Chapter 17

The Search for Compatibility: What Have We Learned?

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1. Introduction

Forest management that seeks compatible production opportunities across several forest resources is the essence of compatible forest management. Most landowners and many land managers are keenly aware that their management actions produce a range of goods or services that contributes to both their personal prosperity and to societal well-being. It is this diversity of ownerships—each with different management objectives—that has a positive influence on compatibility when considered at the landscape scale.

Many of the examples in this book illustrate the inherent ambiguity in describing forest management. Forest prescriptions (plant, thin, harvest) may seem like relatively mechanistic strategies but it is often difficult to describe actual forest management because of the inherent uncertainty in various biophysical and socioeconomic processes and responses. In addition, the prescriptions must be site specific. This uncertainty lends a fuzzy—as opposed to definitive—nature to discussions of forest management. This lack of clarity is due to ambiguous treatment of scale, role of scientific information, specificity of local conditions, and selectivity in a strategic sense.

The experiences described in the various chapters emphasize that discussions of forest management should be addressed at the appropriate **scale**. For example, broad-scale discussions on the effects of forest management

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(e.g., the increased areal extent of softwood plantations) deal with the accumulation of numerous fine-scale effects and decisions by landowners. But these discussions at the broad scale set the context for decisions at the stand level. Much of the recent discussion (see Haynes et al. 2001) about the adoption of ecosystem perspectives for forest management deals with the necessity of shifting broad-scale management direction to specific management practices applied at the stand level.

Many chapters in this book implicitly assert that forest management should rest on the best **science** available. The first step is using the best available science to develop management practices. Scientists often play a key role in identifying and describing the utility of these practices. The best available science includes synthetic efforts that connect disparate research, including theoretical, experimental, and empirical approaches. Some chapters reveal how some scientific facts and, consequently, management practices have changed over time. This changing nature of science might raise questions about the confidence that should be placed in science-based management. But it is more productive to ask about the extent to which scientific knowledge is provisional. Everything that science uncovers is subject to reexamination as new information is revealed. The development of science is an incremental process that moves toward a more complete understanding of the observable world. At the same time, changes in economic and societal values modify the objectives of land management, altering the worth of different types of information. For example, the growing importance of western hemlock (*Tsuga heterophylla* (Raf.) Sarg) as a managed species creates the need for understanding the wood quality properties of managed hemlock.

The **specificity** of local conditions needs to be explicitly considered before management practices are applied. Too often we see a devolution into one-size-fits-all types of thinking in contemporary forest management. In the Pacific Northwest (western Oregon and Washington, coastal British Columbia, and southeastern Alaska) for example, we often see riparian buffer widths on public lands expressed as one tree height, regardless of the underlying biophysical conditions. Management prescriptions should depend on the site conditions and other local management conditions. General prescriptions are less likely to take advantage of localized differences, and, consequently, are less efficient in achieving the desired outcomes. Regrettably, these general prescriptions are defended by those who are adverse to risk (i.e., regulators wishing to avoid as much risk as possible), given their bias for cautionary practices. We need to develop management prescriptions on a site-by-site basis that consider variations in stand density, age, species composition, and history. We also need to consider that most of our research is confined to a relatively narrow range of conditions and stand origins, and its application for any stand will have to be partially tailored to local conditions.

Management should be **strategically selective**. Each landowner or manager approaches forest management with a different set of perspectives reflecting their objectives for managing the stand or forest in question. The requirements imposed by the regulatory environment (e.g., Forest Practices Code of British Columbia 1994, USDA and USDI 1994b) will influence the selection and application of different management practices. Although this regulatory environment is fixed at a given moment, it can be altered in response to changes in societal values and landowner actions. For example, by buffering roads or streams, landowners may achieve greater social acceptability for harvesting or thinning activities than by not buffering.

Perhaps the strongest example of management that is strategically selective is the adoption of variable retention in 1999 by Weyerhaeuser Co. Canada (Weyerhaeuser 2000). In 1998, the forest products company McMillan Bloedel publicly announced it had stopped clearcutting and adopted variable retention on private and tenured Crown forests in British Columbia. One year later the company was purchased by Weyerhaeuser. In effect, Weyerhaeuser purchased an unwritten social contract (no clearcutting) along with McMillan Bloedel's forestry assets. The lack of a well-developed scientific basis for alternatives to clearcutting did not allow this implicit contract to be suspended or broken. As a result, conversion to a variable-retention management system that addresses multiple forest values is being implemented in British Columbia and pilot research programs are in place (Weyerhaeuser 2000).

2. Examination of the Proposition from Chapter 1:

In Chapter 1, we stated a proposition regarding compatibility:

> *Commodity production (timber and nontimber forest products) and the other forest values (biodiversity, fish and wildlife habitat) can be simultaneously produced from the same area in a socially acceptable manner.*

We will examine the proposition by using an evidentiary approach to weigh information before rendering a final judgment. First, we will use direct evidence that includes results from empirical studies. Second, we will use syntheses of empirical data and expert judgments to develop an understanding of how management actions influence forest changes.

2.1. Major Themes

We begin by examining the evidence with respect to eight major themes.

(1) Multiple resource objectives. Perhaps the most distinctive feature of compatible forest management is the emphasis on joint production. Wood production was the dominant forest management objective in the Pacific Northwest for nearly a century. An ongoing debate on sustainability, ecological integrity, forest health, and social acceptability of forest management has been boiling for several decades. Our focus on the joint production of several forest resources is a direct response to this acrimonious debate, which is all too often characterized by dichotomous arguments to the extreme. Either-or choices and extreme arguments regarding a multiresource system are not fruitful.

We adapt the simple concept of Pareto optimality, which does not require a market. The idea is that a management action that increases the production of at least one desirable good without decreasing any other will increase social utility. Simply put, someone is better off and no one is worse off.

Economists expand this idea to the production possibility frontier, which Montgomery (Chapter 2) aptly applied to our problem of compatible forest management. She presents a hypothetical production possibility set for two outputs, wildlife and timber. The combinations of outputs represented by points inside the frontier are inefficient in the sense that one output can be increased at no cost to the other output. If the frontier accurately measures the productive capacity of the site and represents the outputs that matter to society, society will benefit by increasing at least one output while decreasing none. Other forest uses, besides wildlife and timber, may also be modeled (e.g., reductions in fire risk, recreation use, water yield, and aquatic species).

Our premise is that multiple resources can be managed simultaneously—at some scale—while producing wood. The difficulty enters when we add the caveat: in a socially acceptable manner. With it, forest values must be measured, or at least seriously examined, which is an inherently difficult task.

(2) Scale. Examine first the stand scale where management is actually implemented. As we learned after the Multiple-Use Sustained Yield Act of 1960, it is difficult to do everything in one small place. However, this does not mean that stands cannot be managed with multiple objectives. In Chapter 14, for example, Carey found that commercial thinning (wood production) could be used as an effective management tool for promoting wildlife habitat and increasing structural diversity. Also, Wipfli et al. (Chapter 3) found that even without thinning, there was greater understory species diversity in alder (*Alnus* spp.)-dominated second-growth stands than in adjacent second-growth spruce/hemlock (*Picea/Tsuga*) stands. Hence, alder provided increased structural diversity as well as promoting wildlife habitat. Monserud (Chapter 5) surveyed several stand management experiments that focus on joint production of wood and at least one other resource such as biodiversity. Each author is looking for alternatives to the intensive management regime (clearcutting followed by site preparation and planting) that has dominated managed Pacific

Northwest forests since the 1950s. Opportunities for compatible management of understory resources vary widely across forest developmental stages, management approaches, and land classes (Chapter 12). Opportunities will also vary due to site conditions, even across relatively small spatial scales, and that makes management of understory species particularly problematic.

At the watershed and landscape scale, which might consist of several thousand contiguous stands, it becomes easier to address several resource goals simultaneously. As Swanson et al. (Chapter 9) point out, it is important to consider the role of disturbance regimes in order to sustain native species and ecological processes. As we saw in the work of Cissel et al. (1999), an entire watershed (Blue River, Oregon) can be effectively managed with an overriding structural goal such as mimicking an historical disturbance regime (fire, in this case). The result increases the ecological integrity of the watershed from both wildlife and aquatic perspectives. Blocks of contiguous stands are treated as units, with the particular prescription depending on structural condition and disturbance risk. Wood is produced through a series of thinnings and harvests almost as a byproduct of the overall management goal. Fragmentation is considerably reduced compared to the Standards and Guides from the Northwest Forest Plan (USDA and USDI 1994a,b).

