkansas: 198,042 hectares owned and 4,047 hectares under long-term lease in Arkansas

Web Site: www.potlatchcorp.com

Landscape Mosaic, Endangered Species and Non-timber Forest Products

Potlatch Corporation has owned most of their Arkansas forestlands since the 1950s. Traditionally, Potlatch has managed these forestlands on a stand-by-stand basis, but they now incorporate a landscape level assessment into their management systems as well. The intensively-managed, native, loblolly pine plantations provide raw material for a variety of local mills, including two Potlatch lumber mills. The natural pine stands are managed to produce a variety of products, including higher value sawtimber and habitat for the endangered red-cockaded woodpecker. The hardwood lands are managed on an uneven-aged basis to produce high quality oak saw-timber and hardwood pulpwood.

Landscape Mosaic

Potlatch foresters manage the Arkansas forestlands using a mix of natural forest and plantation management systems. Currently, their forestlands are comprised of 48% plantation pine, 32% natural pine stands, and 20% hardwoods. Their long-term objective is to bring the Arkansas land base into a more balanced cover type distribution, creating a mosaic of stands made up of natural pine, managed pine plantations and hardwood. This will be accomplished through selective land acquisitions and

disposals, longer rotations for some pine plantations and silvicultural techniques that create more naturalistic conditions in plantations.

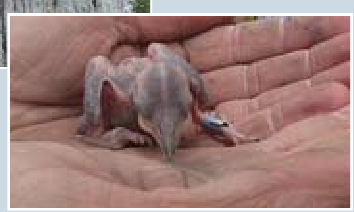
The landscape mosaic encompasses different species, different rotations (30-40 years for planted pine and longer for natural pine and hardwood stands), protected areas and intensively managed areas. Adjacency is carefully considered when planning harvest schedules, as is variation in stand sizes that correspond with landscape qualities (ranging from 8-81 hectares). Unique and high conservation areas are identified and, if they are actively managed, these values are protected during management. Potlatch is creating a landscape level assessment system using metrics such as average stand size, average age difference between stands, stand irregularity, and edge to interior ratios to measure management impact and landscape qualities and values.

A defining component of Potlatch's mosaic is the assurance of connectivity at the landscape level. Stream management zones, hardwood forests and riparian areas have naturally created connectivity across much of the company's forestlands. Where that connectivity does not exist, forest corridors are established to maintain plant diversity and wildlife habitats across the landscape. In 2005 an inventory identified places within Potlatch's Arkansas forestlands that were more than 0.8 kilometer from existing connectivity features. In these areas, a corridor was established to connect them to the larger landscape. Corridors must be at least 91 meters wide and are managed with a longer rotation, different stocking level and more naturally than the plantation pine areas.

Protecting and Creating Habitat for an Endangered Species

In 1995 Potlatch signed a Habitat Conservation Plan (HCP) with the U.S. Fish and Wildlife Service (F&WS) committing to the protection of habitat for red-cockaded woodpeckers (RCW); an endangered species that was living in older natural stands of loblolly pine on company forestlands. The RCW clusters were scattered across 80,000 hectares of non-contiguous Potlatch forestlands. The HCP called for reduced harvesting in RCW foraging and breeding/nesting areas as well as a strategic consideration of trees for future recruitment during harvesting. There are currently 16 active clusters.

Potlatch is currently developing a new HCP with the U.S. F&WS based on advances in science and experience with RCW needs for nesting, breeding and foraging. For example, experience has suggested that the original dispersed clusters were too isolated which limited the birds expansion of territory. Potlatch will create a 5,670 hectare contiguous RCW conservation area with recruitment sites containing artificial cavities. In 2004 five recruitment sites were installed, of which two are now occupied by breeding pairs. U.S. F&WS estimates that about 70 clusters could optimally be supported on 5,670 hectares of suitable habitat (about 80 hectares per cluster).



RCW colonization of unoccupied habitat is an exceedingly slow process as it requires the creation of cavities in living pine trees within open stands with little or no hardwood mid-story and few or no over-story hardwoods. Potlatch is adapting its management in the RCW conservation area to a modified shelter-wood/seed tree system and introduced prescribed fire in 2003 to manage mid-story reduction and encroachment objectives. The prescribed fire program has continued in successive years with slightly more acreage involved each time. Bachman's sparrow and brown-headed nuthatches also use habitat with these characteristics, and several other birds and small mammals will use the cavities excavated by RCWs.

Non-timber Forest Products and Revenues

Potlatch has a long history of community support. The company offers educational tours in its forestlands to schoolchildren and other interested groups. Potlatch leases 98% of its Arkansas forestland to hunting clubs who look for white-tail deer, wild turkey, squirrel, feral hogs and waterfowl. The company has pursued cooperative management opportunities with adjoining forestland owners, and has sought opportunities to sell conservation easements to interested conservation groups and land trusts. The revenue from the leases and conservation easements helps Potlatch meet shareholder return expectations as well as environmental objectives.

Chapter 4

Potential Role of Carbon Sequestration in Plantations

Carbon sequestration is one of several useful ecosystem services provided by forests and trees. Natural carbon sequestration is the absorption and storage of carbon (C) from the atmosphere in plants, soils, and other organic matter. Scientists estimate that human activities now release about seven billion metric tons or gigatons of carbon (GtC) annually into Earth's atmosphere. Of these emissions, approximately 30% are absorbed consistently by oceanic carbon sinks and from 15% to 30% are incorporated by plants and soils annually. The 40% to 55% of emitted carbon that is not absorbed by land or oceans remains in the atmosphere and traps solar heat that helps create a greenhouse effect.[1] The annual variability in land-based absorption especially stimulates interest in forests and plantations as managed carbon sinks to possibly mitigate carbon dioxide (CO_2) emissions.

