Faustmann and the Forestry Tradition of Outcome-Based Performance Measures[1]

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Abstract

The concept of *land expectation value* developed by Martin Faustmann may serve as a paradigm for outcome-based performance measures in public forest management if the concept of forest equity value is broadened to include social and environmental benefits and costs, and sustainability. However, anticipation and accurate evaluation of all benefits and costs appears to present significant challenges, as revealed in the history of public forest policy in the United States. While public forest managers are unlikely to adopt performance measures based on forest equity value, an understanding of this concept may help shape the future direction of public forest management.

Keywords: Faustmann formula, outcome-based performance, forest managers

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Introduction

The forestry profession in the United States has been challenged to develop improved outcome-based performance measures for forestry. The Chief of the USDA Forest Service, Mike Dombeck, recently called upon the Society of American Foresters to help develop land-based performance measures to evaluate "outcomes" rather than "outputs" of forest management; that is, to focus "less on what we take from the land and more on what we leave behind" (Dombeck 1998). The Chief said that U.S. public forests should be managed for outcomes that are important to the American public in the long term, including large and unfragmented landscapes, wilderness and roadless areas, clean water, protection of rare species, old-growth forest, and "naturalness" of the forest. The Chief also recognized a need to convincingly make the case for investments in forestry that may not yield immediate economic profit or short-term gain but may yield long-term benefits (Dombeck 1998). Foresters, beginning with Martin Faustmann in the mid-19th century, pioneered the use and application of outcome-based performance measures in forest management.

The purpose of this paper is to examine whether a singular measure of forest equity value, such as Faustmann's *land expectation value* concept, may serve as a paradigm for improved outcome-based performance measures in forestry. This paper pays tribute to the philosophical tradition of outcome-based performance measures in the forestry discipline and celebrates the 150th anniversary of Faustmann's formula by citing philosophical reasons why Faustmann's concept may yet be relevant in public forest management. These reasons include emphasis on enhancement of forest equity value and fiduciary responsibility. Forest equity value has long been used to evaluate outcomes in forestry and to make the case for investments in forestry, but policy endorsement of forest equity value as a performance measure has been weak and inconsistent. This paper addresses a series of questions about the forestry concept of land expectation value in relation to the goal of developing improved outcome-based performance measures in public forest policy.

The first question is whether land expectation value can serve as an outcome-based performance measure in forestry and whether forestry experts traditionally regard it as such. The answer to this question is strongly affirmative, as forestry has traditionally focused on managing forests to achieve a gain in forest equity over time and land expectation value is recognized as the measure of this equity value. The land expectation value concept reinforces fiduciary responsibility by unifying the concepts of forest valuation and optimal management performance in the forestry discipline.

The next question concern the relevance of land expectation value in the context of National Forest management policies in the United States—whether concepts like land expectation value were integrated into National Forest management policy. The answer is that forestry experts in the United States have always been aware of the concept of evaluating forestry performance in terms of forest equity, but National Forest management policy has never strongly endorsed application of concepts like land expectation value or any similar criterion for optimization of forest management.

This paper is by no means an historical critique of public forest policy or National Forest management policy. Indeed, as explained in this paper, there is simply insufficient economic analysis or data upon which to fully account for the historical performance and outcomes of public forest management and policy in the past century. This reflects a major practical problem with applying the forest equity value concept in forest management; specifically there is great difficulty in estimating or anticipating accurately all benefits and costs of public forest management. Lack of historical performance data probably contributes to a lack of public consensus and lack of strong policy endorsement for outcome-based performance measures.

Finally, this paper focuses on practical or philosophical reasons for incorporating such measures into public forest policy in the future. The philosophical issues include concerns about intergenerational equity and sustainable development. My conclusion is that land expectation value can reinforce intergenerational equity and sustainable development, but policy application will likely be limited by practical considerations such as lack of public consensus and difficulty in assessment of benefits and costs.

Background

The roots of the forestry discipline in the United States can be traced to European origins. Textbooks on forest economics often include reference to the 19th century German forester Martin Faustmann, who is well known for his land expectation value formula (see Klemperer 1996, Buongiorno and Gilless 1987). The original Faustmann formula spanned the time dimension in perpetuity and provided a singular measure by which the equity value of a forest could be determined and by which optimal management regimes could be selected in terms of gain in forest equity value.[i] Faustmann elucidated the concept using modem principles of quantitative investment analysis and discounting. Some of the same general principles eventually became more widely applied throughout the world in modem techniques of fiduciary and managerial accounting, such as discounted cash flow analysis and benefit-cost analysis (Gane 1968). However, Faustmann’s land expectation value formula embodied more than general principles of discounting and net present value computations. It embodied some key assumptions about forestry, including an assumption that cyclical management regimes will be sustained in perpetuity. Faustmann also advanced the idea that management performance in forestry was determined by the gain in forest equity associated with forest management (the difference between discounted benefits and costs associated with forestry activities on the land). Essentially, Faustmann’s formula computed the value of forest equity deriving from management of natural capital on forestland. This established a tradition in the forestry discipline of fiduciary responsibility by unifying principles of forest valuation and optimal management performance.

The forestry discipline is generally dedicated to restoring or enhancing natural capital by selecting and applying management regimes that enhance or improve the value of equity in forest resources. Accordingly, foresters assume fiduciary responsibility to manage forest equity in an optimal manner. To do otherwise is to squander the equity value of the forest. Selecting an optimal management regime on the basis of net gain in equity ensures that the chosen management regime achieves the best possible improvement in equity value. This same fiduciary responsibilty extends to management of public forestlands, although it is complicated because the equity value of public forests is shared by the public and encompasses a wide range of values including financial, social, and ecological values. Optimal performance in that case means achieving the best possible gain in public equity associated with expenditure of public funds. Conversely, neglecting optimal performance in public forest management may be seen as a lack of fiduciary responsibility, the squandering of public funds on suboptimal or ineffective management regimes. Thus, fiduciary responsibility may be reguarded in the forestry discipline as an ethical reason for using performance measures based on forest equity.

Despite the obvious ethical reasons for supporting equity value as a performance measure in forestry and forest policy, it remains dubious whether improved performance measures based on established concepts such as land expectations value will be endorsed by U.S. public forest Policy. A major concern is uncertainty about whether forest management will actually lead to the desired forest conditions. Another uncertainty has to do with current expectations compared to future reality. When the forest has matured, will it still match public values and expectations? It is also conjectural whether such policy endorsement in the past would have significantly changed the course of public forest management in the United States. However, if improved outcome-based performance measures are to be designed for management of public forestlands in the future, as called for by chief Mike Dombeck, then it is important to consider Faustmann's concept of land expectations value in relation to historical and philosophical policy issues.

Land Expectation Value Concept

In 1849, martin Faustmann described his formula for land expectation value (Faustmann 1849). Educated as a forester, Faustmann wrote his article in response to the question of just compensation to forest landowners whose lands were being appropriated for agricultural uses. In particular, Faustmann sought to determine the value which forestland and immature stands possess for forestry in perpetuity, to avoid the prospect that forest landowners would be unjustly compensated for the more limited value of immature trees or bare land. Faustmann was opposed to evaluating forestland solely on the basis of the value of currently available forest outputs. He recognized that forest management generally involved cycles of accumulation and de-accumulation of natural capital (tree planting, growth, maturation, and harvest on a renewable and sustainable cycle). As such, Faustmann recognized that it would be inappropriate to assess the value of forestland based on the current condition of forest capital, without taking into account its renewability. A major thrust of his article was to reject a notion that the value of immature forest stands should be determined on the basis of the sale price of their current standing timber. As Faustmann wrote in his introduction,

. . .in order to present a complete solution we must extend our analysis to immature stands. We must not calculate the value of such stands as represented by the sale price of their present timber content, but by their value as determined from their exploitation when mature, i.e. by the value which attaches to them in the forestry system or by their age class in the rotation.. . (Faustmann 1849)

In essence, Faustmann envisioned that forestry involved restoration of natural capital (growing trees to maturity in recurring cycles) and thus forestry had expected outcomes that enhanced the value of the land. He sought to determine this value by computing the net gain in equity, taking into account the discounted value of all expected future benefits and costs associated with expected forestry outcomes.