There is a growing recognition that aquatic ecosystems are dynamic in space and time and that periodic disturbances may contribute to their long-term productivity (see Chapter 9). Benda et al. (1998) model how aquatic systems respond to periodic disturbances such as wildfire, rain, and landslides in the Pacific Northwest. The model, which attempts to mimic the historical regime of fire, rain, and landslides, helps us understand how disturbance processes interact to introduce sediment and woody debris into channels with fish populations. Landslides are critical in bringing large wood into larger streams where complex habitat, preferred by salmonids, is created (Bisson et al. 1997, Benda et al. 2003, Reeves et al. in press). In fact, at least half of the wood in the fish-bearing portion of the channel network was delivered from smaller, nonfish-bearing tributaries by debris flows or other mechanisms (Reeves et al., in press). It is important to acknowledge large spatial scales, such as watersheds, and temporal scales of decades to centuries, to determine the pattern of natural and human-related disturbance on anadromous fish populations (Reeves et al. 1995, 2002)

Greenough et al. (1999a,b) offer another landscape demonstration (West Arm Demonstration Forest, British Columbia). They used a landscape model (Prognosis-EI) that employed detailed stand management simulations and tracked a broad array of environmental indicators. This allowed for a comparison of potential landscape prescriptions. Their "balanced" management regime succeeded in meeting five management objectives that are seemingly mutually exclusive (Greenough et al. 1999a,b). The management regime

(1) Produced a greater merchantable harvest than forecast for the baseline regimes
(2) Increased the average area of prime ungulate winter range
(3) Maintained a continuous supply of prime grizzly bear (*Ursus arctos*) summer foraging habitat
(4) Maintained a "retention" visual quality designation in all three designated viewsheds
(5) Reduced negative impacts on water quality by reducing the equivalent-clearcut-area in two out of three elevation bands in the watershed

These are simulation results, but they are based on the best available science. Results indicate that management objectives as disparate as wood, wildlife habitat, aesthetics, and water quality can be simultaneously met across a watershed with a management plan. This is compatible forest management.

At the subregional and regional scale, the possibilities for simultaneously producing numerous goods and services from the forest increase. Diversity in ownerships increases as scale increases. With a variety of ownerships comes a wide range of forest structures and conditions. Results from Spies and Johnson (Chapter 8), Haynes et al. (Chapter 10), and Montgomery (Chapter 2) all point to ownership itself as a surrogate driver of diverse management objectives and strategies.

However, long-term projections (100 years) from the Coastal Landscape Analysis and Modeling Study (CLAMS) (Chapter 8) indicate a coastal landscape headed for a condition dominated by two primary states: old, structurally diverse forest (federal land) and young, relatively uniform conifer plantations (private industrial land). Forests on nonindustrial or state lands may moderate this trend somewhat, but this dichotomy still appears likely to emerge over time under current policy. This trend will result in sharp edges at ownership boundaries, decline of intermediate-aged forests (e.g., 50 to 150 years old), and a decline in young, ecologically diverse forests characterized by hardwoods, shrubs, and patches of conifers.

A large landowner (e.g., the U.S. Forest Service) is unlikely to entertain diverse management objectives across the entire holding; organizations—be they businesses or governments—are guided by specific policy guidelines. In decades past, the U.S. Forest Service prided itself on decentralized management (Williams 2000). Recently, this decentralized management has been replaced by strong policy directives (e.g., the Northwest Forest Plan) that induce common management across a region. The result is less diversity in forest structures and conditions, especially in the future (Chapter 10). Uniform management is *de facto* land zoning. This works counter to the goals of compatible forest management.

At large scales, such as an entire region, it is possible that the sheer number of owners (with associated diverse management regimes) can produce a type of artificial compatibility. Assume that each owner has only one management objective, such as wood production to maximize net present value, or aquatic conservation, or the production of salal (*Gaultheria shallon* Pursh), or recreation. Joint production of forest resources does not occur on a single location, yet over the entire region a variety of forest products and services are produced. It is not clear if this multiple one-dimensional resource solution would ever be socially acceptable; if it were, we would have to admit that it met our definition of compatible management at the regional scale. This solution is not what we mean by joint production, although we acknowledge that not every resource can be produced on a given forest stand.

In Chapter 10, the evidence for implementing the various management regimes across the region show they differ both by ownerships and by the expectations of various owners about the financial feasibility of individual actions within the industry. These conditions are expected to remain stable, given the expected market and processing options. These conditions also offer opportunities for compatible management. We can sustain timber harvests while preserving habitat and the services derived from the various forest structural components. At the regional scale, the diversity of ownerships and management objectives helps achieve greater compatibility in forest management.

(3) Historical context. Across a region, we are presented with an array of forest conditions that exist for historical as well as ecological reasons. Treatises by Rajala (1998) and Williams (2000) describe some of the historical reasons for the current conditions of forests in the Pacific Northwest. Mathematicians refer to the current description of the forest as "initial conditions." They simply are, and we must deal with them as they are.

Some biologists refer to the present conditions as a contingency, something that cannot be ignored. Mayr (1983) points out that all biological phenomena have a proximate and an evolutionary cause. Historical context (the proximate cause) shaped the current forest conditions, the contingency that determines the basis for the future. Global vegetation modelers (e.g., Prentice et al. 1992) and global climate modelers refer to current conditions as a transient; the effect of the present on the path to a new equilibrium condition is a transient response. Only with time will its effect die out.

In Chapter 5, Monserud talks about the slow dynamics that characterize forest development. These time scales are long, in human terms. On the short end, an intensive industrial management regime may call for a 40-year rotation. At the other extreme is forest succession, which occurs on a scale close to a millennium in this temperate rainforest. The dominant forest species in western Oregon and Washington is Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), which is paradoxically, an early seral pioneer species that is capable of maintaining its dominance in a forest stand for 500 to 750 years. When we talk of "old growth," it is not a simple state that is quickly reached and maintained. As Franklin (1988) underscores, this rainforest is unique in that it has not only the tallest and largest trees in several important genera (e.g., *Abies*, *Picea*, *Pseudotsuga*, *Thuja*, *Tsuga*), but also the oldest.

Moving the region to a new forest condition is clearly a slow process. Simulation results from Haynes et al. (Chapter 10) and Spies and Johnson (Chapter 8) show that regional demographic changes among alternative policies can be great, but they nevertheless take 50 to 100 years for full effect. Swanson et al. (Chapter 9) model landscape change scenarios over a 600-year period to represent the broad range of stages in forest development. Policies, management, and disturbance regimes can alter the direction over time, but silvics and tree dynamics will determine the rate of growth.

In regard to productive fish habitat, long time scales, from decades to centuries are needed to take into account the full range of disturbances responsible for introduction of woody debris and sediment into stream systems (Reeves et al. 1995). Depending on characteristics of individual landscapes, woody debris and sediment are introduced through disturbance processes including landslides, bank erosion, catastrophic blowdown of trees, and tree mortality (Benda and Sias 1998, Martin and Benda 2001, Benda et al. in press, Reeves et al. in press). Such disturbance mechanisms influence the abundance of large wood in pools, an important element in fish habitat (Burnett 2001). Management policies and practices that are most similar in magnitude and frequency to the natural disturbance regimes will provide the best chances for compatible wood production with the maintenance of productive aquatic ecosystems.

(4) Social response. Social acceptability and many social values are *provisional* (Donoghue Chapter 15, Stankey et al. Chapter 16). The formation of social attitudes can be a fast process, compared to the slow dynamics of forest growth. This disparity between the rates of change for forest conditions and social attitudes results in a forest that is constantly lagging behind the current view of socially desirable conditions. As such, the forest is always viewed as being in a transient condition, with responsive forest managers trying to convert it to some new, more desirable state. Occasionally the problem is compounded by the very professionalism of foresters and their strong command of their subject matter. It is easy for professionals—including scientists—to fall into the trap of knowing the "best" management. The reality is that "best" is determined by a value system, which is inherently personal and provisional.