Carbon sequestration naturally occurs when trees are growing and forests are maturing. With rising concern over the effects of rapid climate change, carbon sequestration may play an increasing role in the establishment and management of forest plantations.[2] In fact, the regeneration of forests in the eastern U.S. following agricultural abandonment in the early 20th century created a major carbon sink effect that measurably offset emissions from industrialization over the same period.[3] Major considerations in defining the role of sequestration in managed forests and plantations involve science, international policies, and economics.[4]

Forest or plantation management activities that substantially disturb or compact soils will generally result in a net carbon loss even if stem growth and related total forest basal area are enhanced by intensive management methods.

Science of Climate Change and Carbon Sequestration

Scientifically, research findings on global climate change have a high level of consensus. Planetary temperature trends correspond closely to atmospheric CO_2 levels, so the balance of carbon sources and sinks has great influence on global warming and cooling cycles. Since the advent of the industrial age, CO_2 concentrations in the atmosphere have increased by 30%, from 280 parts per million (ppm) in 1800, to 367 ppm in 1999.[5] About three-quarters of human-related CO_2 emissions are now due to fossil fuel combustion, and one-quarter due to land-use changes, particularly deforestation. Methods to slow human contributions to climate change are also well understood internationally, that is, restrain CO_2 emissions associated with fossil fuel use and slow rates of deforestation.

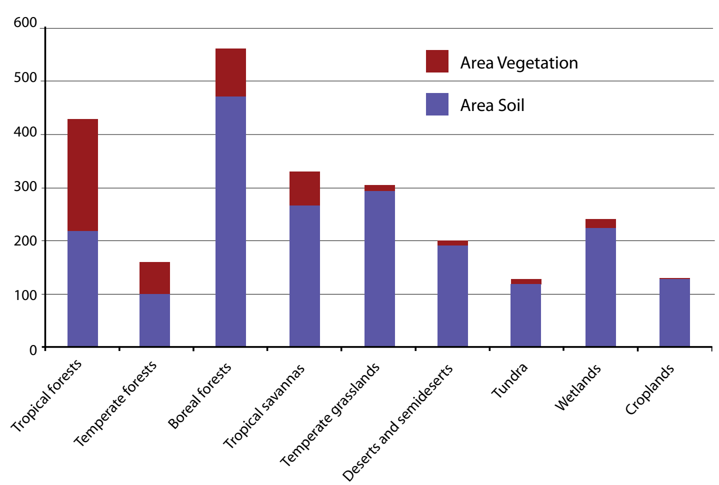
In contrast, natural carbon sequestration that may offset emissions still has large areas of scientific uncertainty. Globally, forests are among the largest reservoirs of carbon and absorb carbon much faster than oceans.[6] Approximately 1146 GtC are stored in the world's forested ecosystems.[7] To put this in context, 1 GtC emission mitigation per year is the equivalent of 1 billion cars operating at double their 2003 fuel efficiency.[8] Most of this sink lies below the living vegetation in forest duff and soils, but substantial amounts are in the woody trunks and stems. Due to this proportional difference, forest or plantation management activities that substantially disturb or compact soils will generally result in a net carbon loss even if stem growth and related total forest basal area are enhanced by intensive management methods.[9]

Total carbon stocks, as well as the proportion stored above and below ground, vary considerably among forest and vegetation types. Boreal forests are the largest overall carbon sinks whereas tropical forests have the largest proportion of stocks above ground. (See Figure 1 (below) "Global Carbon Stocks in Vegetation and Soils.") Increasing the global forest carbon sink could provide a measure of protection from future climate changes depending on several complex and interactive variables. [10]

Major current research issues include accounting for land-use and land-cover changes, dynamic feedback loops between changes in climate and changes in forests, potential for market sequestration in harvested wood products, and the relative permanency of any sinks. Balancing the cumulative uncertainties in the science of natural sequestration against the increasing urgency to do something about climate change suggests a need to incorporate sequestration holistically into plantation and forest management and to monitor results.

One large-scale experiment in Bolivia, the Noel Kempff Mercado Climate Action Project has attempted to avoid emissions of 7-10 millions tons of carbon during its 30-year life by protecting a 1, 619,400 hectare national park that was likely to be logged. This action is projected to offset in part logging activities elsewhere in the country and to generate carbon credits for North American power companies. Notably, 725 distinct carbon monitoring plots have been established (625 on-site, 100 on actively managed forest off-site) in order to verify actual carbon sequestration relative to non-protected sites. The Government of Bolivia will use these measurements to certify that any carbon credits generated are related to actual sequestration in the Noel Kempff Mercado National Park. [11]

Figure 1: Global Carbon Stocks in Vegetation and Soils (IPCC 2000)



International Policy and Sequestration

The Kyoto Protocol to the United Nations Framework Convention on Climate Change, an international agreement to reduce greenhouse gas emissions, was signed by 178 nations in 2001. The treaty came into effect in November 2004 and committed all parties to reducing greenhouse gas emissions by 5.2% from 1990 levels by the year 2012. The U.S. and Australia remain the only developed nations not to sign and ratify the treaty.

There are two major consequences of the fact that the US government has not agreed to reduce greenhouse gas emissions. First, government agencies and businesses in the U.S. are developing potential solutions outside the international consensus on how much and by what methods greenhouse gas emissions could be reduced or mitigated. Second, though the U.S. government publicly advocates for market-driven solutions, the lack of participation in Kyoto by the emitter of 25% of all global greenhouse gases is strangling carbon-emissions trading and mitigation markets in their infancy. This situation adds political and economic uncertainty on top of the scientific uncertainties for U.S. forest and plantation managers. It also creates possible first-mover advantages for managers outside the U.S. who can better respond to opportunities in national and international frameworks for CO_2 emissions reductions and mitigation.