The basic principle of the Faustmann formula is that the value of a parcel of forestland can be determined only by evaluating the expected forest equity value derived from managing the land in perpetuity, taking into account all expected benefits and costs. This is accomplished in the formula for a periodic management regime by discounting all expected benefits and costs to a common point in time under an assumption that the management regime will be maintained in perpetuity. Faustmann was the first in the modem forestry discipline to advance a singular formula for this type of valuation technique, deriving an accurate economic formula for managing the land in perpetuity, taking into account all expected benefits and costs.

More importantly, Faustmann's formula unified the principles of forest valuation and optimal performance in forest management. By measuring the net gain in equity, taking into account all expected benefits and costs, Faustmann's formula provided a means to evaluate and compare relative performance of different forest management regimes and to determine the optimal regime in terms of expected outcomes. Thus, Faustmann established in the forestry discipline a tradition of using outcome-based performance measures focused on the gain in forest equity.

It was perhaps natural that modem techniques to evaluate management outcomes spread over time were developed first and applied early in the forestry tradition, because forestry generally focuses on restoring or improving natural capital, enhancing the value of forest equity over time. In timber management, for example, trees naturally take years to grow resulting in a delay between costs of planting and revenues at harvest. Ecosystem management (managing forest ecosystems toward desired ecological conditions) also involves outcomes that are spread over time, as conditions of forest ecosystems will generally change only gradually in response to management. Forestry, whether focused on timber management or ecosystem management, will generally involve costs and benefits that will be spread over decades or generations. Evaluating performance in forest management thus logically requires a means to evaluate outcomes that are spread over time, whether evaluating financial outcomes, social outcomes, ecological outcomes, or any combination of management outcomes that enhance the value of forest equity.

Early Traditions of Outcome-based Performance Measures

Not long after the debut of the Faustmann formula, reports from the 19th century reveal that the earliest forestry experts in the United States were using outcome-based performance measures focused on forest equity. Early forestry experts in the United States used such outcome-based performance measures to demonstrate the value of forest management at a time when this value was not widely understood. Examples are provided by Franklin B. Hough, who is often regarded as the predecessor of Gifford Pinchot, the first Chief of the USDA Forest Service.[11]

Hough's first report on forestry published by the U.S. government in 1877 shows early use of outcome-based performance measures that focus on net gain in forest equity associated with forest management (Hough 1877). Many passages reveal that early forestry experts used discounting to compute net gains in forest equity associated with forestry investments and land management, deriving net present values from expected benefits and costs of forestry activities. In addition, Hough was aware of broader economic values in forestry, as he wrote "not only for the direct, but also the indirect profits." This broader perspective is illustrated by the following excerpt from a presentation by Mr. O.B. Galusha at the Industrial University of Illinois in 1869:

> A few miles from my residence are a few acres of ground which were cleared of timber sixteen or seventeen years since. There was then left upon the ground a growth of underbrush only, consisting of several varieties of oak, hickory, ash, and some other sorts. I have watched the growth of timber there from year to year, until the present time, and am myself surprised at the result. The land was worth, when cleared, perhaps $12 per acre, not more. There have been taken from it, during the last seven years, poles equal in value, probably, to $10 per acre, and $150 per acre would hardly buy the trees now standing upon it. So that if we estimate the value of the land (at the time mentioned) at $12 per acre, and compute the interest upon this for 16 years at 6 per cent, compound interest, adding the amount of taxes accruing during the time, with interest upon this at the same rates, we have $100 per acre as the net profit of the timber crop; while, of course, the land itself has partaken of the generally enhanced value of surrounding real estate, and would now probably sell for $50 per acre, were the timber removed. (Hough 1877)

Although Faustmann's precise formula for land expectation value was not employed in this case, basic concepts of forest equity valuation were used. A compound interest rate was used to carry forward prior costs of land investment and taxes from the time the timber was cleared, and the present value of expenses was then deducted from the present value of timber to derive a singular "net profit" or net present value. The evaluation of gains in forest equity based on net benefits and costs is clearly evident. Note that this type of analysis was being done routinely by American forestry experts decades prior to the exposition of modem principles of discounting and cash flow analysis by economists such as Fisher (1907) and others.

More importantly from the modem public policy perspective, the excerpt by Galusha and other passages in Hough's report show that early American forestry experts recognized how certain "indirect" economic values could be incorporated into the analysis in addition to "direct" financial values in evaluating forestry outcomes. Apart from the net financial outcome of $100/acre in land and timber values, an indirect enhancement of land value to $50/acre was attributed to the "generally enhanced value of surrounding real estate" resulting from improved forest conditions. This example may be viewed as an early American prototype of outcome-based performance measures in which both the financial and broader economic outcomes of forest management are evaluated simultaneously.

It is clear that Hough was measuring the outcome of forest management in terms of net gain in equity value, what is "left behind" or what is improved in the forest through forest management. He was not simply measuring "outputs" or what might be taken from the forest, but rather showing how forest equity could be improved as an outcome of beneficial forest management. Thus, outcome-based performance measures similar in some respects to Faustmann's formula were part of the earliest traditions of forestry in the United States.

Generalized Interpretation of Faustmann Land Expectation Value

The Faustmann concept of land expectation value may be generalized by the following formula ($LEV\infty$), based on expected economic benefits and costs throughout a periodic management cycle:

$$LEV\infty = \sum_{n=1}^{u} \frac{\left[(B_n - C_n)(1.0 + p)^{(u-n)}\right]}{\left[(1.0 + p)^u - 1\right]}$$

where $B_n$is total benefits in year *n* of management cycle, C_n total costs in year n of management cycle, *p* discount rate, and *u* number of years in each periodic management cycle. Thi`s expression assumes that land expectation value is computed just prior to initiation of a management regime with periodic cycles of determinate length (alternative formulations can be devised if the periodicity assumption is not applicable). This generalized expression simply serves to illustrate more clearly that the forest equity value concept or land expectation value is based on the net difference between expected benefits and costs associated with forest management (B_n–C_n).

In almost all cases, forest managers have a spectrum of management regimes to choose from, affording different levels of expected annual costs or benefits. Thus, different levels of performance in terms of equity value ($LEV\infty$) may be obtained through selecting alternative management regimes. Finding the optimal management regime translates directly to the problem of finding the management regime that yields the maximum equity or land expectation value, subject to certain limiting constraints or qualifications. Optimization in forest management is usually constrained to some extent, by constraints of fixed budgets or by constraints of targeted outputs for example, but this does not preclude optimization. Optimization under budget cost constraints will focus on selecting the management regime that maximizes net benefits subject to fixed limitations on management expenditure costs. Optimization under an administrative requirement to meet certain targeted outputs may focus on selecting a management regime that minimizes costs while meeting targeted goals. Except under the most rigid management constraints there is usually some flexibility in selecting alternative management regimes, and thus there is almost always some room for optimization of forest equity value.

In forestry, the expected timber rotation between planting and harvest may determine the length of the periodic management cycle, as in Faustmann's original formula, or the length of the management cycle may be determined by other natural or ecological growth cycles of the forest. The length of the management cycle itself may be varied and subject to optimization (as in optimization of rotation length under Faustmann's original formula). Much of the forestry literature related to Faustmann's formula is Concerned with optimizing timber rotation lengths (Newman 1988). Alternatively, the length of the management cycle may be fixed (e.g., by administrative decision) and yet the intensity or design of management regimes may still be varied so as to achieve different levels of annual costs and benefits (and different performance levels in terms of LEV_∞). Thus, optimizing management performance in forestry is not exclusively concerned with timber rotations according to the generalized concept of land expectation value. Instead it is generally concerned with optimizing the value of forest equity by managing the flow of benefits and costs over time.

