Sam Nijensohn
Ecological Economics term paper

Sustainable forestry in New England: linear problems, cyclical solutions

Introduction

The increasing value placed on *sustainable forestry* reflects an ongoing evolution of consciousness among forestry professionals and the general public who are increasingly recognizing that our forests are complex resources that should be managed with consideration given to the many functions they provide. This paradigm is an improvement over the timber-oriented *sustained yield* concept which has dominated modern forestry. Sustained yield, an analog of neoclassical economics, focuses on deriving the maximum timber benefit, operating at the edge of a cost/benefit analysis (e.g. timber is harvested up to the exact point where harvesting begins to dip into the growing capital stock). Sustainable forestry, an analog of ecological economics, focuses on the various benefits of forestlands and as such results in a more caution-based, long-term approach to forest management which accounts for externalities and multiple values.

Sustainable forest management is a holistic system that incorporates non-timber values in management decisions. These values generally include a host of externalities provided or maintained by forests such as water, air, and soil quality, viewshed aesthetics, recreational opportunities, carbon sequestration, wildlife habitat, non-timber forest products (including medicinals, foods, and fibers), species diversity, genetic diversity, and human community stability (including secure employment).

Increasingly, *low-impact* forestry is becoming recognized as the method of choice for harvesting needed timber resources under a sustainable forestry paradigm. Low-

impact commonly refers to technologies and silvicultural systems used in sustainable timber operations, but also can apply to recreational options and harvests of non-timber forest products. Low-impact timber harvesting relies on a host of equipment (e.g. horses and small footprint machinery such as tractors, small skidders, and forwarders) and techniques (e.g. directional felling) designed to minimize negative impacts on residual resources; it can also refer to timing (e.g. frozen conditions for certain soil types), intensity (with respect to harvest volumes), and choice of management options (e.g. no use of chemical herbicides and pesticides, no whole tree harvesting, more focus on maintaining structural and species diversity, etc.)

While a host of programs and technologies have been developed to advance sustainable forestry initiatives, the purpose of this paper is to both show how certain facets of our society hinder the enactment of sustainable forest management in the United States and to propose a partial solution *working within the present system*.

Demographics and Consumption

To understand the problems with implementing sustainable forest management, it is important to have some background on the key players (i.e., demographics of forest owners). Unlike many other nations involved in forest management, the majority of forest land (71%) in the United States is privately owned and controlled. The vast majority of owners are private nonindustrial forest owners holding about 60% of the total U.S. timber land (Society of American Foresters, 2002). Although wood and fiber production have generally been focused on industrial landowners, increasing demand for wood, increasing reluctance of forest industry to own land, and decreasing woodlands are

expected to pressure more nonindustrial private landowners towards timber management. This pressure has been further intensified as a result of decreases in harvesting on public land and increasing wood product consumption. As such, this paper focuses on private nonindustrial landowners in New England and the forestry professionals that they might work with. Industrial forestry on corporate owned land in the U.S., and the management of national forests and other public lands by government organizations and private industry would make interesting topics for further ecological economic analyses but are beyond the scope of this study.

It is critical to note that while the focus of this study is on New England, the issues facing sustainable forest management have global causes and effects. In fact, U.S. citizens consume far more wood products than they produce, shifting the burden of production on other nations. For example, citizens in Massachusetts, the eighth most forested U.S. state (by area), presently harvest timber volumes equal to only 2% of their consumption. U.S. citizens consume twice as much wood as Europeans, and three times more than the average human; these levels are mostly attributable to excessive consumption of paper products and an ever increasing trend in house size coupled with a decreasing trend in occupancy (Berlik et al., 2002). This leads to greater global environmental degradation (as wood is imported from poorly regulated nations mismanaging fragile and sensitive ecosystems) than increasing the intensity of local forest management. The reliance on imports has proved detrimental to U.S. forests as well, with the unintended importation of various forest pests (e.g. Asian longhorn beetle) transported in foreign wood products. If the global burden of wood production

responsibility shifts back to the consumers (e.g., the U.S.), private woodland owners will face yet another increase in demand for their timber resources.