The provisional nature of social values and attitudes tempers any claims of attaining compatibility in an absolute sense. We can envision management scenarios where wood is produced economically in a manner that increases, or at least does not decrease a range of important environmental indicators. Other management scenarios may attempt to maintain cultural values rather than economics. Mangers on the Gifford Pinchot National Forest (Washington) are eliminating competing overstory vegetation to reach proper light levels to maintain some traditional huckleberry (*Vacccinium* spp.) areas. Nontimber forest products (NTFP) play important roles in American culture and commerce (Alexander and Fight, Chapter 13). In fact over 200 species of NTFP are harvested from public and private lands in the Pacific Northwest for commercial, personal, and traditional purposes (de Geus 1995).

As values change with context, they also change with time (Chapter 15). Although we can never be sure that the management regime will remain acceptable tomorrow, the manager can do much to ensure compatibility today. We can examine the aesthetics of a given compatible management scenario by using visualization tools such as McGaughey's (2002) EnVision to monitor the visual acceptability of the treatments (see Figure 1, Chapter 7). By involving local people in a cyclical process of understanding, adaptation, and action to evaluate potential forest management, confidence in the compatibility of the management can be increased. These participatory approaches are promising methods for better integrating values into forest management, particularly at the local level.

Donoghue (Chapter 15) argues that stating that compatibility has been achieved implies that knowledge about values, both ecosystem function and social values, exists and has been integrated into forest management decision-making. This implies that scientists and managers understand the fundamental differences in how people value forests within the context of a specific resource management problem. It also implies that managers understand these values sufficiently enough to make judgments about what is compatible and what is not. These are lofty assumptions, given the considerable ambiguity in how we define, measure, and integrate social values in forest management (Chapter 15).

[illegible]) S[illegible]te **specificity.** A fundamental feature of almost all forest management is
[illegible] is site specific. All the determinants of productivity that foresters refer
[illegible] site (soil, nutrient and moisture regimes, physiography, and climate)
[illegible] factors affecting the success of a given forest management prescrip-
[illegible]enetics is also an important component of site productivity, as
[illegible]ud and Rehfeldt (1990) found. It is easy to think of silvicultural tools,
[illegible] thinning and site preparation, as procedures with generally uniform
[illegible] but they are applied in a management prescription for a specific
[illegible]n.

[illegible] are bound by the site-specific legacies of past land management. Rather
[illegible]ish for a different past, we can look to examples such as in Chapter 14
[illegible]tively manage to preserve desirable stand legacies. Legacy retention can
[illegible] from a few live trees to a mixture of trees, shrubs, and coarse woody
[illegible] to entire patches of intact forest. The more legacies retained, the more

a forest-influenced environment is maintained. Important legacies include seeds or seedlings of multiple species of conifers and hardwoods, ectomycorrhizal fungi, large coarse woody debris, and large live trees with epiphytic mosses and lichens (Chapter 14).

Although it is true that all site specificity, like politics, is local, there is a broader geographic and social context. We discuss compatible forest management in the context of the Pacific Northwest. We could provide examples of joint production in other regions of the world, but that is not where our research strength lies. Although we only examine the Pacific Northwest, we strongly feel that the ideas of compatible forest management could be applied to other regions.

(6) Science is incremental. Revolutions in science do occur (e.g., Kepler's Laws of Planetary Motion; natural selection; relativity; quantum mechanics; plate tectonics), but they are rare (Kuhn 1970). Science operates by attempting to reject hypotheses, a continual process of testing or refining the accepted paradigm in a given field. In the process, new knowledge is added in a seemingly haphazard fashion (Kuhn 1970). In the centuries between or following revolutions, most progress is made incrementally. As Swanson et al. note (Chapter 9), the history of forest policy has exhibited decades of relative stability punctuated by abrupt change, suggesting that surprising shifts in policy are an important component of long-term landscape management.

In Chapter 1 we gave a brief history of forest management in the Pacific Northwest. In it, we talked about the lack of a scientific basis (e.g., experiments) 50 years ago for the plantation management of Douglas-fir that became widespread throughout western Oregon and Washington. After a half century, the scientific basis has become quite solid (Smith et al. 1997). Nursery methods for efficiently raising healthy, superior planting stock are now common (Duryea and Dougherty 1991), including techniques for inoculating roots with mycorrhizal fungi to promote quick establishment and sustained growth (Castellano and Molina 1989). Average survival of seedlings has increased to 85% or better (Curtis et al. 1998). Effective methods have been developed for controlling competing shrub and nontimber vegetation, thus promoting rapid growth of established trees (Walstad and Kuch 1987). A range of harvesting systems has been developed to reduce problems such as soil compaction (Curtis et al. 1998). Knowledge was acquired incrementally, study by study. There was no grand experiment that clarified and explained all problems in one fell swoop.

In Chapter 5, Monserud discusses the difficulties and limitations of conducting long-term and large-scale forest management experiments. It is nearly impossible to use classic experimentation on landscapes larger than a watershed. No one would seriously propose a forest management experiment on forest-fire risk reduction, for example, where the treatment units were entire counties, much less states or provinces. No administrator would agree to allow his or her region to be the no-treatment control, even if it were randomly assigned. The spatial limitation in forestry experiments is paralleled by comparable problems arising from the enormous time periods needed to fully test management using long-lived forest trees. These considerations indicate a clear limitation to knowledge that can be gained from classic methods.

Nevertheless, science is still our ally. Fields such as geology and astrophysics are not able to experiment, yet they are well developed branches of science. Theory must be relied on when experimentation is not possible. In biology, our only strong theory (*sensu* Platt 1964) is Darwin's natural selection. Our next strong theory will be an understanding of the genome, but that is decades away.

Forestry and ecology have relied on a series of weak theories that are nevertheless useful. The oldest is the allometric property of self-self correlation, which captures the proportionality between the relative increments of two parts of a plant (Monserud and Marshall 1999). Allometric relations can be used to predict variables that are difficult to measure. For example, leaf area or crown biomass can be predicted from diameter at breast height (e.g., Monserud and Marshall 1999). Another useful theory is the –3/2 power law of self thinning (Yoda et al. 1963). Foresters have used the maximum size-density relationship inherent in self-thinning to construct stand management diagrams (Drew and Flewelling 1979, Farnden 1996). These are graphical representations of stand development which, in various formats, illustrate the interactions between density or some other measure of stocking, and various stand parameters such as mean diameter, top height, and volume (Farnden 1996). The stand management diagrams of Drew and Flewelling (1979) have long guided density control in Douglas-fir plantations in the Pacific Northwest.

Lacking strong theory (Platt 1964), forest scientists perforce have become adept at developing empirical relationships. A yield table is simply a concise summarization of observed stand development with respect to time. A stand growth simulation model is based on the same idea, but uses statistical methods to efficiently estimate the growth parameters (Chapter 6).

Even empiricism has its limits. Many of the landscape models described in Chapter 7 are based on heuristics (expert opinion and general rules that seem to work). SIMPPLLE (Chew 1995), for example, is a knowledge-based expert system. It was designed as a management tool to understand how vegetation and processes interact to affect landscape change (Barrett 2001). The processes modeled are succession, harvest, disease, insects, and fire. Analysis tools at the landscape-to-regional scale must rely strongly on data summarization methods (e.g., ATLAS by Mills and Kincaid 1992) and heuristics.

In the end, the weight of evidence becomes our guide, as it does in the legal system. We use science as much as we can to form decisions, but then we must rely on observation, experience, expert opinion, and heuristics. This is a fairly normal situation for most managers. As scientists, we sometimes would like to withhold judgment until the definitive experiment has been conducted. This is an unrealistic stance, and one that allows for hiding behind an impossibly high standard of knowledge. In the end, the weight of evidence combined with the best available science is a reasonable course of action. The alternatives-to-clearcutting treatments (ATC) study (McClellan et al. 2000) provides a case in point. With the ATC treatments recently established on only two blocks (in 1997 and 1999), managers are already responding to the existence of the treatments (see Figures 2 and 3 in Chapter 5). Most timber sales in southeastern Alaska now call for some form of alternatives-to-clearcutting treatments (M. McClellan, USDA, Forest Service, personal communication, 2002). Apparently, the demonstration that some new type of management is operationally feasible is sufficient for some managers to seriously consider it.