For any activity involving the management of equity a meaningful measure of performance or net gain will necessarily involve a singular *numeraire*, a common unit of account or common standard of value by which benefits and costs of different outcomes may be compared. The original Faustmann formula was developed when outcomes being considered in relation to forest equity were primarily financial outcomes related to timber. Thus, Faustmann's original formula was based on the numeraire of financial monetary value, related to timber management costs and timber revenues. However, modem forest managers on public forestland generally focus on other long-term equity values such as the ecological health of the forest and biodiversity, as well as financial values. General principles embodied in the Faustmann formula are no less valid today when other equity values are taken into account. A meaningful measure of net gain in forest equity still requires a singular numeraire, even though different categories of benefits and costs are to be considered.

Land expectation value in the general sense (LEV_∞) may encompass broad economic values as well as financial values. Here a distinction is made between financial values and broader economic values, as in the literature (Gregerson 1985). In the case of financial values, only monetary costs and revenues that accrue to a particular investor are considered, whereas economic values extend to broader and less tangible social benefits and costs, including environmental benefits and costs. The benefit-cost ratio and discounted net public benefit criteria are two general examples of outcome-based performance measures in the Faustmann tradition that commonly encompass broader social benefits and costs. Although a singular numeraire must be used to derive a meaningful measure of net gain or performance, it is understood in forestry that benefits and costs of management may encompass a broad array of economic values, not just financial values.

Economic theory establishes that while the numeraire of choice may be varied (and social discount rate will vary depending on the numeraire), the selection of the socially optimal management outcome is unaffected by choice of numeraire, assuming that all benefits and costs are accurately evaluated (Dasgupta et al. 1999). The Faustmann concept of land expectation value (or LEV_{∞}) can thus be viewed as a paradigm for broader net public benefit formulas that include non-financial values such as those related to health and integrity of forest ecosystems, as well as financial values related to forest productivity. The choice of numeraire for analysis is not as important as the accuracy and inclusiveness of economic values in the analysis. For example, it has been shown that there is a positive correlation between the optimal length of rotation and the magnitude of environmental values when such values are included in the land expectation value formula in management of Douglas-fir (Bowes 1983, Hartman 1976). It is understood in forestry that an economic trade-off between financial outcomes and broader economic outcomes is typically associated with sustaining the health and integrity of forest ecosystems. Thanks in part to Martin Faustmann, there is a tradition of using outcome-based measures of land management performance that can encompass all economic benefits and costs related to long-term conditions of forest productivity and the health of forest ecosystems. In addition, Faustmann's concept of land expectation value reinforces sustainability.

Following notation used by Klemperer (1996), the infinity subscript (∞) is used to denote that land expectation value in forestry is derived from an infinite series of periodic management cycles (not just one cycle or one rotation). This is an important aspect of the formula in terms of its validity and also in terms of sustainability and intergenerational equity. The land expectation value formula (as in LEV_{∞} or the original Faustmann formula) is valid only if forest management cycles are in fact perpetually sustainable. This is ensured only if the forest is managed in such a way that the forest capital is truly renewable and the cycle of management can be sustained indefinitely. Thus, the stipulation that management regimes are perpetually sustainable is equivalent to a stipulation that resource conditions will remain renewable and sustainable. This stipulation is quite significant, because it can ensure that future generations retain the same production possibilities as the current generation. Production possibilities are preserved from generation to generation when it is ensured that forest capital is perpetually renewable and sustainable. Of course, this will not occur if the management regime is not truly sustainable and future conditions of forest capital do not return to current conditions on a cyclical basis.

Thus, as conceptualized by Faustmann, land expectation value stipulates a strictly egalitarian distribution of production possibilities among all future generations, provided that forest management cycles are in fact perpetually sustainable and forest resources are indeed renewable. Obviously, certain types of destructive management regimes can result in a permanent loss of forest capital and would thus violate the stipulation that management regimes be perpetually sustainable. However, in many cases of forest management in the 20th century, not only was forest management sustainable but the condition of renewable forest resources was also improved by management over time (Fedkiw 1998).

As explained in the literature, Faustmann's formula for land expectation value can measure private *willingness to pay* for bare forestland in timber management (Klemperer 1996), and likewise the general formula for land expectation value ($LEV\infty$) can measure the public's willingness to pay for forest management on public land. For example, if costs (C_n) include public expenditures for forest management, benefits (B_n) are public benefits, and the discount rate is the minimal expected gain in other public expenditures, then $LEV\infty$ is precisely the net public gain to be achieved in relation to public expenditures on forestry versus other expenditure options. It measures precisely the expected gain associated with expenditures on public forestlands versus the expected gain from other public expenditures (determined by the discount rate). Thus, $LEV\infty$ measures both the expected performance of forest management on public forestlands (the equity value of management) and also establishes the public's theoretical willingness to pay for forestry relative to other public expenditure opportunities. This assumes, of course, that all costs and benefits are included along with an appropriate discount rate reflecting opportunity for gain in other public expenditures (outside of forestry).

Despite philosophical reasons to support the land expectation value concept as an outcome-based performance measure in forestry, this concept is seldom used as a standard measure of expected performance in either private sector or public sector forest management. For the most part, measures of expected performance used in the private sector focus on financial outcomes that are achieved in a single rotation, using measures such as net present value or internal rate of return. Private sector forest managers seldom use an infinite planning horizon as in Faustmann's formula, although results of net present value calculations over a single rotation may be similar to results obtained from Faustmann's formula Broader economic consequences (ecological or social costs) and sustainability of management regimes beyond the current rotation are also usually not emphasized in the private sector.

In the public sector, even in modem Germany on forest stands that Faustmann helped establish in the 19th century, management regimes are usually not selected or optimized according to Faustmann's original formula. Silvicultural regimes and rotation lengths on public forests often appear to be based on criteria other than optimal economic performance, including qualitative or prescriptive criteria established by higher level authorities.[iii] Moreover, a general concern with outcome based performance measures and optimization is that there is no guarantee that forest management will actually lead to desired or expected outcomes. This uncertainty in forestry, including uncertainty about whether economic values and expectations in the future will match those operating at the time forest management is initiated, has limited the policy endorsement and applicability of forest equity value as a measure of expected performance in public forest management.

A review of National Forest management policy in the United States reveals that forest equity value was never strongly or consistently endorsed as a measure of management performance or as a criterion for optimizing management performance.

Shifting Paradigm in United States

Although the use of performance measures based on forest equity value is found in the early traditions of forestry in the United States since the time of Faustmann, the use of such performance measures was not consistently emphasized in National Forest management policy or practices. This is somewhat ironic given the fact that National Forest managers were always concerned with enhancing public equity, by caring for watersheds and soil productivity, restoring range productivity, and reducing soil erosion. However, use of a singular or holistic performance measure based on forest equity, such as land expectation value, was not explicitly endorsed by public policy, nor was it widely or consistently applied in management of the National Forests.

A review of National Forest management policy suggests reasons why such outcome-based performance measures are unlikely to be endorsed in public forest policy. Federal forestry legislation and much of public forest policy in the 20th century focused on sustaining multiple uses of National Forests without providing specific guidelines for economic optimization. Early management policies focused on regulation of individual uses or outputs. Restrictive limits on outputs and regulation of management practices so as to avoid damage to watersheds and maintain soil productivity were seen as a way to maintain the permanence of natural capital and thus avoid the destruction of forest equity.