Emerging Carbon-Markets and Sequestration

Notwithstanding the lack of U.S. government participation in Kyoto, many innovative pilot forest sequestration projects and carbon-trading schemes are emerging. These notably include the Chicago Climate exchange (CCX), a voluntary, multi-sector market for reducing and trading greenhouse gas emissions, in operation since 2001. Exchange members have made a voluntary, legally binding commitment to reduce their emissions of greenhouse gases by 4% below the average of their 1998-2001 baseline by 2006. As the market for carbon offsets develops, the Exchange will match up buyers and sellers of carbon reduction or mitigation credits creating, in theory, a more economically efficient framework for emissions reductions than may occur by pollution regulation alone. [12]

In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) convened an Intergovernmental Panel on Climate Change (IPCC), open to all members of the U.N. and WMO. The IPCC has suggested several feasible options to increase the annual uptake of carbon in forests that may generate tradable carbon credits. These include reducing forest conversion or deforestation, setting aside existing forests from harvest, converting marginal agricultural land to carbon plantations, lengthening rotation periods, extending the life of harvested products and improved management of forest fire and pests. Potential CO_2 contributions from each management alternative have been estimated for different forested regions globally.[13]

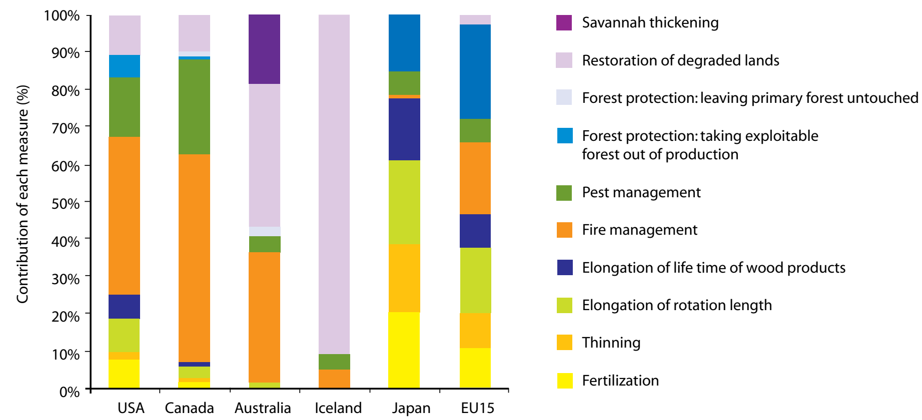
In North America, for example, improved management of forest fires and forest pests that transfer carbon from trees to the atmosphere by burning or decay offers the greatest opportunities for carbon sequestration, followed by restoration of forests on degraded lands, and longer harvest rotation cycles. These alternatives show surprising variation depending on the current status of regional forests, which could generate economic and forest conservation opportunities through market arbitrage. (See Figure 2 "CO_2 Management Alternatives.") For example, an industrial softwood plantation manager in the U.S. considering carbon sequestration may find it more cost effective to buy carbon credits generated from primary boreal forest conservation in Canada than to take industrial forestland out of production.

Carbon Sequestration and Plantations

Global interest in carbon sequestration may offer new economic *and* ecological prospects for forest plantations. As the markets for, and science of, natural carbon sequestration are in development, these opportunities will mainly occur as co-benefits of sound long-term management rather than as a new primary purpose for plantations. Since a large proportion of forest carbon lies at or below the soil horizon, plantation management that explicitly seeks to sequester carbon must focus on soil retention and improvement. Steep, erodable soils should be avoided for tree plantations especially in tropical regions. In addition to longer harvest rotations, the seasonal timing of logging, and the use of equipment and techniques that minimize soil disturbance, compaction and runoff are essential. Whereas the use of traditional heavy logging equipment during rainy seasons will result in soil loss in most situations, more modern low-impact harvester/forwarder systems used during dry or cold seasons can minimize erosion.[14] The use of this type of equipment also tends to reduce residual stand damage, improving plantation productivity.[15] The retention of coarse woody debris, large legacy trees, and dead or dying trees will also aid soil accumulation and reduce runoff.[16]

Careful monitoring protocols will be necessary to make the case that forest plantations are sequestering carbon beyond an estimated baseline for *status quo* activities. In fact, the more direct and finely grained the measurements of carbon stocks and rates, the more likely that documented sequestration activities can be translated into market tradable credits.[17] Independent certification of these activities will likely be necessary as well for international trading.[18] Existing

Figure 2: CO2 Management Alternatives (IPCC 2201)



independent forest certification schemes are already well-equipped to assess forest management practices. Additional criteria for carbon sequestration and measurement indicators should be developed and integrated.

In conclusion, industrial plantation owners and forest managers can improve the ecological benefits of their activities by structuring their management activities to generate net positive carbon sequestration through their operations.[19] This approach could also generate greater social consensus on the benefits of intensive forest management. For example, the U.S. state affiliates of the National Wildlife Federation at their 2005 annual meeting adopted a resolution on "Climate Change and Carbon Sequestration" supporting natural sequestration efforts that protect and restore wildlife habitat while reducing the buildup of greenhouse gases in the atmosphere.

Scientific uncertainty, international climate change policy and emerging carbon offset markets together mandate a holistic approach to incorporating sequestration into plantation and forest management. Land conservation that maintains and expands forest area and progressive forestry practices that especially maintain and build soil tilth can reliably sequester carbon. Alternatively, efforts to elevate one forest ecosystem service, such as carbon sequestration, over and above all other useful functions, will likely fail as they have historically for social, economic, or scientific reasons. Considerations of global climate change and related efforts to increase the role of carbon sequestration can make a positive contribution to plantation management and the practice of forestry.

Chapter 5

Biodiversity Exchanges: Linking Intensive Management and Conservation

While a variety of strategies for improving plantation management have been highlighted in this report, the possibility for plantations to actually relieve pressure on natural forests and enhance biodiversity through the concept of "biodiversity exchanges" or offsets has become a lively topic.

The worldwide growth in hectares under intensive plantation management has been met with legitimate concerns that biodiversity values will be eroded and, in many cases, dramatically compromised at both the site and the landscape level. While a variety of strategies for improving plantation management have been highlighted in this report, the possibility for plantations to actually *relieve* pressure on natural forests and enhance biodiversity through the concept of "biodiversity exchanges" or offsets has become a lively topic. This concept has both political and ecological appeal: it rests on the idea that increasing the output of wood fiber per unit of land can release forestland for other purposes.