(7) Knowledge is fuzzy. Science is a powerful machine for discovering knowledge. We like to think of it as describing how the world works, in exact terms. Actually, uncertainty is a feature of almost all scientific knowledge. Heisenberg's Uncertainty Principle (we cannot simultaneously know an electron's momentum and location) shocked the scientific world in 1927 with its clear limitation on knowledge (Hawking 2001), just as Gödel's Incompleteness Theorem shocked mathematicians in 1931 by proving that not all true statements (theorems) were provable. The world has an essential indeterminacy; it can be pinned down only so far and no farther (Lightman 2000).

Statistical variation is a crucial feature of all experiments. A measure of variability coupled with statistical theory (e.g., Fisher's (1925) Analysis of Variance) allow for the separation of significant from insignificant effects. In experimentation, we know something is true only within the confidence bounds around the mean (some significant effect). Analyzing variation defines the field of statistics and is an essential feature in all observational science.

In forest management, variation and indeterminacy enter into decisions in many ways. All measurements of the forest resource contain measurement error. This is usually not a problem when estimating the dimensions of trees. However, it can be a serious problem when estimating population abundance for mobile, nocturnal, and elusive wildlife species such as the northern spotted owl (*Strix occidentalis caurina*) or its main prey, the northern flying squirrel (*Glaucomys sabrinus*). When managing for wildlife species, the uncertainty regarding population estimates makes it difficult to determine the effectiveness of prescribed management. Partly for this reason, the management focus is often on providing suitable habitat because habitat is more easily observed and measured.

As previously noted, certain social aspects of decisionmaking (social acceptance and values) are provisional and subject to change (Chapters 15 and 16). Donoghue (Chapter 15) points out that managers have several tools (participatory methods) that can help determine which forest values are important to various user groups. Cultural values are enduring, so, for example, it should not be too difficult to find out from local people which forest resources are most important to them. The problem is not how to manage for huckleberries (*Vacccinium* spp.) as much as realizing that it is important to manage for them (Fisher 2002).

Finally, decisionmaking is inherently indeterminant and fuzzy. The manager cannot ever know enough about management alternatives to make the ideal decision. Reynolds (2002) describes the general structure of a logic-based model for evaluating the sustainability of forests at regional and national levels, and illustrates how a logical formalism can be used to represent and evaluate compatibility among resource values and uses. Basically, the model evaluates a proposition. Fuzzy logic is used to weigh the evidence and arrive at a degree of truth for the proposition. Evidence can take many forms: empirical data, theoretical relations, and expert opinion. The intent of Reynolds'(2002) framework is to incorporate lexical uncertainty into the evaluation of a proposition. Even though most concepts that humans use are not precisely defined, people have little trouble making decisions in the course of everyday life.

Reynolds'(2002) tool can be used to compare across alternatives, with compatibility as a management goal (the proposition). The closer the "truth" of a particular proposition (a specific management regime) is to 1.0, the more compatible that regime will be. This is a powerful approach, but its utility relies on building a model of the proposition accurately describing compatible forest management.

(8) Markets provide incentives for management. The history of relentless change in the forest sector of the Douglas-fir region demonstrates the power of markets in altering forest resource conditions. In spite of arguments by advocates for forest management or environmental protection, a myriad of landowners with diverse land management objectives have changed forest resource conditions by responding to various market signals, mostly prices. For many years, changes in timber prices have provided the incentive for landowners (both public and private) to change the intensity and extent of forest management practices. Prices, which are also a function of wood quality, have also provided the incentive for the development (or contraction) of various forest products industries in the region (Chapters 10 and 11).

There is great angst among some that markets are not benign. Often, prices provide insufficient incentive for what advocates of forest management think are the necessary types and intensity of forest practices to ensure sustainable forest management. In the United States, we have frequently debated the role that prices play in private timberland management. In periods of weak stumpage markets (e.g., for small trees) there is concern that landowners and managers will not implement certain forest practices, such as thinning to reduce fire risk. In the case of private timberlands, relatively low financial returns may lead to changes in land use as landowners seek higher returns. These changes may include conversion to agriculture or residential developments (see Cubbage and Haynes 1988, USDA FS 1988, and Haynes 2003 for additional details).

These market-determined changes are not confined to timber markets. There is growing recognition of the values of other goods and services such as nontimber forest products (NTFP), and recreational use, and an emerging interest in valuing services such as carbon credits. Today's forests were determined by past consumer choices regarding their consumption of forest products, as well as the forest management choices made by landowners and managers.

Price plays a powerful role in both sets of choices. As shown in Figure 1 in Chapter 1, forest product prices are often characterized as highly volatile but increasing faster than the overall rate of inflation. The general history of rising prices suggests that timber is relatively scarce and, all else being equal, that there should be changes in various market factors to alleviate the price increases. After all, these are relatively free markets comprising numerous producers and consumers making decisions based on their observations of the market behavior. For example, consumers may substitute nonwood material in some uses such as residential construction (e.g., steel studs for framing) because the real prices of the substitute are more stable than wood prices. It follows that landowners and managers may increase the intensity or extent of land management to produce more timber (to the point where timber prices become stable).

The lack of general agreement about the effectiveness of free markets in increasing quantities of timber supplies (or other forest outputs) in periods of rising prices and perceived scarcity has caused concern among advocates of forest management. (see Cubbage and Haynes 1988 for a summary). Doubts about market effectiveness have often prompted the establishment of public and private programs designed to improve forest management with the intention of slowing the expected rises in timber prices.

Studies of the responsiveness of stumpage markets generally indicate that the price elasticities of supply and demand are unresponsive (see Adams and Haynes 1980, 1996). As economic theory dictates, shifts in the demand or supply curves will have substantial impacts on prices. All of this leads back to the observation that markets are relentless, leading to changes in forest resources that some favor and others strongly oppose.

Regardless of one's view, the Douglas-fir region is an example where rising prices for timber products led to the adoption of relatively systematic forest management regimes consisting of practices that tend to quicken development of well-stocked forests. This increases the economic returns to those (individuals, companies, and various publics) who own timberlands. Current and expected trends show private timberland owners continuing to invest in forest management, subject to increasing regulations of various forest practices. Public lands, on the other hand, are expected to be managed for diverse goals—many not involving the marketplace—reflecting increased recognition of the benefits of many forest goods and services.

2.2. Compatibility Questions

We will address four research questions regarding compatibility to help weigh evidence regarding the proposition:

(1) To what degree can wood production occur without impairing other forest values?
(2) How can the links between management actions and stand-level outputs of goods and services be developed?
(3) What are the methodological problems in developing broad-scale measures of ecosystem condition and performance?
(4) Can broad-scale measures illustrate compatibility or tradeoffs between biophysical and socioeconomic systems at national and ecoregional scales?

Early in the Wood Compatibility Initiative (see Chapter 1 and Haynes and Monserud 2002) we examined these research questions. They helped us assess the progress that was being made toward understanding the opportunities for compatible forest management. These questions focus on the broad issue of managing forests for greater compatibility. The preceding chapters describe numerous instances at several scales of analysis where excellent progress has been made toward understanding the nature of compatible wood production. Furthermore, examples in some chapters and other studies such as Cissel et al. (1999) and Greenough et al. (1999a) demonstrate that the practical needs of the land manager can be addressed and wood can be produced while designing management plans that increase the level of key environmental indicators and other forest values. The actual implementation of these concepts may be hindered by the attitudes and values of landowners toward the different types of approaches (market based or regulatory) taken to institute joint production of some ecosystem services (see Jacobson et al. 2000 for a summary).

(1) To what degree can wood production occur without impairing other forest values?

Forest management in the Douglas-fir region and the maritime forests of coastal British and southeastern Alaska has been evolving for over a century. Experience on even-aged silviculture and plantation management accumulated in the past half-century is vast (Walstad and Kuch 1987, Smith et al. 1997, Curtis et al. 1998, and Chapter 4).

For landowners whose primary goal was timber production, intensive plantation management evolved to take advantage of a highly productive ecosystem. As a result of a relatively predictable silvicultural system, the length of commercial rotations on high productivity lands decreased to as little as 40 to 50 years. Commercial thinning was often eschewed in favor of earlier harvests (Chapter 4).