Regulatory limits on some outputs such as timber were raised over time by intensifying management of forests for those outputs, particularly in the post-World War II era. However, it was found that regulation of individual forest outputs such as timber did not ensure that outcomes were optimal in broad economic terms, or even broadly acceptable in political terms. Environmental outcomes and issues related to intensified timber management precipitated major episodes of public controversy from the late 1960s to 1980s. The general public and policymakers became increasingly concerned about broader and more holistic consequences of forest management on public lands. Consequently, since the 1980s National Forest management emphasis has shifted from maintaining ecosystems for production of outputs to maintaining ecosystems for their broader social and environmental values (Fedkiw 1998).

Thus, one interpretation of history is that the management paradigm for public forestry in the United States has shifted over time from a focus on “outputs” (multiple uses) to a focus on “outcomes” (broader ecological and economic consequences). A different interpretation of history is that policy has always focused on ecological and economic consequences, including protection of forest equity value, but policy has never provided clear guidelines for optimizing management regimes according to the forest equity value concept. Some laws and regulations have at times encouraged assessment of forest equity values, such as the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1978 and regulations issued pursuant to the National Forest Management Act of 1976 (USDA Forest Service 1983). However, optimization of management regimes using outcome-based criteria such as forest equity value did not become permanently institutionalized and today is not widespread in public forest management or planning, even though the classical paradigm of management performance in forestry — land expectation value — was focused on optimization of forest equity value.

Thus, apparently there was a lack of strong public policy endorsement for outcome-based performance measures such as forest equity value, despite awareness of such measures among forestry experts. In the meantime, forest management policy has become strongly influenced by increased public awareness and public interest in management outcomes. If this interpretation of history is correct, then it might seem likely that public forest policy will eventually gravitate toward stronger endorsement and application of outcome-based performance measures. However, historical experience and philosophical issues tend to dampen this outlook.

The Organic Administration Act of 1897 serves as a classical example of how public forest policy was focused on outcomes related to forest equity value but did not explicitly endorse or promulgate any performance measures based on forest equity value (USDA Forest Service 1983). The Act defined the purposes for which National Forests were administered: “to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States.” The Act provided that the Secretary of Agriculture shall make rules and regulations to protect forests ”against destruction by fire and depredations,” and to “regulate their occupancy and use and to preserve the forests thereon from destruction.”

Although the Organic Act focused attention on protecting forest equity, it provided no general administrative guidelines with respect to optimal management of forest equity (other than an authority to conduct periodic surveys). The Act did not give explicit policy guidelines with respect to use of specific outcome-based performance measures in forest management. A pattern of such general policy prescriptions With little or no specific guidance on outcome-based performance measures seems to have been a characteristic of National Forest policy throughout the 20th century. It is true that the Forest Service did seek to improve and protect forest equity, through protection of watershed resources, fire protection, and regulation of forest and rangeland uses. The Forest Service institutionalized local performance measures and developed management guidelines for local administration of forest uses, but policy guidelines generally did not focus on optimization of forest equity value.

The Organic Act may be viewed as a “middleground” between competing political interest groups in the late 19th century (Fedkiw 1998). In the early 19th century, the Federal government sold or granted ownership in a vast amount of land to industrial and private landowners, but by the end of the century the government still retained ownership of many large forested areas. These public forestlands included the so-called forest reserves that were typically located in more remote or mountainous locations, mainly in the western United States. In the late 19th century, some political groups advocated preservation of the forest reserves with either no use or very highly restricted use of forest resources, while other political groups favored unrestricted access to public lands or selling public lands at low prices. The Organic Act responded to these political interests, promoting use of the public forest resources but restricting uses to avoid destruction of resources.

Although the Forest Service was directed to "improve and protect the forest," the concept of managing for optimal equity value was not part of the political response in the Organic Act, or at least it was not spelled out clearly in the Act or Agency interpretations of the Act. Thus, the Forest Service adopted an approach to management that became known as multiple use management, which did not necessarily focus on optimization of forest equity value although it did afford protection of forest equity value and allowed for some enhancement of forest equity value through active forest management.

A book recently published by the USDA Forest Service documents and describes the history of multiple-use management on National Forests in the United States throughout most of the 20th century (Fedkiw 1997). The preface to the book explains that it was difficult to document the history of multiple-use management because there was no specific "staffing, organization, accounting, or reporting for multiple-use management *per se.*" It is stated also that "the policy direction for managing national forests for multiple uses did not give any specific guidelines for applying this policy to specific land areas where management for multiple uses was actually taking place" (Fedkiw 1997). The ideal of multipurpose resource use emerged from the populist conservation movement of the early 20th century. Multiple-use management emerged as "the fitting of multiple uses into ecosystems according to their capability to support the uses compatibly with existing uses on the same or adjoining areas, in ways that would sustain the use's outputs, services, and benefits, and forest resources and ecosystems for future generations" (Fedkiw 1997). It did not emerge historically as the optimization of uses or optimization of forest equity values.

A central element of multiple-use management was the policy of sustained yield of forest products and services, deriving originally from the Organic Act. Embedded in the earliest interpretation of this policy was the idea of "resource permanence," as in Secretary of Agriculture James Wilson's interpretation of the Organic Act transmitted to Gifford Pinchot (Fedkiw 1997). It was perceived from the outset that this outcome was to be achieved primarily by regulating the flow of forest outputs, by restricting excessive or improper use of forest resources in order to sustain the flow of output (rather than primarily through selection of optimal forest management practices). Ensuring the permanence of the forest also meant protecting the soil and watershed resources, and exclusion of fire. To be sure, the Forest Service did seek in many ways to improve forest management practices, in order to enhance forest outputs within sustainability constraints. However, there were no specific policy guidelines for performance measures aimed at optimizing management performance in terms of forest equity under a constraint of sustained outcomes, such as the Faustmann formula Under sustained yield management policy for timber, the Forest Service restricted periodic timber harvests to an "allowable cut" in line with contemporary concepts of *normal* regulated forest management and volume control.

A normal fully regulated forest is an idealized outcome in forestry in which the land area is fully stocked with trees distributed evenly among all age classes and where a constant periodic harvest or "even flow" of timber output has been achieved. In that case, an even flow of timber may be computed by standing volume of timber or by land area, harvesting periodically a fraction of volume that results in a constant periodic harvest (Buongiorno and Gilless 1987). The so-called normal fully regulated forest ideal is in fact an old European concept that predates Faustmann. Bernard Fernow wrote that the concept of the normal forest "was evolved in 1788 by an obscure anonymous official in the tax-collectors' office of Austria" where it was used for tax purposes (Fernow 1907, Gane 1968). Although the concept of regulated forest management was of European origin, the concept was applied and modified in the United States under sustained yield policies to regulate harvest of old-growth timber on National Forests in the western United States. Thus, in the United States, the von Mandel formula for volume control was used initially for computing the allowable periodic timber harvest level or "allowable cut" on the National Forests in the early 1900s. However, by the mid-1900s, the Hanzlick formula became more popular and eventually the Forest Service adopted the long-term sustained yield formula.[iv] The sustained yield policy was later augmented by the National Forest Management Act of 1976, which specified that forest stands should reach the culmination of mean annual increment in growth before harvest, equivalent to the maximum average annal output of timber (Newman 1988).

To some, sustained yield was a policy designed to stabilize forest industries, while the Forest Service regarded the policy as a means of regulating output of timber so as to sustain the productive capacity of forests (to achieve "resource permanence"). Both are examples of desired outcomes. The Forest Service also managed for other criteria that served the objective of resource permanence, such as soil, watershed and wildlife protection. However, selection of management regimes to serve these outcomes was not routinely optimized according to any singular measure of performance in terms of overall forest equity value. Although the concepts of volume control and regulated forest management can be linked in forestry to optimization of management regimes, there was little administrative guidance and no explicit or routine policy guidance for such an optimization process throughout the 20th century.