This concept is attractive in areas of the world where plantation yields greatly exceed natural forest management and where the biodiversity values of primary or endemic forests are especially high. In these situations it may well make sense to concentrate production forestry in plantations while minimizing or preventing intervention in nearby natural forests. In other places that are less threatened ecologically, the purpose of an exchange might be to substitute low-intensive (natural forest) silviculture for intensively managed plantations with the goal of lessening the footprint over some landscape unit while maintaining (or increasing) an equivalent output of fiber. In either case, the forestland that is released through intensive plantations is theoretically available for conservation via set-asides, wildlands, and special habitat zones, as well as low-impact recreation, hunting and fishing, or other non-timber uses. Such an exchange theoretically creates a win-win solution between wildlife and biodiversity and the benefits of continued fiber output and local employment.

The biodiversity exchange theory has circulated in forest policy and management circles for roughly ten years.[1] But where has this approach been tried? How well has it worked? Is it a genuine and practically useful technique for landscape level forest management? What are the necessary ingredients for making such exchanges meaningful? Without secure conservation commitments, conservationists worry that such exchanges could merely be a smokescreen for further conversion of native forests. This chapter examines these issues and proposes a rough taxonomy for how such landscape level bargains between plantation management and conservation zones might go forward. We will also ask several questions that need to be explored by forestry experts, researchers, and practitioners.

Forest Valuation – Some Key Considerations

The economic value of complex forests is typically measured in two ways: what can be commercially grown and removed for timber and fiber, or what are the types of non-forest uses that could occupy the same area (for example, agriculture or development). For a very small percentage of forests there are seasonal or spot markets for other forest services, such as privatized hunting, harvesting of medicinal plants, or drinking water supply. In general, society has not found a way to capitalize and reward landowners for the value of ecological services provided by complex forests. Thus, whether it is conversion to parking lots or intensive plantation management, the incremental loss of biodiversity is a cost that is borne by society at large. In economists' terms these costs have been externalized.

Biodiversity values, especially those that benefit society at a landscape level, such as carbon sequestration, habitat for wildlife, or the filtering of air and water, are likely to have "public goods" attributes. This means, in essence, that they are shared by all. Without a well-defined market or well-defined property rights for biodiversity services, private landowners have little incentive (other than their personal land ethic and sense of community) to provide these services for free. Public goods typically require some kind of investment (or compensation) by society as a whole if they are to be preserved.

Biodiversity exchanges that seek to offset management intensity with conservation can be expected to bring up tricky issues of valuation. In setting up such an exchange or offset program, which costs should be borne exclusively by the landowner/forest operation and which should be borne by society as whole? For example, what is fair ecological compensation to society for the "permission" (via regulatory standards, a certification system, tax policy, or broader social contract) to practice intensive plantation forestry? Some would argue that keeping trees growing under *any* management system creates societal value that exceeds any incremental loss in biodiversity (for example, because of carbon uptake or resisting conversion to non-forestry uses). Conversely, what is fair compensation to a company practicing intensive plantation management for pulling *other* lands out of production, or for having to buy and retire timber production from nearby lands in order to ensure a certain output of biodiversity services?

The answer to such questions is, of course, a matter of degree. It is the degree to which society is willing to pay, the degree of scarcity or uniqueness of the forest and habitat types under question, the degree of external threats from conversion or development, and the degree to which biodiversity outputs (or benefits) can be measured and verified. Many of these questions are unknowable until they are answered in their specific context, in a specific forest landscape with a willing forest operation and willing stakeholders (including government.) As will be argued at the end of this chapter, NWF thinks the best place to start figuring these questions out is, prophetically, at the beginning! It is very hard to sort out these issues in the abstract. Experimentation, application in real forest/plantation settings, and monitoring of results is needed.

Biodiversity Exchanges As Mitigation: Sell Out or Sensible?

Fundamentally, a landscape-level exchange of conservation for intensive plantation forestry is a *mitigation* strategy. It is an explicit compromise between complete exploitation of the growing capacity of the land (for example, planting fence row to fence row) and a strictly preservationist approach. In addition to the valuation questions discussed above, it is important to acknowledge that for mitigation to succeed, requires an agreement about *what exactly* is being mitigated and *how to verify* whether the mitigation has served its purpose. This brings up a complementary set of policy questions, several of which may inform the design of a biodiversity exchange. For example, the following questions may arise:

- Is the goal of mitigation to achieve an equivalent output of biodiversity or to simply minimize its loss? In other words how much biodiversity loss/gain do we expect from a landscape exchange between plantations and conservation zones?
- Are the physical or environmental values being exchanged or offset substitutable? Is it more justified and reasonable to create exchanges involving the same forest types and species associations rather than leapfrogging across ecological borders? Leapfrogging may be convenient in terms of securing acreage set-asides but inadequate in securing commensurate biodiversity values.

– How well can we measure and verify whether an exchange approach is likely to work? What are the right proxies or metrics for undertaking such exchanges, especially if a "precautionary principle" approach is applied?

Towards a Set of Ground Rules for Biodiversity Exchanges

Based on NWF's research, there is limited experimentation underway around applying the exchange concept in forested landscapes. Although some models are emerging, it would be premature to say that a consensus view or a systematic approach has been developed. The science about how to construct and measure such exchanges is still largely untested and most countries or states lack either a regulatory framework or the tax and economic incentives to promote such exchanges.

Not surprisingly, the areas of high biodiversity in a given landscape often coincide with sites that are the most productive for intensive forestry. Thus, the application of an exchange or offset approach has been primarily within-unit set-asides or reserve areas held and managed by the same landowners within a contiguous management boundary. Off-site mitigation or exchanges have not been developed that are specific to forest management as a whole. (There have been, however, exchanges for specific forest attributes such as wetlands mitigation or carbon offsets.) [2] To the extent that such exchanges are seen as acceptable, the use of voluntary programs, such as third-party certification, may offer the best opportunity for developing such approaches in the future.