Land parcelization has been proceeding at a rapid rate in New England and threatens the viability of forest management for various reasons. Forestry professionals are concerned about the difficulties of harvesting timber from smaller parcels. New residents and absentee second home-owners are generally more reluctant than established residents to manage their woodlands. New landowners are often philosophically opposed to all types of harvesting; either from a hypocritical "not in my backyard" attitude, or because they lack the awareness needed to link their personal consumption of wood products to the forests that provide them. Smaller lots are also less economically viable for most woodland managers and professionals because there is more time involved in non-revenue generating activities (per volume harvested), such as bidding for deals, preparing contacts, obtaining permits, filing tax forms, cruising potential lots, transporting and setting up equipment, laying out roads, preparing and reseeding landings, and forming relationships with landowners. Estimates of the minimum tract size worth managing for timber range from 50 acres (Sampson and DeCoster, 2000) to 25 acres (McEvoy, 2002). Of the 9.9 million nonindustrial private landowners in 2000, 94% owned less than 100 acres, and the average ownership was 24 acres; by 2010 the average ownership is expected to be 17 acres (Sampson and DeCoster, 2000). The "working forest" is increasingly becoming a chain of backyards. Furthermore, smaller parcels mean a lower total harvest income, and a less regular stream of income, both of which can lead to decreased landowner interest in harvesting. A few hundred acres can provide income opportunities every five years or less, but a 25 acre parcel can only provide

income at long time-spans (many decades). The smaller the parcel, the more intensive the harvest may need to be to provide revenues above the costs of management itself, providing a further disincentive (Beattie et al., 1993). This trend towards smaller parcels could have a dramatic impact on the future viability of forestry, particularly in New England. This clearly poses a threat to both local and global sustainable forestry management, as jobs are lost and timber needs are directed at over-harvested international supplies.

The problem

Economic Problems for Forest Landowners:

Good forestry is unique from an investment standpoint for various reasons, including low rates of stumpage value increase (usually lower than inflation), long time period of investment, low liquidity of timber, low willingness among lenders to accept land as collateral, low rates of return, and constant changes in capital gains treatment (Society of American Foresters, 2002). First and foremost, the long time period involved in managing forest lands is vastly different from other investments with daily, quarterly, or yearly earnings/losses. This long time period often requires investors to endure costs which may never realize a return for them and their generation. The greatest cost to forest owners, and the number one concern (for 16 of the past 18 years) of the private woodland owners belonging to the National Woodland Owners Association, are taxes (NWOA, 2003). Three types of taxes are especially pertinent to forest landowners who manage their land: property tax, income tax, and estate tax (generally in that order of importance; some states also have yield taxes).

Misplaced tax liability demonstrates a societal misvaluation of forest land. While private forests provide multiple benefits to a community (e.g. clean water) and require less public costs than developed land (e.g. forests don't require traffic lights), property is still taxed based on market value, not based on services (provided or consumed). This is extremely important because towns derive their operating budget from taxation of real property. Hence, forest owners are disproportionately bearing the burden of the town costs associated with development. One study estimates (conservatively, I would add) that local taxes paid on undeveloped land are often 3 times the cost of the municipal services rendered from that land, whereas in developed areas people pay higher taxes per acre but receive services equal to or exceeding that value. Only 0.1% of local spending services private forests, and less than 0.5% of federal public spending goes to programs benefiting private forests (Sampson and DeCoster, 2000).

Tax laws relevant to forestry are complex, vague, and often changing. This in itself can be a deterrent to some investors interested in socially responsible investments through sustainable forest management. Occasionally, tax laws are created that assist such management. For example, most states have "current-use" programs which allow managed forest land to be taxed at a rate less than its 'highest and best' economic value (i.e., usually its potential value as developable land). Such programs are steps in the right direction for maintaining the integrity of our forest landscape, however, the majority of tax laws cause the opposite. Furthermore, many forest owners do not participate in these programs for various reasons including: it requires active participation (and some owners may not have the gumption or knowledge to initiate the process), initial costs are often higher than initial benefits (some landowners may not be able to afford the fees of a

forester, who must inventory the property and write a management plan), many owners are reluctant to manage the land and would prefer to leave it as a preserve (however, proof of intent to manage is part of current-use programs), owners may be concerned that an inventory might find threatened or endangered species on their land (which can result in various limitations on their property rights), and owners may not be willing to engage in the contractual obligation to pay penalties and back-taxes if they do decide to develop portions of their land in the unforeseeable future (e.g. to provide home sites for children).