Instead, timber harvest regulation through volume control or "allowable cut" and the goal of maintaining an even flow of timber outputs became central elements of administrative attention under sustained-yield policy. In the 1960s and 1970s, when it was determined initially that allowable cut levels in some regions could not be sustained indefinitely under existing management practices, the management practices were intensified through accelerated reforestation and timber stand improvement in order to achieve higher allowable cut levels. Thus, the policy was seen as adaptive or flexible at times, as it afforded some room for improvement of management practices in terms of outcomes, but philosophically the policy centered more on regulation than optimization. The policy was also seen as providing support for certain macroeconomic objectives such as helping to contain economic inflation by providing an adequate supply of lumber during the housing booms of the 1960s and 1970s (Fedkiw 1997).

Whatever the historical justification for sustained yield policy, it has been criticized in recent years for fostering a shortsighted focus on timber outputs rather than a focus on broader forestry outcomes (Miller 1997). Critics assert that volume control management reflected a desire by foresters to convert western National Forests to fully regulated forests according to European ideals (Miller 1997, Wilkinson and Anderson 1987, Langston 1997). This criticism may be viewed as unjustified, insofar as the central focus of policy since the Organic Act was on "resource permanence," and not any particular European ideal. Nevertheless, critics also claim that sustained harvesting coupled with fire suppression led to unforeseen ecological outcomes on certain western National Forests, such as replacement of old-growth ponderosa pine by densely overcrowded stands of small-diameter fir and lodgepole pine (Langston 1997). Thus, in the case of ponderosa pine, it is claimed that sustained yield policies resulted in unsustainable and ecologically destructive forestry practices and contributed to the decline of a segment of forest industry in the West (Langston 1997).

The critics seem to suggest that long-term management outcomes on some western National Forests were obscured by an administrative focus on regulation and maintenance of forest outputs. Thus, the administrative approach to sustained yield policy (focusing on output regulation or volume control for timber harvest) reinforced a perception among critics that the Forest Service was not concerned about broader outcomes, or that the only measure of management performance was the output of timber. In fact, timber harvests were also constrained by other criteria designed to protect watershed quality, wildlife habitat, and soil productivity, but there was no policy to select or optimize harvest levels according to an overall measure of forest equity value. Statements of sustained yield policy in legislation reinforced this view, with a focus on outputs and protecting the land but no endorsement of explicit outcome-based performance measures. The Multiple-Use Sustained Yield Act of 1960 defined the "sustained yield of the several products and services" as "the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the National Forests without impairment of the productivity of the land" (USDA Forest Service 1983). A remedy that critics might support would be to focus attention less on regulating and maintaining outputs and more on the full spectrum of benefits and costs of forest management, by adopting forest equity value as a management performance measure.

In theory, the Forest Service could have adopted forest equity value as a performance measure within constraints of multiple-use management and sustained yield policy if the Agency had chosen to do so, but the Agency also retained discretionary authority not to do so. Throughout much of the 20th century, the Forest Service retained broad discretionary decision-making authority that provided local managers with considerable management flexibility within limited regulatory constraints (Fedkiw 1997). However, episodes of public controversy in recent decades raised doubts in some circles about the breadth of this discretionary authority, and some would no doubt question the ability of the Agency to determine optimal management regimes at the local level. The desire to preserve discretionary authority and flexibility within the Agency as well as concern about the exercise of such authority are both likely political reasons why the use of specific outcome-based performance measures was never strongly endorsed by the Agency or in public policy.

Probably the most significant scientific reason why forest equity value was never endorsed by the Agency as a standard performance measure in forest management is simply the technical difficulty in obtaining accurate and complete data on expected benefits and costs of forest management activities or outcomes. It was perhaps simply recognized that it would be easier to manage forests within general policy constraints (such as sustained yield and even flow) than it would be to truly optimize management of forests in terms of expected benefits and costs.

The one principal case in which the Forest Service did develop and rigorously apply an outcome-based performance measure was when *net public benefit* was articulated as a means to evaluate forest management alternatives in National Forest management planning in the late 1970s. Regulations adopted pursuant to the National Forest Management Act of 1976 specified that management alternatives developed in the National Forest planning process should be accompanied by estimates of the net public benefit (the discounted market value of expected future uses less expected management costs). As implemented, this criterion was not precisely the same as the land expectation value concept, as it was based usually on a finite time horizon and sustainability was not an explicit assumption. However, net public benefit was similar to land expectation value in that it provided a measure of gains in forest equity associated with forest management. A large linear programming computer model was developed in the 1970s to assist in the process of determining optimal management alternatives according to the net public benefit criterion (FORPLAN model). Although net public benefit estimates and FORPLAN received a fair amount of attention during the late 1970s and early 1980s, the concept of optimization based on forest equity value was never explicitly endorsed by regulation or policy. Instead, the net public benefit criterion was used commonly to present a "preferred" management alternative, while various other management alternatives were also developed in the planning process (including alternatives that were not optimal in terms of net public benefit). Also, management plans were goal-oriented and net public benefit computations were generally not site-specific or project-specific, rendering ambiguous the application of results to management (Fedkiw 1997).

In any case, emphasis on net public benefit computations and use of FORPLAN largely fell out of favor by the late 1980s, amid growing public controversy and growing awareness that consensus on forest management issues was not being advanced by the derivation of expected net public benefit. The public was represented by many interest groups. Competing interest groups seldom found advantage in compromising or reaching consensus on matters such as net public benefit. Lacking strong policy commitment, the use of this performance measure (logical as it may have been) gradually declined and is seldom used today. The experience with FORPLAN and the net public benefit criterion reveals a general lack of public consensus on how to determine the long-term optimum combination of National Forest uses (Fedkiw 1998). The lack of public consensus is yet another political reason for the absence of any strong policy endorsement for outcome based performance measures.

The absence of performance measures based on forest equity leads to a significant gap in fiduciary responsibility, an inability to fully account for gains in forest equity resulting from current or past forest management. It is probable that the Forest Service did contribute to some significant gains in forest equity through forest management in the 20th century, such as restoration of forests on public lands in the eastern United States and large-scale restoration of wildlife populations throughout the country (Fedluw 1998). However, the equity gain resulting from sustained yield policies and multiple-use management on the National Forests has never been fully compiled or thoroughly assessed (Dr. Fedkiw acknowledged that his historical account of multiple-use management is not an economic assessment per se). There was always a concern in the Forest Service about outcomes of management on the ground at the local level, but there was never an institutionalized general policy for expert evaluation of outcomes on an aggregate basis. Unfortunately, there is currently no Comprehensive assessment of the historical or expected equity gains associated with managing U.S. National Forests. Instead of being shaped by policies operating through fiduciary principles or comprehensive assessments of benefits and costs, National Forest management and forest policy was shaped in recent decades primarily by major episodes of controversy, often adjudicated in Federal courts. Episodes of controversy arose typically when the public perceived the occurrence of negative environmental outcomes associated with forest management. In some cases, these negative outcomes and episodes of controversy were not well anticipated by National Forest managers who were operating under sustained yield and multiple-use policies. Under those policies, timber management and timber harvesting was intensified on the National Forests in the 1960s and 1970s, with growing public demand for wood products. Although the Forest Service adhered to sustained yield policy and allowable cut limits for timber harvest, the Agency perceived that it had the discretionary authority to intensify the management of forests to increase allowable cut. Thus, timber management was intensified by reducing the length of timber rotations, accelerated reforestation, thinning and timber stand improvements, and by using more intensive timber management practices such as clearcutting and even-aged management (Fedkiw 1997). Episodes of public controversy arose in association with intensification of timber management, and the episodes of public controversy became key determinants in the evolution of public policy.