The policy decision about whether to promote such exchanges starts with several important assumptions. In encouraging this debate and in recognizing the potential risk for such exchanges to fail, NWF feels it is important to be clear about the biases that we bring to this issue. These biases deserve to be debated and tested in the field.

– *Plantations **can** have a role in landscape-level forest conservation*, especially if they are sited and managed in such a way as to *meaningfully and demonstrably* contribute to conservation objectives. This is especially true for the many regions of the world where plantations can be a restoration tool for previous intensive agriculture, a necessary rural employment strategy, or the first line of defense in conversion to other non-forest uses. There is a threshold question as to what kinds of plantation systems should be encouraged to participate in biodiversity exchange projects.

– *The theory behind a biodiversity exchange is attractive*, but application of this theory is in its infancy. Much more experimentation and empirical analysis is needed before it can be widely adopted or be seen as a genuine tool in biodiversity conservation. Without strong economic incentives and a landscape-level registry under which exchanges can occur and be monitored, the concept will likely only be practiced in the form of within-unit set-asides or reserves by individual landowners and managers.

– *The level of mitigation achieved through exchanges should necessarily vary with the size and intensity of the forestry operation.* For example, small family forest plantations of less than 100 hectares, have different (and perhaps no) obligations to provide set-asides or offsets compared to the obligations of larger private or public estates (for example, greater than 1,000 hectares).

– *If the scale or management system prevents within-unit offsets, biodiversity exchanges or offsets should be provided as close to the operation as possible, preferably adjacent to intensive plantation management units.* However, to the extent that tenure or land constraints prevent this, offsets should be limited to the same forest type and preferably within the same watershed so that commensurate biodiversity values are secured. While there is a role and likely need for discontiguous offsets in certain settings, it is likely that both political and managerial challenges will increase as a function of distance.

– *Certain forested areas should be set aside (or restored) for their intrinsic conservation status or biodiversity values.* Not all forests should be eligible to participate in such exchanges, although currently protected areas, such as public lands may serve as offsets if their linkage to a plantation system can be justified. In many cases this will require a careful refinement of the values and attributes to be protected in endangered forests or high conservation value forests since these can be productive growing sites at the proper scale and intensity.

– *Exchanges should not be used to excuse, or inadvertently promote, blatantly bad performance within the plantation unit.* Minimum environmental and social performance and best practices standards must be upheld for intensive plantation management, especially in regions that are ecologically sensitive or where regulatory and stakeholder processes are weak.

Approaches to Achieving Biodiversity Exchanges

As mentioned above, most forest offsets have been *within-unit* set-asides or reserves under the same ownership since these areas are under the direct control of the forest operation. We expect that this will continue to be the predominant form of mitigation for local biodiversity issues. However, several approaches have emerged in different areas of the world that have applicability at the landscape level across multiple ownerships. Some of these models have been carefully researched, even though there is still little widespread implementation or recognition. And because these approaches are still relatively new there is little if any long-term data by which to measure their success. Testing and monitoring of different approaches to offsets needs encouragement and support. Existing tools such as FSC regional standards, state or provincial best management practices, and related forestry guidance or regulatory reviews are a good place for this dialogue to occur.

Three approaches are discussed here. While they are not the most definitive, they are representative of the diversity between different land ownerships and forest types under which they were conceived. The term "triad approach" was initially coined in the northeastern U.S. by Robert Seymour and Malcolm Hunter. The New Zealand "self regulatory" approach was developed by the country's prominent landowner association and various key stakeholders after years of wrangling. And the "mosaic landscape" approach has been applied by large private landowners, such as Klabin and Veracel in South America. Each of these approaches is briefly profiled here.

The Triad Approach

In the mid-1990s Seymour and Hunter first proposed the triad approach, which is widely seen as a thoughtful model for balancing intensive and so-called "new forestry" approaches in the North American landscape context.[3] In essence, the triad consists of a balance, but not necessarily a proportionate distribution, of core reserves, intensive production plantations, and lightly managed natural or matrix forests. Seymour and Hunter have since reframed the original triad concept as "balanced forestry" that begins with a landscape view and works down to the stand level. The key to the model, in Seymour's words, is *"[t]he allowable cut effect for expanded production forestry is taken in the form of ecological reserves, not expanded harvest levels."*[4]

Already there is experimentation with aspects of this model on some of the large private concessions in Canada under a demonstration program.[5] The triad or balanced forestry model proposes general criteria for plantations, reserves and matrix areas. Plantations, for example, should be sited in recently or historically disturbed sites, on productive soils with no more than 10% slope, and a maximum area of 100 hectares.[6] Ecological reserves should include existing conservation areas, large tracts of undisturbed forest, (for example, preferably > 500 hectares), as well as wetlands, steep slopes, and high elevation areas.[7]

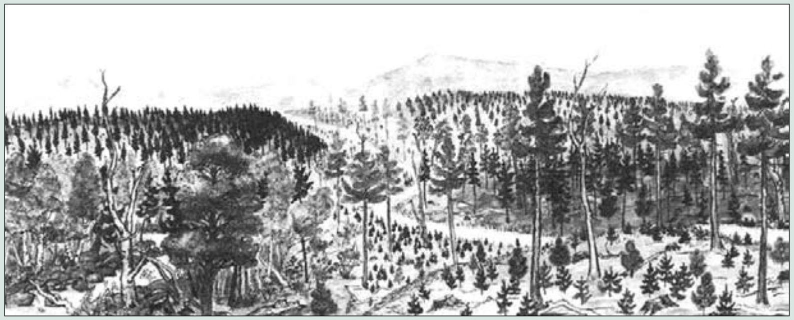
The authors suggest that getting proper definition and implementation of ecological forestry on the matrix lands component may be the hardest part of the model to implement. This is due in part to a clear trade-off between plantations and reserves, while the criteria for a matrix forest are more subjective and in many instances require longer time horizons (for example, achieving vegetative diversity or providing for biological legacy trees).