For other landowners where timber production was one of several goals (e.g., on federal lands), silivicultural systems evolved that gave the manager considerable flexibility without appreciable loss of productivity. For example, federal land managers often used longer rotations (Curtis 1995). This strategy had several advantages: it reduced the area in the regeneration phase, and therefore, the up-front regeneration costs; larger trees with higher quality products were grown, with a continued flow of products from commercial thinning; opportunity to improve unbalanced regional age distributions increased; habitat for some wildlife was improved; carbon storage increased by delaying harvest; and opportunities were available to increase stand health and vigor through thinning.

The current decade has seen shifts in societal values that have led to major shifts in forest management practices in the Pacific Northwest. Greater emphasis, especially on public timberlands, has shifted toward managing for old-growth characteristics (see Appendix 1, Chapter 1), with related goals of protecting endangered species and fish habitat and promoting biodiversity. The popular management paradigm holds that the complex, multiple-story structure of typical old-growth stands derives from a stand development sequence that includes a dense closed-canopy stem-exclusion phase (Smith et al. 1997). Self-thinning following the stem-exclusion phase (second stage; Chapter 1, Appendix 1) then reduces stand density and allows understory regeneration of shade-tolerant tree species to form intermediate canopy layers. There is recent research by Tappeiner et al. (1997) suggesting a different successional approach. They found that regeneration on 10 old-growth sites in the Oregon Coast Range occurred over a prolonged period; trees grew at low density with little self-thinning and bypassed the dense stem-exclusion phase. These results suggest that thinning may be needed in dense young stands where the management objective is to speed development of old-growth characteristics (fourth and fifth stages; Chapter 1, Appendix 1). At the same time, a reexamination of a nearly forgotten experiment called "selective cutting" (similar to contemporary proposals for creation of gaps by using small [0.8-4.0 ha] clearcuts) in the Douglas-fir region in the 1930s would maintain the late-seral characteristics described in Chapter 1, Appendix 1 (Curtis et al. 1998). As Hummel (Chapter 4) points out, in order to measure biodiversity in a meaningful way, links need to be made with forest structure, species richness (a proxy for compositional diversity), and harvestable wood volume.

Examining the state of uneven-aged management in the Douglas-fir region, Emmingham (1998) concluded that regional silviculturists will need many decades to develop and maintain productive uneven-aged stands. Emmingham (1998) found that good natural models and reliable experience with uneven-aged stands are lacking. The lack of information about how to create and manage productive uneven-aged forests is a major impediment and threatens the ability of land managers to manage the late late-successional reserves according to the Record of Decision in the Northwest Forest Plan (USDA and USDI 1994b). Emingham notes that without further management, stands that have attained multilayer condition may return to single-canopy mature forests before they reach old-growth condition and thereby not attain the conditions desired for nontimber values (e.g., wildlife habitat), nor the flexibility desired for changing management objectives.

(2) How can the links between management actions and stand-levels outputs of goods and services be developed?

A relatively rich literature exists for selected products and species. For example, an enormous amount is known regarding almost all aspects of Douglas-fir management for wood production in the Pacific Northwest (e.g., Curtis et al. 1998 and Chapter 11). Considerable work also has been done on Sitka spruce (*Picea sitchensis* (Bong.) Carr) (Peterson et al. 1997). But in general, our knowledge is more limited for many other species (e.g., red alder (*Alnus rubra* (Bong.)), particularly for most nonwood values. A major impediment to effective management of nontimber forest products (e.g., mushrooms, salal, and huckleberry) is that almost all lack yield functions. Our knowledge is limited even for wood production of some key forest species, such as western hemlock (a climax species over most of the Pacific Northwest). In large part such limitations result from the singular success of intensive Douglas-fir plantation management for wood production in the past 50 years.

Limitations also result from a failure to bridge the gap between relatively abstract academic research and the high level of empiricism commonly employed to manage most forest stands. Although one can view a yield table or growth model projection as an abstraction, land managers invariably combine such forecasts with as much relevant site-specific information as they can marshal. The resulting management prescription is highly site-specific. Contrast this, for example, with work that attempts to explain ecological change based on changes in potential vegetation patterns (e.g., theoretical successional pathways) without any reference to actual current vegetation or site conditions. Another example is older growth and yield work based on fully stocked stands (McArdle and Meyer 1930) rather than the more common case of partially stocked stands.

The differences among various yield approaches, broader ranges of management regimes, and management and for a wider range of products are becoming clearer. In the past decade, for example, carbon storage has become increasingly important as a potential mitigating strategy to slow the rate of predicted global warming (Watson et al. 1996), and the development of various carbon accounting schemes has become part of inventory modeling research.

Progress is also being made in developing approaches to evaluate broad management policies for specific periods of time. Monserud (Chapters 6 and 7) discusses a wide range of stand and landscape management models. Few if any landscape models existed in the 1970s. Today, fire risk is one factor of many that can be examined in detail across a large landscape.

Spies et al. (2002a,b) have developed one of the most comprehensive large-scale management models. In the Coastal Landscape Analysis and Modeling Study (CLAMS), they have modeled the entire Coast Range of Oregon in a level of detail that allows for comprehensive examination of broad, regional policy. These simulated outcomes (Chapter 8) can be used as input into other analyses directed toward aquatic, terrestrial, and socioeconomic consequences. In the case of both aquatic and terrestrial wildlife species, simulated forest and range vegetation conditions are inputs to empirical or causal relations among factors that influence wildlife species viability.

However, less information exists on how and why public perceptions of acceptable forest management change and how to properly deal with them (Chapter 16). In general, knowledge about how the public makes and expresses choices about acceptability of forest management practices and the roles that different institutions play in these choices is poor. Related to this is a need to improve understanding of the social and economic acceptability of forest management, both on public and private timberlands. Furthermore, we need to understand how policy actions on one set of ownerships affects conditions on another set of ownerships (Chapters 8 and 10).

(3) What are the methodological problems in developing broad-scale measures of ecosystem condition and performance?

The tendency to focus on finer scale aspects of problems that are amenable to the scientific method has led to considerable resistance within the scientific community to developing composites of individual measures as broad-scale indicators. A National Research Council (2000) report describes many of the methodological issues. The forest science community, in particular, has been slow to embrace the development of broad-scale measures. This lack of enthusiasm partially stems from the experience of some scientists who find their issues become less significant—and even insignificant—when working at broader scales. Ultimately, management—like politics—is local. But policy is broad-scale, and policy drives management.

Another significant methodological problem is that work at broader scales has to rely more on simulation techniques and expert judgment models than on experimentation. Such models often rely on a mix of empirical and judgmental relations (Chapter 7). They are used to estimate how changes in input condition (especially those related to land management) result in changes in output measures of performance. Validation is difficult, and often is approximated by using sensitivity analyses to examine the soundness of the process relations and the robustness of projected outcomes.

Scientists' beliefs can be a problem. For example, some of the most contentious science issues involve understanding the extent and nature of tradeoffs that are assumed to occur among biophysical and socioeconomic components of large ecosystems. Much of the framework for this debate has been provided by scientists who often view themselves as advocates for a sustainable biosphere (Risser et al. 1991) and perceive limited opportunities for mutual gains in both biophysical and socioeconomic systems. The natural resource policy debate in the Pacific Northwest in the 1990s was often portrayed as involving direct tradeoffs between environmental changes and socioeconomic well-being. The implicit assumption is that this is a zero-sum game, which remains to be seen. This debate has been based on assertions or piecemeal collections of data. Composite measures can be developed to examine the direction and extent of tradeoffs between ecological and socioeconomic conditions as different management strategies are considered. The challenge is to develop composite measures that act as proxies for discussing these two dimensions, and for examining changes that may occur in ecological and socioeconomic conditions under different management alternatives.

(4) Can broad-scale measures illustrate compatibility or tradeoffs between biophysical and socioeconomic systems at the national and ecoregional scales?

There is a growing literature in forestry that illustrates the nature and extent of compatible wood production. Work on porcupine and owls described by Montgomery in Chapter 2 illustrates practical approaches. Much work also focuses on managing for multiple values (Lippke and Oliver 1993a) and on tradeoffs (Weyermann et al. 1991, Lippke and Oliver 1993b). The larger issue is what role science can play in the search for compatibility in terms of developing the methodological basis and dealing with issues that significantly affect broad-scale science.