Major episodes of controversy in the 1960s and 1970s ranged from a timber clearcutting dispute on the Monongahela National Forest in West Virginia to a dispute over land terracing and tree planting on the Bitterroot National Forest in Montana (Fedkiw 1997). In the 1970s and 1980s, an extended controversy and dispute arose surrounding broader issues of harvesting of old-growth Douglas-fir and protection of endangered species such as the western spotted owl in the Pacific Northwest. Particularly controversial were Forest Service efforts aimed at intensification of timber management, application of clearcutting on public lands, impacts on endangered species, and occasional disasters such as landslides that were associated with timber harvesting. Although many lawsuits in such controversies were filed against the Forest Service primarily on the grounds of administrative procedures, the concern of most plaintiffs was ultimately with the outcome of management practices on the ground. Despite the controversy surrounding management outcomes, the use of performance measures to evaluate expected outcomes never became firmly established in public forest policy.

Instead of placing greater emphasis on outcome-based performance measures amid controversy over management outcomes, the Forest Service adopted the approach of ecosystem management, an approach that became popular in the 1980s and was formally adopted by the Agency in 1992. Ecosystem management places priority on maintaining and restoring forest ecosystem conditions, such as wildlife habitat, while relegating forest outputs such as timber to secondary importance. Ecosystem management evolved from early efforts to integrate wildlife management or conservation biology into the conventional framework of sustained yield timber management (focused mainly on constraining timber outputs rather than broader outcomes).

Roots of the modem paradigm of ecosystem management on the National Forests are traced to the 1979 Forest Service report on wildlife habitats in managed forests of the Blue Mountains of Oregon and Washington (Thomas 1979). The report was edited by Jack Ward Thomas, who became Chief of the Forest Service in 1993, and it is cited by Fedkiw (1977) as establishing the methodology of ecosystem management. This report provides extensive and very detailed information on how wildlife and wildlife habitats are affected by forest management in the Blue Mountains. The report was perceived as a landmark accomplishment within the Forest Service because it showed in great detail how the goals of wildlife habitat protection could be accomplished within the context of timber management, specifically by constraining timber outputs. Other National Forest regions quickly adopted the methodology of the 1979 Blue Mountains report, and it became the paradigm for the modem approach of ecosystem management on the National Forests. All of the detailed information on wildlife habitats in the Blue Mountains report was focused ultimately on a narrow question of how much timber output would be reduced by constraints designed to enhance wildlife habitat. In the final chapter, “Impacts on Wood Production,” examples showed how timber output in the Blue Mountains would be reduced by snag habitat management and old-growth habitat management. The report did not provide any information on the relative benefits or costs of such outcomes, nor did it provide any examples of broader outcome-based performance measures by which relative benefits and costs or net gain in forest equity might be evaluated.

Since adoption of the ecosystem management approach, the annual volume of timber harvested on U.S. National Forests has been reduced to about one-third of the levels that were sustained in the 1970s and 1980s. The decline in annual timber harvest represents a significant loss in the equity value of forests to the public, while it is also believed to represent a gain in equity value in terms of wildlife habitat, ecological integrity, aesthetic values, and other forest amenity values. A general presumption might be that the decline in timber harvest is offset by gains in other National Forest equity values, such as improved wildlife habitat and biodiversity. Nevertheless, relative benefits and costs of this shift in management remain weakly articulated and not well documented. Ecosystem management focuses on ecological outcomes that are broader than timber outputs, and the former constrains the latter, but the paradigm is not based on fiduciary principles or broad outcome-based performance measures. Although ecosystem management is strongly supported by the Forest Service, the overall fiduciary performance or net gain of ecosystem management (e.g., in terms of wildlife habitat benefits and ecological benefits in relation to administrative costs or the cost of reduced timber output) remains ambiguous at the national level.

The shift to ecosystem management seems to support the popular notion of a forestry "paradigm shift"—the U.S. forestry is now experiencing a shift in culture from output-based performance measures to "outcome-based" performance measures. This perspective may be contrasted with recent recommendations for National Forest management appearing in the report of the national Committee of Scientists.[v] The report indicated that sustainability—the preservation of plants, animals, and habitats—should be the first priority in managing Forest Service natural resources. The scientists also recommend more partnerships with outside groups such as industry, recreational groups, and environmental groups, as well as other government agencies, in making management decisions. Many of these recommendations are already embodied in Forest Service policy and are reflected in the Forest Service concept of ecosystem management. However, the final report and recommendations of the Committee of Scientists does not suggest any specific outcome-based performance measure for forest management, such as land expectation value. Although the general principles of ecosystem management may be well known, scientists have yet to establish any widely accepted management theories or outcome-based performance measures within the concept of ecosystem management (Fedkiw 1998).

Although National Forest management and public forest policy in the United States may appear to have experienced a shifting paradigm during the 20th century, with increasing awareness of the need to focus on broader management outcomes, it is also true that public forest policy has never really endorsed broad outcome-based performance measures. Considering the policy choice between a traditional output-based regulatory approach and the approach of economic optimization, it may be simply that the public can more easily reach consensus over the former than the latter. It is beyond the scope of this paper to examine historical economic benefits and costs of public forest management in the 20th century or to determine how management might have achieved different outcomes, leaving to conjecture the possible impacts that application of broader outcome-based performance measures might have had. It is apparent, however, that a lack of firm policy endorsement for outcome-based performance measures was historically associated with a weakness in their application on the ground in National Forest management. This may be simply because performance measures based on forest equity value are perceived as difficult to estimate or difficult to quantify.

Regardless of public forest policy, Faustmann's land expectation value concept remains an established outcome-based measure of performance in the forestry discipline, focusing on enhancement in equity value. It provides an alternative paradigm to output-based regulatory approaches that prevail in public forest policy. Faustmann understood that looking at forest outputs alone would not optimize performance in terms of forest equity value; but rather it was necessary to look at forestry as an intertemporal activity with benefits and costs spread over time. Faustmann advocated a performance measure based on forest equity, and he stipulated that management regimes should be maintained in perpetuity. By implication, Faustmann was evaluating forestry outcomes in terms of what is "left behind" or what is improved in the forest for perpetuity. Thus, it is widely understood today that performance in forestry depends not simply on outputs but also on quantity and value of inputs (costs), the variable values of outputs or outcomes, productivity (the relationship between inputs and outputs), the timing of benefits and costs, and discount rates.

Intergenerational Equity and Sustainability

Although land expectation value is regarded as an outcome-based performance measure in the forestry discipline, it raises other philosophical issues that need to be addressed in relation to public forest policy, including the issues of intergenerational equity and sustainability. For example, some economists have raised fundamental technical issues related to discounting in benefit-cost analysis, such as whether discounting over long periods is unfair from the standpoint of intergenerational equity. An assembly of some of the world's foremost economists was gathered recently to discuss this topic at a conference in the United States; their findings have been published in a book on discounting and intergenerational equity (Portney and Weyant 1999). The economists were unanimous in recommending that it is appropriate to use a discount rate that reflects the opportunity cost of capital for the purpose of making present value comparisons in evaluating projects with time frames of 40 years or less. Only in the case of much longer time frames did some experts suggest a need to adjust discount rates in benefit-cost analyses, some suggesting a need to use lower discount rates for very distant future values.

Recent concern about discounting and intergenerational equity is related to the issue of global warming associated with combustion of fuels for energy and the build up of carbon compounds in the atmosphere (Portney and Weyant 1999). It is recognized that global warming could have significant long-term economic consequences but they are likely to occur so far in the future that their discounted present value is quite small, suggesting that only small and perhaps ineffective expenditures will be justified to remedy or avoid those consequences. Since the greater consequences of global warming are likely to be borne by future generations, the question is whether discounting is unfair from the standpoint of intergenerational equity.

In essence, some of the economists view environmental externalities (e.g., environmental pollution) as one reason why lower discount rates might be appropriate when evaluating negative consequences of outcomes such as global warming using general equilibrium economic models (Dasgupta et al. 1999). The idea is that environmental pollution may be a by-product of economic activity that is not entirely taken into account by economic models. In that case, it may be appropriate to use social discount rates that are lower than private discount rates (the effect being to "magnify" expected negative consequences of pollution in the general economy).[vi] This approach assumes that environmental pollution results in a depreciation of natural capital that cannot be entirely taken into account by general economic models. As explained by others, an alternative approach is simply to account for environmental externalities by adjusting the benefit–cost formula to account for depreciation of natural capital (Smith 1999). In summary, although economic models or discount rates may need to be adjusted to account for long-term environmental externalities, experts generally endorse the conventional approach of discounting in benefit–cost analysis when deriving net present value comparisons (Portney and Weyant 1999).