The TRIAD Concept of Forest Land Allocation

Ecological Reserves

New Forestry

High-yield Plantations



Arrangement of the TRIAD on the landscape

New Zealand Plantation Standards

Following an extensive stakeholder consultation arising from the groundbreaking 1991 Forest Accord, which established principles for plantation management, the New Zealand Forest Owners Association unveiled a new plantations standard in August 2005. [8, 9] While the standards are voluntary, several aspects are worth noting for their contribution to the connection between plantation management and biodiversity, and the role of offsets and set-asides. Below are some highlights:

- Strong definitions for "natural forest" and "reserves" including minimum set-aside areas of 5 hectares consisting of native overstory species that can grow to at least 30 cm dbh, and 1-5 hectare set-aside for native species with average height of 6 m
- Clear standard of responsibility by the plantation manager for the release of fugitive seedlings (termed "wildings") on adjoining lands and continued prohibition on GMO (genetically modified organisms) trees
- Explicit language against conversion of native forest types, along with plantation design and management criteria that consider adjoining properties and forest values
- Management planning that addresses non-timber values, encourages harvest plans for each unit, and requires a minimum 5 meter setback on all riparian areas

Mosaic Landscape Approach

The mosaic landscape approach is being practiced on several large-scale (150,000-350,000 hectares) plantation units in Latin America. Because of the scale of these efforts, the approach is instructive for how offsets might work under more fragmented ownerships where decisions are needed between production and conservation zones, and acompensation scheme arranged. Case Study #4 on page 23 describes Klabin's mosaic landscape efforts, visually shown in the image above. Another good example of the mosaic landscape approach to plantation management is demonstrated by Veracel's operation in Bahia State in Brazil. Eucalyptus plantations are located on higher elevation plateaus and in previously degraded land areas. They are also set back from the natural watercourses to minimize runoff and disturbance to the natural water cycles, while the remaining natural Atlantic rainforest type is preserved in the valleys. [10, 11]

More Real Projects and Incentives Needed

Each of the models discussed above start with a "precautionary approach" to respecting and preserving biodiversity values within a working landscape. Compared to the agricultural model that has dominated most tree plantation systems, NWF sees the evolution of ecological models in plantation management as a significant and positive change for biodiversity conservation. This is the direction in which complex plantation forestry needs to move.

This evolution has led to experimentation and robust models of within-unit biodiversity offsets through the use of set-asides, reserves, or conservation zones. These examples deserve broader recognition and replication in areas of intensive plantation forestry such as in the southeastern United States. It remains to be seen whether this evolution can lead to models that create meaningful *offsite* biodiversity exchanges. With the major questions, biases, and caveats discussed in this chapter as a guide, NWF encourages such experimentation to move forward.

Chapter 6

Endnotes

Chapter 1: Introduction

[1]Center for International Forestry Research (CIFOR), "Typology of Planted Forests" *CIFOR infobrief* (15 March 2002).

[2]P. J. Kanowski, "Plantation Forestry for the 21st Century," XI World Forestry Congress, 13-22 October, 1997, Proceedings, XI World Forestry Congress.

[3]J-M Carnus, et al., "Planted Forests and Biodiversity," presented at UNFF Intersessional Experts Meeting on the Role of Planted Forests in Sustainable Forest Management, New Zealand, March 24-30, 2003; available at *www.maf.govt.nz/mafnet/unff-planted-forestry-meeting/conference-papers/planted-forests-and-biodiversity.htm*; Internet, accessed 13 October, 2003.

[4]Ibid.

[5]Ibid.

[6]ABARE and J. Poyry, "Global Outlook for Plantations," paper for Intergovernmental Forum on Forests, (Canberra, Australia, 1999).

[7]D.N. Wear and J.G. Greis, "Southern Forest Resource Assessment: Summary of Findings," *Journal of Forestry* 100, no. 7 (2002).

[8]Ibid.

[9]Ibid.

[10]D. N. Wear and J. G Greis, eds., "Chapter 5: Maintaining Species in the South," in the *Southern Forest Resource Assessment*, *Gen. Tech. Rep. SRS-53*(Asheville, NC: Southern Research Station, Forest Service, U.S. Department of Agriculture, 2002).

[11]NatureServe, "U.S. Species at Risk: A State-by-State View," in *Biodiversity Insights*, No. 1, (2002); available at *www.natureserve.org/consIssues/usSpeciesatRisk.jsp*; Internet, accessed November 2, 2005.

[12]F. Cubbage, et al., "Comparative Timber Investment Returns for Selected Plantations and Native Forests in South America and the Southern United States," notes accompanying speech presented at the Annual Southern Forest Economics Workers (SOFEW) Meeting, April 18-20, 2005, Baton Rouge, Louisiana.

[13]D. N. Wear and J. G. Greis, eds., "Chapter 6: Land Use" in the *Southern Forest Resource Assessment*, *Gen. Tech. Rep. SRS-53* (Asheville, NC: Southern Research Station, Forest Service, U.S. Department of Agriculture, 2002).

[14]D. N. Wear, "Assessing Market Impacts on Forest Conditions in the US South," notes accompanying presentation at Global Markets Forum in Orlando, Florida, February 15-17, 2005.

Chapter 2: Incorporating Plantation Management Strategies That Support Biodiversity

[1]D. B. Lindenmayer and J. F. Franklin, *Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach* (Washington: Island Press: 2002).

[2]M. A. MacDonald, "The Role of Corridors in Biodiversity Conservation in Production Forest Landscapes: a literature review," *Tasforests* Vol. 14 (2003).

[3]D. Salt, D. Lindenmayer and R. Hobbs, *Trees and Biodiversity: A Guide to Australian Farm Forestry*, (Australia: Joint Venture Agroforestry Program, 2004).

[4]Lindenmayer and Franklin, *Conserving Forest Biodiversity.*

[5]Ibid.