First, broad-scale science poses significant challenges for the scientific community. An effective partnership among scientists, managers, and those

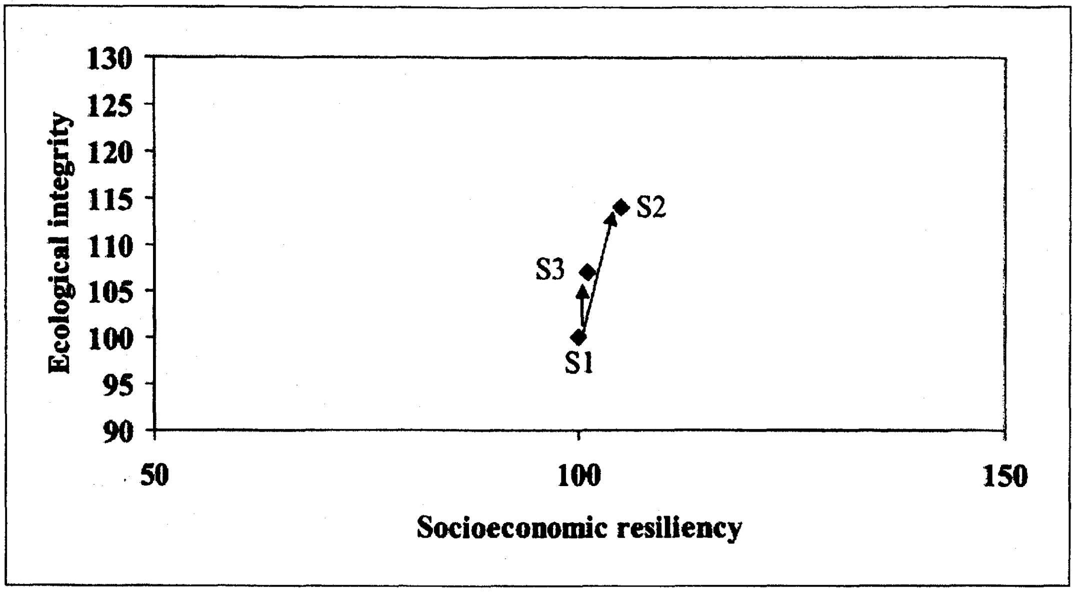

Figure 1–Tradeoff between ecological integrity and socioeconomic resiliency indices for management alternatives in the interior Columbia River basin assessment area for each management alternative (S1, S2, S3). Alternative S1 was used as a baseline comparison to index alternatives S2 and S3 (see Haynes and Quigley 2001).

engaged in the political tasks of governing is essential. The lack of clarity in the socioecological problems that lead to the need for comprehensive broad-scale strategies is frustrating for scientists. It becomes difficult to distinguish issues that reflect different policy preferences among the governing partnership from issues attributable to the lack of information. Furthermore, this lack of clarity surrounding the issue creates confusion about the appropriate spatial and temporal scale of response to various issues.

Second, the science and policy debate since the 1990s has been narrowed considerably by asserting ecological limitations but not acknowledging the full scope and complexity of deliberate societal choices. Evidence of this includes the relatively tight grouping of values for ecological integrity and for socioeconomic resiliency (Figure 1) for the three alternatives for managing almost 31 million hectares (ha) of federal land in the interior Columbia River basin (Haynes and Quigley 2001). These alternatives were designed with varying mixes of ecological restoration, maintenance of reserves, commodity production, and multiple-use management activities. While other alternatives might have been developed to reflect a broader spectrum of potential outcomes, public land managers reveal in their choices of alternatives that they have no incentive to consider a wider array of outcomes.

Third, the shift to managing ecosystems across relatively broad spatial extents stretches the limits of traditional science and of traditional management (Chapter 8). The key scientific tool, experimentation, (including the concepts of randomization, replication, and control) is essentially impossible

Table 1. Weighing the evidence for and against the proposition on compatibility.

		Testing the proposition		
Themes	**Weight, importance**	**For**	**Inconclusive**	**Against**
1. Multiple resource objectives	Moderate	X		
2. Scale	Strong	X		
3. Historical context	Weak	X		
4. Social response	Strong			X
5. Site specificity	Moderate	X		
6. Science is incremental	Strong	X		
7. Knowledge is fuzzy	Moderate		X	
8. Markets provide incentives	Strong		X	
Questions				
1. To what degree can wood production occur?	Strong	X		
2. How can links among management actions and outputs be developed?	Strong	X		
3. How can broad-scale measures be developed?	Weak		X	
4. Can broad-scale measures illustrate compatibility?	Moderate	X		

to use at the broad-scale level (Monserud 2002). As a result, "data" must be compiled and synthesized with less emphasis on the usual components of experimental science and little notion of its reliability.

Research into compatible forest management has better informed environmental policy discussion. But we need to acknowledge that these discussions can be characterized, since at least the early 1970s, as a constant tug-of-war among an unholy alliance of ignorance, ideology, and self-interest (see Blinder 1987 and Rolston 2000 for discussion on the roles scientists have played). Scientists can quickly be challenged beyond the limits of their scientific knowledge when asked to predict and interpret broad-scale social and biophysical consequences of management alternatives.

2.3. The Proposition: Conclusion

At the beginning of this section we stated a proposition and said we would offer evidence to assess whether we could accept or reject it. We considered direct evidence and synthetic information around four research questions that have been part of the Wood Compatibility Initiative. Our evaluation is summarized in Table 1.

2.3.1. The direct evidence—Considerable evidence indicates that compatible forest management is possible. The spatial scale is clearly the strongest factor affecting the proposition: as the scale of analysis (or management) increases, options are available to managers to increase overall regional compatibility between wood production and ecosystem functioning and integrity. Once the provincial or regional scale is reached, the sheer diversity of ownerships and management objectives ensure that multiple products and services are produced from the forest landbase.

At the stand scale, where management is actually implemented, we have evidence that multiple resources can be simultaneously produced in a mutually beneficial manner. Carey's (Chapter 14) wildlife management prescriptions call for increasing the diversity of forest structure and composition while removing some wood through thinning. By investigating the production possibility approach, Montgomery (Chapter 2) concludes that there appears to be substantial opportunity to improve current management. She provides strong evidence from the Oregon Coast Range that management for wood production and wildlife, or wood production and biodiversity, is not a zero-sum game. She demonstrates that current management is well below the production possibility frontier, and that increases in both resources can be made simultaneously. Opportunities for improvement do exist.

Working in southeastern Alaska forests largely dominated by only two species (western hemlock and Sitka spruce), Wipfli et al. (Chapter 3) found that the inclusion of red alder in young coniferous forests may mitigate some negative impacts of clearcutting on nontimber resources such as fish and wildlife, and provide acceptable levels of wood production from these young forests. Because of the short life span of red alder relative to its long-lived conifer associates, greater structural diversity was found in mixed alder-conifer forests than in those consisting nearly entirely of either alders or conifers. The greater diversity and abundance of vascular plants found with more alder increased forage production for deer and improved habitat for small mammals.

Both Kerns et al. (Chapter 12) and Alexander and Fight (Chapter 13) discuss the growing importance of managing for nontimber forest products, especially in the understory. These include a wide array of products, such as floral greens, boughs, craft materials, wild edibles, medicinals, transplants, and other materials. These species are also important for their ecological roles in forest communities. They contribute to biological diversity and long-term ecosystem productivity, underpin mammalian and avian abundance, and are important aesthetic components of forests (Kerns, Chapter 12). Often the management effort and decisions regarding NTFP are primarily related to managing people to control access to harvest NTFP (Chapter 13). Nevertheless, there is an increased focus on using a variety of forest management practices to enhance commercial understory products while maintaining an economically viable overstory tree crop (e.g., Weigand 1998). Kerns (Chapter 12) provides a detailed case study of salal management, including the use of overstory commercial thinning to control light levels for optimum salal production.

