

An adaptive management process for forest soil conservation¹

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ABSTRACT

Soil disturbance guidelines should be based on comparable disturbance categories adapted to specific local soil conditions, validated by monitoring and research. Guidelines, standards, and practices should be continually improved based on an adaptive management process, which is presented in this paper. Core components of this process include: reliable monitoring protocols for assessing and comparing soil disturbance for operations, certification and sustainability protocols; effective methods to predict the vulnerability of specific soils to disturbance and related mitigative measures; and, quantitative research to build a database that documents the practical consequences of soil disturbance for tree growth and soil functions.

Key words: soil disturbance; soil compaction; rutting; monitoring (implementation, effectiveness, and validation); criteria and indicators; Montreal Process

RÉSUMÉ

Les directives portant sur les perturbations du sol devraient être établies à partir de catégories comparables de perturbation adaptées aux conditions spécifiques du sol affecté et validées au moyen d'un suivi et de recherches. Les directives, les normes et les pratiques devraient être continuellement améliorées en fonction d'un processus de gestion adaptative qui fait l'objet d'une présentation dans cet article. Les principaux éléments de ce processus comprennent : des protocoles fiables de suivi pour évaluer et comparer les perturbations au cours des opérations et pour des protocoles de certification et de durabilité; des méthodes efficaces de prédiction de la vulnérabilité de certains sols en matière de perturbation et des mesures de mitigation qui s'y rattachent; et, des recherches quantitatives pour élaborer une base de données qui documente les conséquences pratiques de la perturbation du sol sur la croissance des arbres et les fonctions du sol.

Mots clés : perturbation du sol, compaction du sol, orniérage, suivi (implantation, efficacité et validité), critères et indicateurs, Processus de Montréal

Introduction

A number of models exist for the development and continual improvement of guidelines and standards for sustainable forest management (e.g., ISO 14001 (ISO 2001)). However, there is no consensus on components required in such models to ensure conservation and possible enhancement of soil productivity. This paper presents an adaptive management framework for soil disturbance that supports internal operations and policy as well as external reporting for due diligence in forest soil management. To support this framework, common language and key components should be defined and agreed upon (Curran *et al.* 2005c). These components

include clear definitions of the various types of monitoring, which are critical to the adaptive management process.

It would be mutually beneficial for agencies and companies to cooperate and develop the key components of reliable soil conservation procedures. This would:

- ensure continuous evolution of Best Management Practices (BMPs),
- enable coordinated development and implementation of training materials and new tools,
- facilitate reporting for sustainability protocols and meeting objectives of third-party certification, and

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- enhance the exchange and application of research results from various sources.

Long-term research in representative ecosystems is essential for understanding and managing the effects of forest practices on long-term soil productivity. Regional databases need to be developed to quantify the consequences of various practices and treatments on tree growth, soil-plant processes, and other forest resources like water quality.

Adaptive Management for Soil Conservation

The adaptive management process that has evolved based on the British Columbia (B.C.) Forest Practices Code and related soil disturbance guidelines (B.C. Ministries 1995a), and now the Forest and Range Practices Act (FRPA), demonstrates useful adaptive management components (Fig. 1). These are not unique to any one organization or jurisdiction and other recent examples of similar frameworks include the presentation by Terry *et al.*¹¹ and the World Forestry Congress handout by Jette¹². We suggest that scientists can and should contribute to all components of the adaptive management cycle, by developing procedures, providing strategic data from research, and consulting on guidelines, operations and BMPs. Participating in these activities provides opportunities for scientists to better understand the practical issues of sustainability. Due to limited resources and a large land base, B.C. Ministry of Forests (BCMoF) scientists are responsible for both research and operational support, ensuring this integration. To have an effective adaptive management process for soil conservation, each jurisdiction needs to address three objectives: (1) more uniform terms for describing soil disturbance; (2) cost-effective techniques for monitoring and assessing soil disturbance; and (3) reliable, site-specific methods to rate soils for risk of detrimental soil disturbance (Curran *et al.* 2005c). These are briefly discussed below:

The need for more uniform categories of soil disturbance

All jurisdictions responsible for regulating forest soil disturbance require clear definitions of disturbance caused by permanent access such as haul roads, and in-block disturbance caused by forest practices such as harvesting. Currently, many classification systems exist for characterizing soil disturbance related to rutting, soil compaction, displacement and mixing. Consequently, it is difficult to compare results without first correlating the different systems and developing a common language for such comparisons. The objective is to have visually identifiable, unambiguous, commonly used categories of disturbance that are:

- inclusive of the range of disturbance likely to occur, visually discernible and readily recognized by equipment operators or lay people,
- classed as detrimental or inconsequential (for tree growth or hydrology), or as ameliorated,
- site-specific, and

¹¹Terry, T.A., R.L. Heninger and R.G. Campbell. Sustainable site productivity: A forest industry perspective. Paper presented at LTSP 2000 conference, Alexandria, Louisiana.

¹²Jette, J.-P. Protecting forest soils through an adaptive management approach. Research note (describing Quebec soil disturbance standards and monitoring results). Tabled at the XII World Forestry Congress – Quebec, Canada, 2003.

- consistent with on-going validation monitoring (research) that tests the assumptions of “detrimental,” or “ameliorated” to site productivity or hydrology.

Curran *et al.* (2005c) discuss examples of visual disturbance criteria developed by BCMoF, Weyerhaeuser, and the United States Department of Agriculture, Forest Service (USFS).

Cost-effective monitoring to facilitate reliable assessment of soil conservation efforts

The USFS recognizes three types of soil quality monitoring (Avers 1990, USFS 1991):

- **Implementation monitoring** tests if the prescribed soil management practices have been implemented as designed or authorized (e.g., is the disturbance level within the acceptable limits?). This is also referred to as compliance monitoring which is an important requirement for third-party certification.
- **Effectiveness monitoring** tests if the prescribed soil management practices were effective in meeting management objectives (e.g., do authorized harvesting systems efficiently meet the disturbance target? Are sensitive soils identified and treated adequately?).
- **Validation monitoring** tests the assumptions of the monitoring standards and guidelines to ensure they are appropriate for maintaining soil productivity (e.g., do specific disturbance types actually result in a significant or measurable loss in productivity?).

In B.C., implementation monitoring is carried out by compliance and enforcement staff at the Forest District level, effectiveness evaluations are now required under FRPA and are carried out at the District, Region, and Provincial levels depending on the level of detail, and validation monitoring is carried out by the Ministry Research (Forest Sciences) Program. In the USFS, implementation monitoring is usually accomplished by planners, timber sale, and contract implementation staff. Effectiveness and validation monitoring are the responsibility of soil scientists. Validation monitoring may require involvement by, or coordination with, research scientists.

The purpose of implementation (compliance) monitoring of soil disturbance is to estimate the percentage of a total area in specified disturbance categories. This estimate is then compared with allowable limits. This presumes that meeting standards ensures no subsequent effects on soil productivity. This assumption needs to be tested by effectiveness monitoring and research on actual effects on tree growth and hydrology. One example of soil compaction and organic-removal research is the North American Long-Term Soil Productivity network (Powers *et al.* 1998). This research is starting to produce results (e.g., Gomez *et al.* 2002, Powers *et al.* 2005), but it will take longer for regional trends to be elucidated.