Despite this apparent consensus on applicability of discounting among leading economists, some forestry specialists continue to challenge the application of discounting in evaluating forest management activities, especially in the context of public forest management. Home et al. (1999) provide one example of this challenge, citing a recent case in forestry where "economists decided not to discount future benefits or to calculate present net value because doing so obscures impacts on future generations." In apparent support of this logic, these authors cite three so-called "perplexing problems" of discounting in forestry. These perplexing problems are considered here in the context of Faustmann's concept of land expectation value, the traditional measure of performance in forestry that is based on the application of discounting.

One perplexing problem of discounting is said to be political—we do not know the preferences of future generations and they cannot give advice or consent to our decisions. Therefore, future generations are "politically" underrepresented in today's decisions (Home et al. 1999). This circumstance generally prevails under any mode of long-range decision making. It cannot be avoided, but there is a renewable resource management principle designed to compensate for this circumstance, namely the principle of *sustainable development.* This principle helps explain why discounting is necessary. The Bruntland Commission developed the most widely cited statement of the principle of sustainable development, as that which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). Many have sought to interpret this principle, and one useful interpretation by economists is that it means living off of our income in the present while preserving equity for the future (David Heeney, IndEco Strategic Consulting). Forestry in the most general sense is concerned with the task of improving either the productivity or the condition of forests, which are the embodiment of natural resource equity. Likewise, discounting in forest management helps ensure that the principle of *sustainable development* is met, that enhancement of forest equity for future generations is not ignored. The principle of *sustainable development* is ultimately concerned with passing the equity value of renewable resources from one generation to the next without compromising the productivity or equity value of the resources. Discounting accounts for the opportunity cost of capital, the minimum acceptable rate of gain for equity value that is expected over time. Discounting helps ensure enhancement or gain in equity over time, because management activities will be identified as acceptable (with net present value of benefits exceeding costs) only if they achieve the minimum acceptable gain in equity over time (determined by the discount rate). Thus, to ignore discounting is to compromise equity value for future generations, violating the basic principle of *sustainable development.*

The second so-called perplexing problem is said to be "uncertainty about future consequences of present decisions; we do not know what conditions future generations will encounter" (Home et al. 1999). In fact, discounting in economic analysis is partially justified because of the need to recognize and account for uncertainty about future outcomes. In general, apart from the opportunity cost of capital (computed at certainty equivalents), the discount rate in managerial accounting usually includes a risk factor, an added element that accounts for uncertainty about future benefits and costs by reducing their relative significance. Future benefits and costs are always less certain than current costs or benefits, and the more distant they are in the future the greater the uncertainty. Thus, the fact that more distant future preferences are less well-known merely adds to rather than detracts from the logic of discounting their value in economic analysis. Accounting for risk or uncertainty is in fact a classical justification for discounting in managerial accounting.

The third perplexing problem is said to be that "intergenerational discounting may violate its own logic" (Home et al. 1999). "Natural capital" is said to be "different" in that its consumption by the present generation can produce "alternative futures" which include loss of irreplaceable resources ("hedonistic consumption of pleasure that only returns to the future a nostalgia for past pleasures enjoyed by others"). In fact, "hedonistic consumption" is more of a concern in relation to limited stock resources than in relation to renewable forms of natural capital, such as forest resources. In the case of forest resources, consumption and use of the resource may be associated with enhancing the management, productivity, and equity value of the resource, although improper use may also damage the resource, There is no denying that natural resources (including forest resources) can be neglected, squandered, or destroyed by mismanagement, but it is equally clear that this vision of resource destruction would violate the principle of sustainable development. As noted previously, discounting supports the principle of sustainable development by helping to ensure gain in equity value over time. Avoiding resource destruction is really not an argument against discounting, but simply an argument in favor of sustainable development (which is implicitly supported by discounting as already explained). Furthermore, since Faustmann's concept of land expectation value stipulates an egalitarian distribution of production possibilities for all future generations, this concept goes well beyond discounting in support of the principle of sustainable development.

As long as a forest management cycle can be sustained indefinitely and the forest resources are truly renewable, then it is axiomatic that future generations will obtain the same production possibilities as the current generation. This is not to claim that future generations must maintain the same management regime indefinitely. Management regimes may be changed over time, as technology, values, and human needs change. However, a stipulation that each management regime must be one that ensures renewability of the natural capital of the forest also ensures that the current range of production possibilities or management options are maintained from one generation to the next. Whatever the forest may be used to produce in the future (commodity outputs or environmental amenity values), the production possibilities will remain the same as long as the chosen management regime can be sustained in perpetuity and the natural capital of the forest is renewable. Thus, in a very precise technical sense, the needs of one generation are not compromised relative to other generations when production possibilities of the forest are preserved from one generation to the next. Perpetually sustainable management regimes, as stipulated in Faustmann's concept of land expectation value or the LEV_∞ formula, thus help ensure an egalitarian distribution of production possibilities among future generations.

The stipulation of perpetually sustainable management regimes may impose significant responsibilities and significant constraints on exploitation of forest resources in each generation. Management regimes that are perpetually sustainable and renewable may offer fewer outputs and fewer benefits to the current generation than unconstrained exploitation. Also, it may be technically difficult to assure that management regimes are in fact perpetually sustainable. However, choosing perpetually sustainable and renewable management regimes while optimizing management of forests according to the Faustmann concept of land expectation value is one way to assure that needs of the current generation are met without compromising the ability to meet the needs of future generations. Faustmann's concept of land expectation value thus provides a framework for optimization that reinforces intergenerational equity and sustainable development, although it creates a substantial burden of assuring that management regimes are perpetually sustainable and that forest resources are renewable.

Summary

Land expectation value has served as the traditional paradigm of outcome-based performance measures in the forestry discipline, with forest equity and fiduciary responsibility serving to unify the principles of forest valuation and performance. However, policy endorsement of such performance measures is weak and inconsistent. Early forestry experts in the United States were aware of the concept of evaluating forestry performance in terms of gains in forest equity, but National Forest management policy has never strongly endorsed application of concepts like land expectation value or any similar criterion for optimization of forest management. The concept of land expectation value reinforces intergenerational equity and sustainable development, but policy application will likely be limited by practical considerations. Limiting factors including lack of public consensus on methods, difficulty in ensuring that management regimes are sustainable and renewable, concerns about discretionary authority and flexibility within public agencies, and technical difficulty in obtaining accurate and complete data on expected benefits and costs of management activities.

It is enormously complex to determine equity values for expected managerial outcomes such as large and unfragmented landscapes, wilderness, clean water, and protection of rare species, old-growth forest, and "naturalness" of the forest. It may be relatively easy for economists to assign hypothetical values to social or environmental benefits of forest management. It is a far more complex task for local forest managers to develop accurate measures of such benefits or to establish a credible linkage between benefits and costs. Some form of policy guidance on the values of various social and environmental benefits and costs would seem appropriate.

The history of managing the National Forests of the United States during the 20th century reveals that broader environmental benefits and costs of management activities have been difficult to anticipate (and by implication difficult to account for). Finding a way to reasonably account for expected benefits and compare them to expected costs of management on the land is a logical prerequisite for developing improved outcome-based performance measures in public forest management. Adopting the numeraire of monetary expenditures will present a temptation to place greater emphasis on those benefits that are easily quantified according to the same numeraire (e.g. financial benefits), and this may result in an inappropriate lack of emphasis on social or environmental benefits or costs in public forest management. Undeniably, foresters, biologists, sociologists, and economists are finding it challenging to estimate all expected economic benefits or costs of forest management.