Perhaps the most promising scale to focus on is the watershed. Simulation results from Greenough et al. (1999a) in British Columbia and Cissel et al. (1999a) in Oregon both indicate that several environmental indicators can be increased while producing wood. The key is to manage the entire watershed simultaneously rather than in a piecemeal fashion. In Cissel's case, the organizing principle is duplicating the structure of the long-term disturbance (fire) regime by using thinnings and harvesting to match the desired structure across the watershed. This approach uses information on historical and current landscape conditions, disturbance history, and social goals to set objectives for future landscape structures that provide desired plant and wildlife habitat, watershed protection, timber, and other functions (Cissel et al. 1999). The result is a management plan that increases the ecological integrity of the entire watershed while still producing timber and other forest values.

Because clearcutting and plantation management have been the dominant management paradigm in the Pacific Northwest for over a half century, we do not have many demonstration areas to point to as examples of compatible forest management. Several operational-scale experiments in joint production are underway (see Chapter 5), but they are all less than a decade old. This situation forces us to rely on simulation models for analyses of compatibility. As Monserud demonstrates in Chapters 6 and 7, we have many strong tools available for both stand- and watershed-scale analyses. And the work of Spies et al. (2002a,b) on CLAMS (see Chapter 8) demonstrates that province-wide policy analyses can be conducted with enough detail to examine ecological integrity in relation to forest management. These numerous models are summaries of the best available science and knowledge on forest management. With them, we conclude that the possibilities for finding compatible forest management are great.

Of the eight themes reviewed in section 2.1., two (social response and markets) offer the least conclusive evidence (Table 1). Evidence from both of these is given strong weight because of their individual importance. In the case of the social response to compatible forest management, both Donoghue (Chapter 15) and Stankey et al. (Chapter 16) remind us that many social values are provisional. Consequently, the acceptability of forest practices depends on efforts by managers to engage the public and better integrate social values with forest management. Without this engagement, the available evidence suggests acceptance of compatible forest management is unlikely. In the case of markets, Haynes et al. (Chapter 10) describe how powerful markets have been agents of changes in forest management or resources. Because markets are not benign and exist only for a subset of goods and services, their impact on compatible forest management is inconclusive. Both cases suggest that there is great uncertainty about the possible implementation of compatible forest management when societal values, markets, and regulatory actions are all considered.

2.3.2. Synthetic information—We also considered the answers to the four research questions discussed earlier as evidence. The first two questions have the greatest weight importance (Table 1) and uniformly suggest that significant levels of compatible forest management already exist. The extensive application of multiple use management has given the Pacific Northwest a rich legacy of forests managed for a variety of goods and services. These forests demonstrate that there is a high degree of wood production taking place without impairing other forest values. There are examples where this takes place at the site or stand level as well as across broader landscapes. The relatively long history of deliberate forest management undertaken by many landowners with diverse objectives has contributed to this rich legacy. The application of forest practices to manipulate forest conditions has stimulated interest in both theoretical and applied research that has contributed to a rigorous scientific basis for management.

The third and fourth questions questions are important but carry less weight in this discussion (Table 1). The development of broad-scale measures is shrouded in methodological issues and as a result, this question is inconclusive in the context of judging compatibility. Measures that are developed raise interesting notions about unintended consequences, broad-scale science, or emphasize there are opportunities for mutual gains. These measures reveal the growing importance of expert judgments based on both experimental science and results derived from simulation models. There is not agreement about the development of broad-scale measures. Given the universal measures of economic, human health, and demographic factors used in today's society, it is only a matter of time before forest managers make statements about rating forest integrity or the socioeconomic resiliency of forest dependent communities.

2.3.3. Judging the proposition—Based on the weight of both the supporting direct and synthetic evidence (Table 1), we accept the proposition that we can produce commodity products and the other forest values simultaneously. Although both the scientific and empirical evidence suggests that this can be done at different scales, the provisional nature of social acceptance suggests caution in saying that this can be done at all scales in a socially acceptable fashion.

3. Closing

Before closing we return to several points. We evaluate the usefulness of the conceptual model that guided our efforts and summarize some of the limitations we have found. We also summarize how compatible forest management relates to sustainable forest management.

3.1. The Value of the Conceptual Model

Figure 2 lays out the conceptual model that has guided the development of this book. Some may ask if it has been a useful framework for our efforts and of its value to forest managers. Its greatest value to us, and to forest managers, has been contextual. It demonstrates both some of the components and the connections within the general management problem. It helped us define the relative roles of science and management, appreciate inherit differences in temporal or spatial scales, understand where the need for functional and integrated information exist, and realize that some aspects of forest management are so embedded in broader society that separate treatment is unnecessary.

As a framework, Figure 2 poses parallel challenges for both science and management because we often know more about what is in the boxes than we know about the lines (arrows) that connect them. From a systems analysis point of view, the boxes contain state variables and the lines connecting them are fluxes; it is much harder to model the fluxes. We have often thought about the five boxes as representing a set of processes or functions (e.g., How does stand composition change?). In this sense, the lines connecting the boxes represent the context setting and the cause and effect relations. But like most scientists, we struggle to consider the lines connecting the boxes as having equal stature and meriting equivalent levels of scholarly endeavor.

We have not treated the various boxes equally. The management actions component and the forest resource component have been discussed in many chapters. Much of the emphasis has been on the evolution of management strategies or regimes and the silvicultural practices employed in them. Descriptions of the regimes have changed over time (see Chapter 4 and Appendix 1, Chapter 1), and their application has become more selective (see Figure 3, Chapter 10) than often asserted. Highly robust silvicultural tools, such as thinning, are being applied in nontraditional ways to achieve an array of desired future conditions (see Chapters 12 to 14). Our treatment of the forest resource component has changed from relatively simple stand tables to more complex growth and yield models and on to inventory projection systems (see Chapters 6 and 7). While these have evolved to represent the forest resource, less progress has been made describing the nontimber outputs and conditions (Chapters 12 and 13). The same case can be said of the treat-

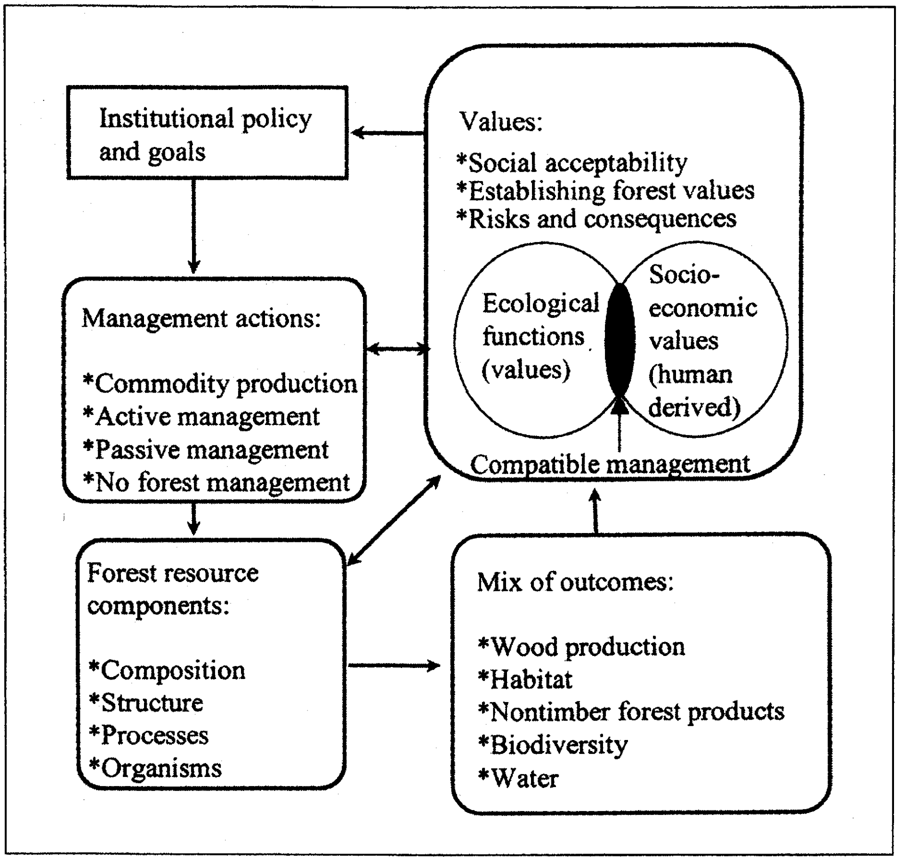

Figure 2. A general conceptual model for the Wood Compatibility Initiative.

ment or need for spatial resolution and the means that exist to aggregate across spatial scales.