As outlined in Table 1, methods and intensity vary by types of monitoring and must strike a balance between affordability and utility (credibility). Visual assessment of soil disturbance is qualitative by nature, relatively inexpensive and can provide a reasonably efficient measure of soil disturbance, making them preferable for compliance monitoring. More quantitative measures of soil disturbance, such as soil physical properties, are more expensive. These are appropriate when testing assumptions as part of validation monitoring and long-term research. Direct evidence provided by

Table 1. General characteristics of monitoring categories applied to soil disturbance*

Item	Type of monitoring		
	Implementation (compliance)	Effectiveness	Validation
Duration	Duration of development activity	Short to medium-term	Medium to long-term
Intensity of data collection and analysis	Low to Medium	Medium	High (intensive)
Area sampled	Entire operating area	Representative operating areas	Representative ecosystems
Principle activities and objectives	Compliance and enforcement; Basic data on disturbance levels	Do standards work? Optimum prescription? Data on what does and does not work	Controlled experiments; Other trials; Data testing underlying assumptions
Outcomes	Data for penalties and reporting;	Modify policy and BMPs;	Published science;
	Priorities for effectiveness and validation monitoring	Identify validation monitoring and research needs	Recommendations for improving policy, guidelines, and practices
Responsibility	Approving agency or landowner (technical staff, third-party auditors)	Staff specialists	Research scientists

*Risk assessment is presumably used to apply the greatest monitoring resources to highest risk, highest priority areas. Conversely, less resources (less frequent, less intensive monitoring) are allocated to the lowest risk areas. Risk elements will vary based on values of concern (e.g., social, environmental, forest productivity).

site factors related to topography and drainage. For example, the BCMoF compaction hazard key is based mainly on soil texture and coarse fragment content. In B.C., the compaction hazard key, topsoil displacement key and surface soil erosion hazard key are used together to determine allowable soil disturbance limits and which disturbance types are of concern on a given harvest site.

We need to develop and test rating systems to ensure they reflect the site-specific differences that are observed during operations and research. For example, on sandy soils in southern B.C. we have found that percent clay appears to influence disturbance effects on tree growth. On sandy loam sites that would be rated the same under current guidelines, growth results varied with the clay content (Curran *et al.* 2005a), which needs to be incorporated in adaptive changes in rating systems and guidelines. A remaining challenge is to justify localized rating systems, while still ensuring comparability across jurisdictions to enable sharing operational and research knowledge.

Data for hazard ratings may be based on detailed soil mapping at a 1:24,000 or larger scale. These hazard ratings can be combined with some understanding of the consequence of operating equipment under certain climatic conditions to create risk ratings for planning. This is the level at which most direct risk-rating methods have been developed in the US Pacific Northwest. On-site inspection is still needed to confirm accuracy of the mapping and to rate the actual soil series. In the absence of detailed soil mapping, each area proposed for harvest requires its own soil assessment as part of harvest planning; this is the procedure used in B.C. (Curran *et al.* 2000).

External Reporting On Research, Guidelines and Protocols

Outputs from internal adaptive management within a jurisdiction can and should facilitate the development of effective approaches for using operational monitoring to meet various external objectives, including requirements of third-party certification and international protocols like the Montreal Process and objective comparisons of current soil-disturbance guidelines.

Using results of operational monitoring to meet various protocols

The Montreal Process (MP) identified seven criteria and 67 indicators to characterize conservation and sustainable management of temperate and boreal forests. Criterion 4 encompassed the conservation and management of soil and water resources. Of its eight indicators, five are related to soil and three are related to water. In addition, Criterion 3 (Maintenance of Forest Ecosystem Health and Vitality) and Criterion 5 (Maintenance of Forest Contribution to Global Carbon Cycles) also relate to soils (Ramakrishna and Davidson 1998).

In the First Approximation Report (Montréal Process Working Group 1997), the soil and water conservation criterion was the most difficult to report. Gaps in knowledge, monitoring, and data were identified at about 60% for the indicators of soil and water resources criterion. Further problems with indicators included a lack of appropriate measures, issues of scale, and monitoring approaches (Montréal Process Working Group 1997). These problems are understandable because of the need for a common language for soil disturbance, and also because all but one of the soil indicators are

“b” indicators: “those which may require the gathering of new or additional data and/or a new program of systematic sampling, or basic research” (Montréal Process 1995).