[6]A. W. Allen, Y. Bernal, and R. Moulton, "Pine Plantations and Wildlife in the Southeastern United States: An Assessment of Impacts and Opportunities," Information and Technology Report 3, U.S. Department of the Interior, National Biological Service, January 1996.

[7]D. B. Lindenmayer, R.J. Hobbs, and D. Salt, "Plantation Forests and Biodiversity Conservation," *Conference Proceedings on Prospects for Australian Plantations* (Canberra: Bureau of Rural Sciences, 2002).

[8]Lindenmayer and Franklin, *Conserving Forest Biodiversity.*

[9]M. J. Hartley, "Rationale and Methods for Conserving Biodiversity in Plantation Forests," *Forest Ecology Management*, no.155 (2002).

[10]Lindenmayer, Hobbs, and Salt, "Plantation Forests and Biodiversity Conservation."

[11]Hartley, "Rationale and Methods for Conserving Biodiversity."

[12]P. D. Erskine, "Diversity and Production in Tropical Reforestation" presented at Production Versus Rainforest Biodiversity: Trade-offs or Synergies in Farm Forestry Systems? Conference, Cairns, Australia, November 10, 2003.

[13]Allen, Bernal, and Moulton, "Pine Plantations and Wildlife."

[14]Cooperative Research Centre for Tropical Rainforest Ecology and Management, *Rainforest Plantation – Restoring Productivity and Biodiversity to Degraded Lands* (May 1999).

[15]Virginia Department of Game & Inland Fisheries, *Managing Pine Stands for Wildlife*, (2004); available at *www.gdif.state.va.us/wildlife/habitat_partners/infosheets /managing_pine_stands.html*; Internet, accessed 1 September 2004.

[16]M. J. Hartley, "Biodiversity Consequences of Wood Production in Intensively Managed Plantations versus Dispersed, Low-intensity Management across the Landscape," presented at Intensive Plantation Forestry in the Pacific Northwest: Assessment of Future Potential &

Economic, Environmental & Social Implications Conference, Portland, Oregon January 20-22, 2004.
[17]Allen, Bernal, and Moulton, "Pine Plantations and Wildlife."
[18]J. Evans and J. Turnbull, *Plantation Forestry in the Tropics* (New York: Oxford University Press, 2004).
[19]C. Moorman and R. A. Hamilton, "Developing Wildlife-Friendly Pine Plantations," in *Woodland Owner Notes*, North Carolina Cooperative Extension Service (2000); available at *www.ces.ncsu.edu/forestry/wildlifepubs.htm*; Internet, accessed September 1, 2004.
[20]D. B. Lindemayer and J. F. Franklin, "Managing Stand Structure as Part of Ecologically Sustainable Forest Management in Australian Mountain Ash Forests," *Conservation Biology* Vol 11, No 5 (1997).
[21]Personal conversation with Dr. Brenda McComb, June 29, 2005.
[22]C. Moorman and R. A. Hamilton, "Developing Wildlife-Friendly Pine Plantations."
[23]Pacific Northwest Research Station, *Ecological Foundations of Biodiversity: Promoting Habitat Complexity in Second-Growth Forests* (Portland, OR: USDA Forest Service, 2003).
[24]R. J. Mitchell, et al., "Natural Disturbance-Based Silviculture for Restoration and Maintenance of Biological Diversity," (National Commission on Science for Sustainable Forestry, 2003).
[25]P. S. Muir, et al., Managing for Biodiversity in Young Douglas-Fir Forests of Western Oregon, Biological Science Report USGS/BRD/BSR-2002-0006 (U.S. Geological Survey: 2002).
[26]A. Carey, "Active Intentional Management (AIM) for Biodiversity and Other Forest Values," presented at Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry Conference, Portland, Oregon, August 15-20, 2004.
[27]J. F. Franklin, et al., "Ecosystem Disturbance and Response: Central Role of Biological Legacies," submitted to Ecosystems, 2003.
[28]Lindemayer and Franklin, "Managing Stand Structure."
[29]Pacific Northwest Research Station, *Ecological Foundations of Biodiversity.*
[30]S. E. Moore and H. L. Allen, "Plantation Forestry" in *Maintaining Biodiversity in Forest Ecosystems* (Cambridge University Press: Cambridge, Great Britain, 1990.)
[31]J. Hayes, "Impacts of Intensive Plantation Management on Biodiversity within Stands," presented at Intensive Plantation Forestry in the Pacific Northwest: Assessment of Future Potential & Economic, Environmental and Social Implications Conference, Portland, Oregon, January 20-22, 2004.
[32]Personal conversation with Dr. Brenda McComb, June 29, 2005.
[33]Hartley, "Rationale and Methods for Conserving Biodiversity."
[34]Pacific Northwest Research Station, Ecological Foundations of Biodiversity.
[35]Lindenmayer, Hobbs, and Salt, "Plantation Forests and Biodiversity Conservation."
[36]Georgia Forest ★A★Syst Forest Resources Management, "Forests and Wildlife"; available at www.gfc.state.ga.us/Resources/Publications/ForestManagement/ ForestsAndWildlife.pdf; Internet, accessed February 2005.
[37]National Wildlife Federation, Clean Water Act: Wildlife and Wild Places Under Threat, February 2006.
[38]Lindenmayer and Franklin, Conserving Forest Biodiversity.
[39]Oregon State University Forestry Executive Committee, McDonald-Dunn Forest Management Plan -- June 2005; available at www.cof.orst.edu/cf/forest /mcdonald/plan/ files/mcdunn_plan.pd; Internet, accessed August 2005.
[40]Center for Applied Conservation Biology at the University of British Columbia, "An Ecological Rationale for Changing Forest Management on MacMillan Bloedel's Forest Tenure"; available at www.forestbiodiversityinbc.ca/forest_strategy/pdf/ EcologicalRationale.pdf; Internet, accessed September 16, 2005.
[41]R. J. Mitchell, et al., "Natural Disturbance-Based Silviculture."
[42]C. Moorman and R. A. Hamilton, "Developing Wildlife-Friendly Pine Plantations."
[43] Lindenmayer, Hobbs, and Salt, "Plantation Forests and Biodiversity Conservation."
[44]Personal conversation with Bill Beese, Cascadia Forest Products, September 15, 2005.
[45]Greater Okefenokee Association of Landowners, website *www.srs.fs.usda.gov/r8 /goal/*.