Representing the values component focuses on two key issues: establishing notions of social values and social acceptability. These issues are indispensable in developing compatible forest management strategies. Raising the stature of these issues is a significant outcome of our efforts. We found that we did not need to explicitly consider the institutional policy and goals component because various institutional issues are already woven throughout contemporary forest management. This does not mean that foresters, landowners, and public are in universal agreement but, rather, there is an understating of the reality imposed on management debates by the existing instructional structures.

The connections between components are equally important but often neglected. Some of this reflects the way that contemporary research is structured; little attention is paid to cause and effect relations except in the case of some timber-related relations. Differences in spatial and temporal scales among the boxes add complexity to the lines that connect them. For example, the timber inventory resource is often described in terms of decadal age classes, harvests, and net growth that is applied annually, but societal values that influence social acceptability of forestry activities are in almost constant change. To some the volatility of social values seems chaotic and their coping strategy is to ignore social values. This often leads to gridlock among different interest groups. Acknowledging the volatility and working with it may lead to more successful forest management strategies.

Figure 2 also reveals areas where integrated and functional types of information are needed. A danger in contemporary forest management is thinking that every problem requires an integrated approach. As Figure 2 reveals, there is a need for both types of information. A land manager needs to know functional information, such as how trees grow or will respond to thinning. He or she will also need to know how to use that information to describe their contributions to broad management goals, such as sustainable forest management. The measure of success is addressing the right question at the right scale (either spatial or temporal) with the best information available.

Finally, Figure 2 suggests that the forest management decisions are hierarchical because they must recognize both the context set at higher scales and an understanding of specific lower scale processes. This allows managers to consider management actions at the level where they are to be implemented and where impacts will be observed. This gives managers a proactive way to deal with highly dynamic ecosystems and constantly changing social values.

3.2. Limitations to Achieving Greater Compatibility

There are a number of limitations to achieving greater compatibility in forest management. One of the greatest has been the focus on inputs of management strategies rather than the outputs. For example, the number of snag trees per hectare (input) is often managed for rather than the greater abundance of cavity nesting birds (output).

Another example is found in aquatics management. We have spent much of the last decade studying an aquatic conservation strategy that too often gets reduced to a discussion of buffer widths with scant mention of the results of different buffer widths in terms of habitat conditions or fish populations. This orientation has resulted from the focus of current land management around the implementation of different standards and guidelines imposed by regulatory or quasi-regulatory agencies (e.g., USDA and USDI 1994b). Hummel (Chapter 4) finds that there is insufficient data to support the supposition that silvicultural treatments used to create diverse forest structures conserve biodiversity better than those resulting in structural simplification.

It is not fully understood how selected management regimes affect the various components of the forest resource base. Generally we know how a management regime affects timber volumes but relatively less about how it affects other components, such as wildlife abundance or edible mushroom production. We tend to know more about the traditionally managed species such as Douglas-fir but less about other species types like western hemlock.

The growing importance of NTFPs in the Pacific Northwest (Chapters 12 and 13) is stymied by one fundamental shortcoming: yield functions do not exist for most of them. Yield functions for timber production are almost as old as forestry, with the first tables dating to the 18th century. In contrast, the expected yield of almost all NTFPs is uncertain and variable. Mycologists and experienced mushroom hunters have a wealth of experience that can direct them to likely locations (e.g., morels in the year following a forest fire), but actual yield functions or tables are speculative at best. Without a clear idea of productivity for a given product, harvest levels are rather arbitrary. Determing sustainable harvesting levels requires that the site potential be known. Unfortunately, all too often it is not.

Another limitation is the lack of background information on how social values influence forest management. While we understand that science-based information may be provisional because emerging information may alter our understanding, we are generally reluctant to acknowledge the provisional nature of social acceptance of management. Given the biases of foresters to provide sound stewardship of resources where change is measured in decades, we are often confused by the rapid dynamics of social change. The challenge is to better understand the linked nature of broad-scale societal changes and the goals for land management. After all, as land stewards we should strive to preserve as many options as possible for future generations who may value the forests for life support, economic, recreation, aesthetic, wildlife, biotic diversity, scientific, natural history, cultural, spiritual, and intrinsic values.

3.3. How Does Compatible Forest Management Relate to Sustainable Forest Management?

In this book we have examined forest management as a set of compatible production opportunities at the stand and landscape levels. Several examples have demonstrated that opportunities exist to simultaneously produce multiple forest goods and services, maintain the ecological integrity of the forest resource, and reduce social conflict regarding management. In this sense, compatible forest management is complementary to (and likely a component of) sustainable forest management.

The United States and Canada are signatories to the Montreal Process for Sustainable Forest Management. The Montreal Process is one of several frameworks that seeks to balance environment, economic, and equity considerations of forest management from a societal viewpoint (Mihajlovich 2001, Tittler et al. 2001). The criteria and indicators used in the debate about sustainable forest management reflect these three broad areas. Sustainable forest management often does not consider ownership differences other than the contributions of selected ownerships to broad-scale measures. Much of the debate about sustainable forest management is in the context of broader societal goals for sustainable growth (Mendoza and Prabhu 2000). These goals are described in terms of their contributions to economic prosperity that is socially just and environmentally sound.

One of the key differences in compatible forest management is its focus on compatible production opportunities at the stand and landscape levels from the perspectives of owners and managers. Here landowners or managers must decide how they can produce a range of goods and services as they practice forest management. This emphasis on relating management inputs and possible outcomes in an economic and financial context has long been recognized as the heart of the forest management question (see Baker 1950, Davis 1966, and Davis and Johnson 1987, Davis et al. 2001). It also implies that the benefits of compatible forest management need to accrue to those who pay the costs.

This focus on the financial aspects of management is a fundamental distinction between compatible forest management and sustainable forest management. Simply put, compatible forest management has to demonstrate that it can pay for itself on private timberlands. There are instances where forest regulations impose additional costs (e.g., riparian buffers). As long as these regulations are equitably applied, result in positive public benefits, and do not reduce the value of the land, they are generally not perceived as an onerous economic burden.

Compatible forest management on public timberlands often focuses on production of public goods, such as habitat. For example, much of the public land management in the Pacific Northwest is within the context of various habitat conservation strategies where the primary focus is on maintaining selected habitat while at the same time providing recreational opportunities, some timber harvest, gathering of nontimber forest products, and protection of culturally significant sites.

The spatial scales in compatible forest management are significantly different that those of sustainable forest management. Compatible forest management is often considered at the ownership and landscape scale. In the United States, we often ask about the management consequences across an ownership or across all owners at the regional level. The debate about sustainable forest management, however, is actually conducted at the broadest of scales: ecoregions and nations. As signatories to the Montreal Process, forest managers and planners in the United States and Canada have to assess the indicators of sustainability at the national level based on understanding processes at the next lowest spatial level (e.g., ecoregions).

Temporal scales are also different for compatible and sustainable forestry. In the current debate on sustainable forest management, the focus has been on assessing current progress toward sustainable forest management at a specific point in time. Discussions about compatible forest management tend to move back and forth along the time spectrum. Several chapters in this book trace the evolution of management strategies over the past 50 years whereas others consider the evolution of future trends.

Compatible forest management seeks production opportunities that feature mutual gains in selected sets of outputs. Some of the best examples are at finer scales where owners seek compatible forest management by focusing on different outputs. But on the broadest scale, the collective actions of many owners also contribute to both compatible and sustainable forest management.

Regardless of the distinction between compatible and sustainable forestry, sustainability of forest resources is an enduring issue in scientific and political discussion. Clearly, measures of sustainability become increasingly complex as the spatial scale increases from the stand to landscape to region and on to national and global scales. Although much of the work with criteria and indicators of sustainability are at the national scale, forest management is implemented at the stand scale where there has been an emphasis on sustained yield management.

4. Epilogue

The primary issue in land management is stewardship. As Solomon said some 2600 years ago, "One generation comes and another passes but the land remains." As land stewards, our task is to manage forests to contribute to economic prosperity with actions and goals that are socially just and environmentally sound. In one sense, compatible forest management merges our scientific understanding with changing societal values to shape the forest legacy for the next generation.

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