While property taxes are a large part of the cost of keeping forest land intact, this cost (along with other management-related expenses) can be deducted from federal income taxes. However, for most forest owners, these deductions can only occur in a year of forest income generation (e.g. timber sales), and must be delayed until such an event (Haney Jr. et al., 2001). This ultimately means that tax laws reward shorter rotations (McEvoy, 1998) which may be financially and ecologically inferior in the long-term (Erickson et al., 1999). For this reason among others, the Society of American Foresters argues that timber should not be treated like other investments in terms of income tax deductions (Society of American Foresters, 2002).

Another example of tax law that can assist forest management is the ability to treat timber sales as long term capital gain, resulting in lower income tax liability. However, the tax laws surrounding this issue are complex and occasionally vague. Certain types of sale structures may not be eligible for capital gains (e.g. splitting the profit with the logger based on mill receipts), while others are (e.g. the logger paying for the stumpage outright). Confusion leads many forest owners to file their returns from the timber sale as "other" income, meaning that they do not receive capital gains treatment

and are charged additional self-employment taxes (McEvoy, 1998). Without the help of an experienced accountant or attorney (a cost many woodland owners cannot afford), filing advantageous tax returns (and initiating the appropriate sale structure) is difficult.

"Forest time" is on a different scale than "human time", which makes long-term planning difficult because investors will likely not live long enough to enjoy the financial return on their investment in sustainable forestry (in fact, even their children or grandchildren may not live long enough). Because of our present economic system, where money "earns" money through compounding interest, such long term investments are especially difficult to justify. For example, a small tree shelter (present value, $3) purchased to protect a seedling early in a rotation must be financially examined in terms of its opportunity cost (i.e., the alternative return that $3 could "earn" invested differently). For a 120 year rotation, at an annual opportunity cost of 6%, that small tree shelter truly "costs" $3,264.56[1]! In other words, it is difficult to justify sustainable forestry practices in economic terms, because sustainable forestry will *initially* tend to have higher costs (e.g. cost of management planning, proper road building, "worst-first" thinning operations, etc.), even though such practices should improve the value of the forest and timber resources in the long-term. This can make the long-term benefits of sustainable forestry a tough sell for present land owners with neoclassical economic mindsets operating on the edge of a cost/benefit analysis in "human time".

Economic Problems for Forest Professionals:

---

[1] $\$_{future} = \$_{present} * (1 + \%interest)^{time}$
$3,264.56 = $3.00 * (1.06)^120

The economics of timber harvesting generally makes it a low profit (or no profit) business, especially on the small scale often conducive to sustainable forest management. Within this poorly paid profession, there is no built-in economic incentive to practice sustainable forestry. While woodland owners may get a tax break if they have a management plan under current use laws (albeit there is a tenuous link between having a management plan and practicing sustainable forestry), there are no tax benefits directly associated with being a responsible logger or forester. In fact, the low profit margin of forestry professionals often leads to poor forest practices (e.g. high-grading, using machinery inappropriate for the site, polluting with leaky equipment, operating on wet soils rather than awaiting better conditions, leaving damaged residual trees, not accounting for various externalities such as water quality, etc.). This raises the pressing issue of how loggers are paid. Unlike many other professions, the income these professionals earn is rarely determined by the quality of their work. Usually, conventional loggers pay landowners for standing trees (or pay a set rate per mbf. per species, the volume of which is determined by mill-tallies), and profits are the mill sales minus the costs of extraction. Therefore, the only way to profit (outside of bidding well for stumpage and brokering logs to high paying mills- two elements the logger has minimal control over) is by having competitive extraction costs. Hence, there is no economic incentive to do anything other than high-grade using the most economically efficient equipment, ignoring any potentially harmful long-term effects on the forest.

Some states have developed logger education classes to help prevent such land abuse. This is a step in the right direction, however the high cost of attending these classes (both tuition costs and work time lost) are generally borne by the participant.

Even after the classes, the logger still needs to be able to make a living within a system that doesn't place economic value on sustainable practices. There are many alternative payment systems (or combinations thereof) that could foster sustainable forestry, including: performance incentives, hourly wages, variable stumpage expectations accounting for environmental conditions, fines for poor work, long-term contracts that provide a logger with a stake in the future well-being of the forest, payments on volume regardless of species/grade, etc. While such systems are the rule in more advanced nations (e.g. in Scandinavia), they are practically nonexistent in the U.S. (Lansky, 2002).