Chapter 4: Potential of Carbon Sequestration in Plantations

[1]Intergovernmental Panel on Climate Change (IPCC) Working Group I, *Climate Change 2001: The Scientific Basis* (The IPCC Secretariat: 2001).
[2]L. C. Irland and M. Cline, *Role of Northeastern Forests and Wood Products in Carbon Sequestration*, (Washington DC: CONEG Policy Research Center, 2001).
[3]R. A. Houghton, et al., "The U.S. Carbon Budget: Contributions from Land-Use Change, *Science* (1999) 23: 574-578, and C. L. Goodale, et al., "Forest Carbon Sinks in the Northern Hemisphere," *Ecological Applications* (2002) 12.
[4]G. C. Hurtt, et al., "Projecting the Future of the U.S. Carbon Sink," *Proceedings of the National Academy of Sciences* (2002) 99.
[5]IPCC, Working Group I.
[6]J. M. Adams, *Estimates of Total Carbon Storage in Various Important Reservoirs,* (Oak Ridge, TN: Environmental Sciences Division, Oak Ridge National Laboratory, 2005); available at *www.esd.ornl.gov/projects/qen/carbon2.html*; Internet, accessed November 12, 2005.
[7]R. K. Dixon, et al., "Carbon Pools and Flux of Global Forest Ecosystems," *Science* (1994) 263:185-190.
[8] J. J. Dooley, "Carbon Capture and Sequestration as a Means for Managing Carbon Dioxide Emissions," presented at IEA Asia Pacific Conference on Zero Emissions Technologies, Queensland, Australia, February 17-19, 2004; available at www.iea.org/Textbase/ work/2004/zets/conference/presentations/dooley.pdf ; Internet accessed 07 February, 2006.

[9] D.W. Johnson, and P. S. Curtis, "Effects of Forest Management on Soil Carbon and Nitrogen Storage: Meta Analysis," *Forest Ecology Management* (2001)140:227-238.
[10] R. G. Newell and R. N. Stavins, "*Climate Change and Forest Sinks: Factors Affecting the Costs of Carbon Sequestration," Journal of Environmental Economics and Management* (2000) 3.
[11] FAN (Fundación Amigos de la Naturaleza), Noel Kempff Mercado Climate Action Project/ Carbon Monitoring (2005), available at *www.noelkempff.com/English/CarbonMonitoring.htm*; Internet, access November 20, 2005.
[12] R. N. Stavins and R. Richards, *The Cost of U.S. Forest-Based Carbon Sequestration,* (Arlington, VA: Pew Center on Global Climate Change, 2005).
[13] IPCC, Working Group I.
[14] R. D. Perlack, et al., *Biomass Fuel from Woody Crops for Electric Power Generation* (Oak Ridge National Laboratory: 1995).
[15] B. Limbeck-Lilienau, *Residual Stand Damage Caused by Mechanized Harvesting Systems,* University of Natural Resources and Applied Life Sciences, Vienna, Austria (2003).
[16] J. F. Franklin and K. Kohm, *Creating a Forestry for the 21st Century: The Science of Ecosystem Management,* (Washington: Island Press: 1997).
[17] K. Johnsen, et al., "Carbon Sequestration in Loblolly Pine Plantations: Methods, Limitations, and Research Needs for Estimating Storage Pools," *Gen. Tech. Rep. SRS–75* (Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station, 2004).
[18] FAN.
[19] Z. Harkin and G. Bull, *Towards Developing a Comprehensive Carbon Accounting Framework for Forests in British Columbia,* Interim Report IR-00-46. International Institute of Applied Systems Analysis, Vienna, Austria.

Chapter 5: Biodiversity Exchanges: Linking Intensive Management and Conservation

[1] R. Sedjo and D. Botkin, "Using Forest Plantations to Spare Natural Forests," *Environment* 39(10), 1997.
[2] I. Powell, A. White, and N. Landell-Mills, Developing Markets for Ecosystem Services of Forests (Washington DC: Forest Trends, 2002).
[3] R. S. Seymour and M. L. Hunter, Jr., "New Forestry in Eastern Spruce-Fir Forests: Principles and Applications to Maine," *Miscellaneous Publication 716 of the Maine Agricultural Experiment Station*, April 1992.
[4] R. S. Seymour, *"Production Forestry and Ecological Forestry: Discord or Harmony"* presented at New England Society of American Foresters Meeting, March 25, 2004, Quebec City, Quebec, Canada.
[5] D. MacLean et al., "Management Implications of Forest Dynamics, Succession, and Habitat Relationships under Differing Levels of Silviculture in New Brunswick Forests"; available at *www/sfm1.biology.ualberta.ca/english/projects/en_macleandmana11.htm*; Internet, accessed October 11, 2005.
[6] Seymour, "Production Forestry."
[7] Ibid.
[8] *The New Zealand Forest Accord* signed August 14, 1991; available at *www.nzfoa.org.nz/file_libraries/agreements_accords/new_zealand_forest_accord*; Internet, accessed June 13, 2005.
[9] New Zealand Forest Owners Association Incorporated, "*National Standard for Environmental Certification of Plantation Forests in New Zealand* – August 2005"; available at *www.nzfoa.org.nz/file_libraries/standards_guidelines/national_standard_for_sustainable_plantation_forest_management*; Internet, accessed August 20, 2005.
[10] Available at *www.veracel.com.br*; Internet, accessed February 13, 2006.
[11] Stora Enso, "The Veracel Vision – A Model of Sustainability," *Sustainability 2003*.

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