Agencies such as the Canadian Council of Forest Ministers (CCFM 2003) have developed national-level indicators that use the status of local standards as proxies for the more detailed MP “b” indicators. The underlying assumption is that ongoing adaptive management and research will test these proxies against the MP indicators. The rationale is that MP indicators are too onerous to track everywhere, and local-level standards should already be addressing these sustainability issues. A well-designed and carefully executed adaptive management process will help identify soil properties that are critical to measure and report (regionally, nationally and internationally). This mirrors the process used by the USFS since 1987. Each USFS region has been developing and modifying soil quality threshold standards aimed at detecting a 15% decline in a site’s potential capacity for growing vegetation (Powers *et al.* 1998). Because these standards vary by region, and they are in continual upgrade, they are by definition adaptive. A similar process supports the B.C. standards and has been developed, or is under development in Quebec, Ontario, Alberta, Saskatchewan and Nova Scotia.

Use of soil conservation principles and tools across jurisdictions

Soils are distributed on both sides of international borders and other ownership and administrative boundaries. For example, B.C. borders three U.S. Forest Service Regions, four U.S. states, other U.S. jurisdictions (e.g., U.S. Bureau of Land Management), private forest companies, and three other Canadian provinces and territories. Thus, fundamental compatibility of guidelines across jurisdictional boundaries is desirable. We acknowledge that agencies and landowners will view risk differently based on their mandates and management objectives. Individual guidelines will reflect these differences. We assert, however, that similar principles of soil conservation and management should be applied in all jurisdictions.

Some resource management tools also exist across jurisdictional boundaries. For example, soil mapping or ecological unit inventories may support extrapolating monitoring results, adjusting definitions of soil disturbance categories, or adjusting soil-quality standards across jurisdictional boundaries. Technical committees currently operating or proposed for regional, national, and international levels should compare soil management procedures and tools. They should explore opportunities for improving consistency in approaches; this is currently being started at the regional level in the Pacific Northwest under the auspices of the NW Forest Soils Council. At the National level, a Canadian Forest Soil Disturbance Working Group has started some initial activities towards this common goal, under the direction of the first two authors of this paper.

Summary

Soil conservation should be based on an adaptive management process. Necessary components include common soil disturbance categories, reliable protocols for measuring and assessing soil disturbance, and effective hazard ratings to categorize soil sensitivity or anticipated degree of degradation (e.g., degree of compaction). Moreover, long-term research is needed to quantify the effects of forest management practices

on sustainability indicators and their linkages with direct measures of tree growth and soil function.

We suggest that the following summary points are relevant to most sustainable forest resource management issues:

All components of the adaptive management process outlined in Fig. 1 are critical to the overall success of sustainable forest management and this appears to be gaining acceptance.

There needs to be clear distinction amongst the three types of monitoring required for adaptive management. Roles and responsibilities associated with these activities require clarity within each organization as they sort through these functions. Effectiveness monitoring is relatively new for some.

There needs to be an adequate balance of effort spent on the various types of monitoring, and this is still being sorted out by various agencies.

Clear links are needed between monitoring activities, third-party certification, local “state of the resource” reporting and protocols like the Montréal Process. A common approach to describing soil disturbance will facilitate this process, and some progress towards this goal has been reported by Curran *et al.* (2005b). Reporting on the status of standards as proxies for detailed indicators is useful, but requires validation through continued efforts on long-term research.

Longer-term research is critical: to test assumptions of sustainability guidelines, to demonstrate sustainability, and to adjust guidelines and practices as more data becomes available about specific sites or practices. Regional databases need to be constructed and maintained as data linking disturbance to longer-term hydrologic and productivity effects becomes more available.