A similar problem exists with forester payment. Foresters include industrial, service, research, and extension foresters. Of these, only industrial foresters and consulting foresters are likely to direct harvests in a nonindustrial private landowner's woods. Industrial foresters clearly have no direct economic incentive to practice sustainable forestry- they are employed to find monthly quotas of wood and pay landowners for their timber. They may present themselves as being interested in maintaining the sustainability of the landowner's forest, but their true loyalty is ultimately dictated by their primary objective of fulfilling their employer's wood requirements. A consulting forester, on the other hand, has the opportunity to work in the best interests of the landowner and the forest as a whole. Nevertheless, it is common practice for consulting foresters to be paid on commission as a percentage of timber sale proceeds. This system presents a potential conflict of interest between the forester's need to make a living and the values inherent in sustainable forestry. Paying hourly or contract rates are preferable alternatives.

Community Problems

So far we have examined how both forest landowners and forestry professionals are faced with problems in the implementation of sustainable forestry practices. The community at large also bears its share of problems stemming from the short-sighted forestry practices resulting from our present social, economic, and technological systems.

We have already introduced the problems that land parcelization presents at the scale of individual ownership. At the community scale, the problem adds dimensions. As landscapes become increasingly parcelized, there follows a fragmentation of purpose with respect to forest management. This makes management increasingly difficult at ecological and landscape scales. Forest management is generally planned at the parcel level (or even at the stand level), however, sustainable forest management must consider forest systems that extend beyond ownership boundaries. Parcelization, and the resultant increase in the number of owners and infrastructure, makes it increasingly difficult to manage on the scale of larger ecosystems (e.g. wildlife needs through corridors and home ranges, watershed-wide water quality planning, aesthetic viewshed planning, etc.). Therefore, not only does fragmentation in New England threaten the economic viability of logging (Baker and Kusel, 2003), leading to reliance on imports (which is globally unsustainable), but it also presents potentially insurmountable difficulties in community-scale planning necessary for sustainable forestry in New England.

There are also social implications of unsustainable forestry that must be addressed. In particular, the trend towards increasing mechanization of the harvesting process results in the replacement of labor, leading to a reduced number of job opportunities in local communities. Furthermore the debt incurred by the high cost of such equipment places contractors into a position of "servicing debt" where they must

focus on short-term unsustainable monetary gains in order to pay high monthly bills (Byers, 2000).

The number of mills has also been steadily decreasing. Sawmills in Vermont have decreased by about 50% in the last two decades, and are expected to decrease by 90% in the next decade (Thom McEvoy, personal communication). This decrease and consolidation further affects the number of forest-dependant jobs in local communities and leads to an exportation of the vast majority of the total value of timber grown in a community. The "freight cost advantage" (Berlik et al., 2002) isn't sufficient to feed local mills and value-adding businesses (e.g. furniture makers), perhaps partly due to low oil (trucking) costs. Such processes can transform a healthy community-based industry into a unidirectional extractive economy. These economies tend to be volatile, further discouraging investments, and leading to the formation of "poor timber towns" (Durning, 1999). This loss of value and employment ultimately leads to further loss of forest land as community members cannot afford to maintain a "working forest" when faced with development options.

Solutions

There are numerous of "top-down" solutions that could temporarily alleviate some of the problems raised in the previous section, including property tax reforms, environmental regulations, third-party certifications, selective sales taxes, importation tariffs, subsidies and cost-sharing, and land/ development-right buyouts. However, the ever increasing awareness of sustainable forestry concepts presents opportunities for "bottom-up" solutions that could be more effective in implementing long-term societal

changes to the way we perceive forest management and value forest land and labor. Furthermore, such an approach is less likely to be subject to the whims of changing political powers. The solutions I propose entail more than a change in action or policy; they dictate a change in consciousness. These solutions have two elements: one technological and one social/organizational.

As local timber harvesting must remain part of the strategy to maintain forest land and prevent global unsustainable resource use[2], I believe it is prudent to begin by proposing alternatives that overcome some problems of present harvesting operations. Horse logging (i.e., using horses to extract timber) is a low-impact technology that provides a multitude of advantages over modern systems commonly used today. As described earlier, low-impact forestry generally refers to the technologies and methods used for harvesting timber under a sustainable forestry paradigm.