In the absence of firm policy direction, it seems unlikely that managers of public forests will adopt outcome-based performance measures patterned after the Faustmann concept of land expectation value. However, as it has in the past, an understanding of the Faustmann concept of land expectation value may help to shape the future direction of forest management. Certain enduring elements of the Faustmann concept will likely remain philosophically important well into the future, including the emphasis on management outcomes, fiduciary responsibility, intergenerational equity, and sustainability.

Literature Cited

Bowes, Michael D. 1983. Economic foundations of public forestland management. Discussion Paper D–104. Resources for the Future: Washington DC. 80 p.

Buongiorno, Joseph, and J. Keith Gilless. 1987. Forest Management and Economics. MacMillan Publishing Company: New York. 285 p.

Dasgupta, Partha, Karl-Göran Mäler, and Scott Barrett. 1999. Intergenerational Equity, Social Discount Rates, and Global Warming. *In* : Portney, Paul R., and John P. Weyant (eds.). 1999. Discounting and Intergenerational Equity. Resources for the Future: Washington DC. pp. 51–77.

Dombeck, Michael P. 1998. Remarks of Chief Dombeck at Society of American Foresters (SAF) Convention. Traverse City, Michigan, September 21, 1998. [Available at http://www.fs.fed.us/intro/speech/19980921.html].

Faustmann, Martin. 1849. [Linnard (tr.) and Gane (ed.)1968]. On the Determination of the Value Which Forest Land and Immature Stands Possess for Forestry. *English* Translation in: Martin Faustmann and the Evolution of Discounted Cash Flow (Translated by W. Linnard; with editing and introduction by M. Gane). 1968. Commonwealth Forestry Institute Paper No. 42. University of Oxford: Oxford, England. [Translation republished with permission from Commonwealth Forestry Association in *Journal of Forest Economics* 1:1(1995).]

Fedkiw, John. 1997. Managing Multiple Uses on National Forests, 1905-1995. USDA Forest Service: Washington DC. 284 p.

Fedkiw, John. 1998. National Forests and the Performance of the Organic Act. *Forest History Today*. Forest History Society: Duke University. (1998):12–17. [Annual]

Fernow, Bernard E. 1907. A Brief History of Forestry in Europe, the United States and Other Countries. University Press: Toronto.

Fisher, Irving. 1907. The Rate of Interest. Macmillan: New York and London.

Hartman, R. 1976. The Harvesting Decision When the Standing Forest Has Value. *Economic Inquiry*. 14(1):52–58.

Home, Amy L., George Peterson, Kenneth Skog, and Fred Stewart. 1999. Understanding Economic Interactions at Local, Regional, National and International Scales. Economic Dimensions (359–382).

Hough, Franklin B. 1877. Report Upon Forestry. Government Printing Office: Washington DC. 650 p.

Langston, Nancy. 1997. Forest Dreams, Forest Nightmares: An Environmental History of a Forest Health Crisis. In: Miller, Char (ed.),. American Forests—Nature, Culture and Politics. University Press of Kansas: Lawrence, Kansas. p. 247–271.

Klemperer, W. David. 1996. Forest Resource Economics and Finance. McGraw-Hill Series in Forest Resources. McGraw-Hill: New York, NY. 551 p.

Miller, Char (ed.). 1997. American Forests—Nature, Culture and Politics. University Press of Kansas: Lawrence, Kansas. 289 p.

Newman, David H. 1988. The Optimal Forest Rotation: A Discussion and Annotated Bibliography. U.S. Department of Agriculture, Forest Service. General Technical Report SE–48. Southeastern Forest Experiment Station: Asheville, North Carolina 47 p.

Portney, Paul R., and John P. Weyant (eds.). 1999. Discounting and Intergenerational Equity. Resources for the Future: Washington DC. 186 p.

Smith, V. Kerry. 1999. Substitution and Social Discount Rates. In: Portney, Paul R., and John P. Weyant (eds.), Discounting and Intergenerational Equity. Resources for the Future: Washington DC. p. 79–85).

Thomas, Jack Ward (Technical Editor). 1979. Wildlife Habitats in Managed Forests—the Blue Mountains of Oregon and Washington. United States Department of Agriculture. Agriculture Handbook No. 553. USDA Forest Service: Washington DC. 512 p.

USDA Forest Service. 1983. The Principal Laws Relating to Forest Service Activities. USDA Forest Service. Agriculture Handbook No. 453. Washington DC. 591 p.

WCED. 1987. Our Common Future. World Commission on Environment and Development. Oxford: Oxford University Press.
Wilkinson, Charles F., and H. Michael Anderson. 1987. Land and Resource Planning in the National Forests. Island Press: Washington, DC. 396 p.

Endnotes

[1]The original Faustmann formula for land expectation value (*Bodenerwartungswerte*) was

$$B = \frac{1}{(1.0 + p)^u - 1}\left[E + rD - C(1.0 + p)^u\right] - \frac{A}{p}$$

where *B* is forest land expectation value, p interest rate (discount rate), *u* rotation length, *E* cash value of forest at end of each rotation, *rD* value of thinnings during each rotation compounded to end of rotation, *C* plantation cost necessary at start of each rotation, and *A* annual expenditure for administration, protection, etc. (Faustmann 1849). The formula computed net present value of all costs and benefits in perpetuity for a forest managed with perpetually recurring rotations. Other similar formulas can be designed for other forest management regimes, and other costs and benefits besides timber values can be included in the formula.

[ii]Franklin B. Hough was the first "Federal forestry agent" employed by the U.S. Department of Agriculture in 1876. Rough's Agency was upgraded to the Division of Forestry in 1881 and made a permanent bureau in 1886. In 1898, Gifford Pinchot became chief of the Bureau of Forestry; in 1905, the Bureau was merged with the new Forest Service and Pinchot was named Chief.

[iii]Forest stands established in Germany originally under Martin Faustmann's supervision were visited during the field tour organized in conjunction with the recent IUFRO symposium celebrating 150 years of the Faustmann formula. The stands consisted of planted Scotch pine (*Pinus sylvestris*) being managed by German state foresters on prescribed 130-year rotations. The management regimes were based on prescriptive criteria related to perceptions of wood quality as well as other social or political criteria established by higher level authorities. The foresters explained that management was not being optimized according to Faustmann's formula and in fact the formula is seldom used today in Germany, although foresters recognize it as an available tool for valuation and optimization.

[iv]The von Mandel formula was $Y = 2G/r$, where Y is annual allowable harvest, *G* is growing stock volume, and *r* is rotation length. The von Mandel formula was eventually deemed inappropriate for managing older mature forests in the western United States, because allowable harvest would far exceed slow forest growth rates. The Hanzlick formula, which became more popular by the mid-1900s, was $Y = I + V_m/r$, where *1* is the

annual growth of immature timber and V_m is the volume of mature timber (Wilkinson and Anderson 1987). In the 1970s, the Forest Service abandoned the Hanzlick formula when studies in the Douglas-fir region indicated that harvest levels could not likely be sustained after liquidation of old-growth timber. The Forest Service then adopted the policy of non-declining even flow, using a formula similar in appearance to the von Mandel formula but based on long-term sustained yield: LTSY = *V/r*, where *V* is the estimated total future volume of intermediate and final harvests of managed stands (Wilkinson and Anderson 1987).

[v]Secretary of Agriculture Dan Glickman convened the Committee of Scientists in 1997 to develop recommendations for management of national forests and grasslands. The Committee issued its report in 1999. The report is available at www.fs.fed.us/news/science/

[vi]Partial equilibrium economic models are not appropriate for this type of global warming analysis. Only general equilibrium models that encompass economy- or worldwide effects on production possibilities are appropriate (Dasgupta et al. 1999).

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