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References

- Avers, P.E. 1990. Standards and guidelines: What they are and how they are used. In D.L. Schwitzer and M.J. McNaughton (comps.) Proc. National Workshop on Monitoring Forest Plan Implementation. Minneapolis, MN. May 14–17, 1990. pp. 52–53. USDA Forest Serv. Land Mgt. Planning, Washington, D.C.
- B.C. Ministries of Forests and Environment. 1995a. Soil conservation guidebook. Victoria, B.C. 20 p.
- B.C. Ministries of Forests and Environment. 1995b. Hazard assessment keys for evaluating site sensitivity to soil degrading processes guidebook, June, 1995. Forest Practices Code of British Columbia. Victoria, B.C. 24 p.
- Canadian Council of Forest Ministers (CCFM). 2003. Defining sustainable forest management in Canada. Criteria and indicators 2003. Canadian Forest Service, Ottawa, ON. 20 p. Available at http://www.ccfm.org/2000pdf/CI_Booklet_e.pdf
- Curran, M., I. Davis and B. Mitchell. 2000. Silviculture prescription data collection field handbook: Interpretive guide for data collection, site stratification, and sensitivity evaluation for silviculture prescriptions. B.C. Min. Forests Land Management Handbook No. 47. 156 p. Includes forms FS39A and B.
- Curran, M.P., R.L. Heninger, D.G. Maynard and R.F. Powers. 2005a. Harvesting effects on soils, tree growth and long-term productivity. In USFS GTR-PNW-xyy. Productivity of Western Forests: A Forest Products Focus. pp. 3–15.

- Curran, M.P., R.E. Miller, S.W. Howes, D.G. Maynard, T.A. Terry, R.L. Heninger, T. Niemann, K. Van Rees, R.F. Powers and S.H. Schoenholtz. 2005b. Progress towards more uniform assessment and reporting of soil disturbance for operations, research, and sustainability protocols. *J. For. Ecol. Manage.* (In press).
- Curran, M., D. Maynard, R. Heninger, T. Terry, S. Howes, D. Stone, T. Niemann and R.E. Miller. 2005c. A strategy for more uniform assessment and reporting of soil disturbance for operations, research, and sustainability protocols. Submitted to *The Forestry Chronicle*.
- Gomez, G.A., R.F. Powers, M.J. Singer and W.R. Horwath. 2002. Soil compaction effects on growth of young ponderosa pine following litter removal in California's Sierra Nevada. *Soil Science Society of America Journal* 66: 1334–1343.
- Lee, L.W. and G. A. Bradshaw. 1998. Making Monitoring work for managers. Accessed at http://www.icbemp.gov/spatial/lee_monitor/preface.html (October 22, 2002).
- International Organization for Standardization (ISO). 2001. ISO 14001 description. Available at: <http://www.iso.ch/iso/en/iso9000-14000/pdf/iso14000.pdf>.
- Montréal Process. 1995. Criteria and indicators for the conservation and sustainable management of temperate and boreal forests. Canadian Forest Service, Hull, QC. 27 p.
- Montréal Process Working Group. 1997. First approximation report on the Montréal Process, 1997. The Montréal Process Liaison Office, Canadian Forest Service, Ottawa, ON. 47 p.
- Powers, R.F., D.A. Scott, F.G. Sanchez, R.A. Voldseth, D. Page-Dumroese and J.D. Elioff. 2005. The North American long-term soil productivity experiment – findings from the first decade of research. *Forest Ecology and Management* (In Press).
- Powers, R.F., A.E. Tiarks and J.R. Boyle. 1998. Assessing soil quality: Practicable standards for sustainable forest productivity in the United States. In M.B. Adams *et al.* (eds.). The contribution of soil science to the development of and implementation of criteria and indicators of sustainable forest management. pp. 53–80. SSSA Publ. 53. SSSA, Madison, WI.
- Ramakrishna, K. and E.A. Davidson. 1998. Intergovernmental negotiations on criteria and indicators for the management, conservation, and sustainable development of forests: What role for soil scientists? In E.A. Davidson *et al.* (eds.) The contribution of soil science to the development of and implementation of criteria and indicators of sustainable forest management. pp. 1–16. SSSA Publ. 53. SSSA, Madison, WI.
- USFS. 1991. FSH 2509.18 Soil Management Handbook, Chapter 2 – Soil Quality Monitoring. WO Amendment 2509.18-91-1. Effective 9/3/91. United States Department of Agriculture, Forest Service, Washington, D.C.