Horse logging can enable timber extraction while better maintaining the productivity and value of the residual forest for several reasons. First, horses weigh about 1,600 lbs. compared to an average skidder which weighs about 10,000 lbs., and their hooves apply pressure in a different way than the continuous motion of wheeled or tracked vehicles (Kirsch, 2002). This results in less soil compaction and shearing, an unfortunate common cause of declined future productivity and health resulting from mechanized harvesting. Compaction can stress and kill residual trees, harm other organisms including fungi and invertebrates, reduce future growth, affect nutrient cycling, and alter hydrologic cycles. Recovery (through shrinking and swelling

[2] These solutions assume (for many of the reasons already discussed) that maintaining a "working forest" while practicing long-term sustainable forestry is an integral part of maintaining private woodlands, community sustainability, and global ecosystem health.

processes) can take a long time, leading to potential accumulations of effects over multiple rotations (Worrell and Hampson, 1997). Also, horse skid trails are considerably narrower than most mechanized trails, leaving less of the woods developed into harvest road systems. This prevents as much as a 25% productivity loss from reducing the effective size of the forest by making wide extraction trails (Lansky, 2002). Finally, horse logging often results in less above-ground damage to residual trees due to better maneuverability and shorter logs being skidded. Skidder wounds result in decay and loss of future profit both from volume loss and grade loss. Preventing wounding is the best solution (Whitney, 1991). Thus, from a long-term perspective, horse logging better allows a stand to maintain its health, productivity, and value.

There are several other benefits horse logging can contribute to sustainable forestry in New England. Because horses are quiet and "natural", their presence may be more acceptable to landowners who are intimidated by large machinery on their land. In this way, horses might provide an appealing option for landowners otherwise reluctant to manage their woodlands. Enabling harvesting on this land would help reduce our dependence on imported wood and boost the local forest products economy. Because horse logging is labor intensive, focusing on this harvesting system would increase local employment availability; it takes 3-4 times the amount of timber to support one conventional logging job than one horse logging job (Borsato, 1998). Furthermore, most of what a horse logger earns can stay within the community, while the majority of a conventional logger's earnings end up in Manhattan or Tokyo after they pay their equipment bills (Alderliesten, 1998). Also, horses consume locally-derived renewable

energy, do not contribute to air pollution, and do not leak engine oil and hydraulic fluid. The only "pollution" they do produce is fertilizer.

Horses can also be economical for the operator. The decreasing tract size that makes harvesting uneconomical for mechanized operators is less of a problem for horse loggers. Smaller tracts often mean shorter overall skid distances. Shorter skid distances make horse logging financially competitive with machines. There is also less time and cost involved in transporting and setting up equipment for a horse logger than for a mechanized operator. Workman's compensation insurance rates are lower (Allstate Insurance Company, personal communication), and horse loggers sustain less injuries (Lansky, 2002). The cost of maintaining a horse for one year is less than the cost of a new skidder tire. Start-up costs for horse loggers are about one-tenth of what it costs to start-up as a mechanized logger, reducing the pressure to "service debt" by acting unsustainably (Kirsch, 2002).

The question remains, what bottom-up approaches could be used to promote horse logging as a sustainable solution and encourage more individuals to work as horse loggers? The most practical way to enable this is to create a market demand for horse logging services.

One feasible means of accomplishing this locally could be through the formation of a forest landowner cooperative. By pooling multiple landowner resources, a cooperative would have the leverage to make horse logging an economically viable alternative in the short-term, with the added benefit of increasing long-term sustainability. The cooperative could provide a network for communication and education, encouraging landowners to learn about global forestry and their own

woodlands. Resultant woodland familiarity would likely breed a stewardship ethic that would serve our forests well.

Pooled landowners would also enjoy economies-of-scale, allowing them more economical access to professional foresters, bulk items, equipment, and a better ability to market and truck their logs. The excess profits realized through cooperation could more than offset the slightly higher short-term costs that may result from harvesting with horses. Additional equipment could be purchased to increase the efficiency of horse logging (e.g. a forwarder). If members were willing, cooperatives could add value to their logs with a sawmilling operation, and even a woodshop. A value-added component would give interested members more opportunities to actively participate and could provide additional local employment opportunities. Unique opportunities to market their wood products as local, co-op "draftwood" (e.g. harvested with a draft animal) could realize a green premium without the expense of third party certification. Draftwood marketing has already been initiated in Virginia (Rutledge, 2003).

Horse loggers and other independent contractors could be offered unique payment methods that provide sustainability incentives, such as profit shares or long-term harvest rights. Eventually, the co-op might develop its own in-house staff of loggers, foresters, truckers, sawmillers, lawyers, accountants, etc. The co-op could even form an apprenticeship program to increase the number of horse loggers, and the market demand created by its reliance on horse loggers could potentially spread beyond its membership. If successful, the co-op could also become a powerful lobbying force for promoting some of the aforementioned "top-down" changes.

While the "devil is in the details" and a feasibility study, including landowner surveys, would need to be done to assess the viability of such an endeavor in any specific locality of Vermont, the co-op structure has proven itself in similar circumstances and environments (e.g. Cabot Creamery). Ultimately the major driving force behind any change in the sustainability of forest practices in New England must come from a change of consciousness. To endorse horse logging in a technological age requires a paradigm shift from a simple linear progressive conception of time to a cyclical understanding of the interconnectedness between our consumption and our production, and our past and our future. Only by thinking on the scale of "forest-time" will we realize that looking backwards to old ways can lead us forward to a future of healthy forests. By joining forces, nonindustrial private landowners can create the environment needed to ensure the long-term sustainability of New England's forests.

References

Alderliesten, J. 1998. From an essay submitted to Forest Renewal B.C. and the Credit Union Bursary Program, from which John Alderliesten was awarded a $1000 bursary, May 9, 1998. Available at: www.televar.com/~gcaudell/July98.HTML

Baker, M., and Kusel, J. 2003. Community forestry in the United States: learning from the past, crafting the future. Washington D.C., Island Press.

Beattie, M., Thompson, C., and Levine, L. 1993. Working with your woodland: a landowner's guide. Hanover, University Press of New England.

Berlik, M., Kittredge, D., and Foster, D. 2002. The illusion of preservation: a global environmental argument for the local production of natural resources. Journal of Biogeography, v29: 1557-1568.

Borsato, R. 1998. From: Horse Loggers Association of B.C., available at: www.televar.com/~gcaudell/July98.HTML

Byers, A. 2000. Efforts to protect biodiversity and promote sustainable forestry in the Appalachian Mountains. Mountain Research and Development v20n3: 232-235.

Durning, A. 1999. Green-collar jobs: working in the new Northwest. NEW Report 8: Seattle, Northwest Environment Watch: 33.

Erickson, J., Chapman, D., Fahey, T., and Christ, M. 1999. Non-renewability in forest rotations: implications for economic and ecosystem sustainability. Ecological Economics v31: 91-106.

Haney Jr., H., Hoover, W., Siegel, W., and Greene, J. USDA Forest Service Agricultural Handbook No. 718: Forest landowner's guide to the federal income tax. March, 2001. available at:
www.fs.fed.us/publications/2001/ 01jun19-Forest_Tax_Guide31201.pdf

Kirsch, K. 2002. Four-legged logging. Independent Sawmill and Woodlot Management v32.

Lansky, M. 2002. Low-impact forestry: forestry as if the future mattered. Maine Environmental Policy Institute.

McEvoy, T. 1998. Legal aspects of owning and managing woodlands. Washington D.C., Island Press.

McEvoy, T. 2002. Expectations of forest owners in the U.S. Forest Products Equipment Journal, March issue: 16-19.

National Woodland Owners Association. 2003. Top ten private forestry issues 2003-2004. NWOA Woodland Report v20n5: 1-3.

Rutledge, J. 2003. Jason Rutledge is the president of the Healing Harvest Forest Foundation. More information can be found at:
http://community.roanoke.com/main.wsi?group_id=11

Sampson, N., and DeCoster, L. 2000. Forest fragmentation: implications for sustainable private forests. Journal of Forestry, v98n3: 4-7.

Society of American Foresters. 2002. Federal tax treatment of timber investments. available at: www.safnet.org/policyandpress/psst/FedTaxTrtmt.6_21_02.pdf

Whitney, R.D. 1991. Quality of eastern white pine ten years after damage by logging. The Forestry Chronicle. Feb. 1991: 23-26.

Worrel, R., and Hampson, A. 1997. The influence of some forest operations on the sustainable management of forest soils- a review. Forestry v70n1: 61-85.