Discussion Paper

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Monitoring the effects of forest practices on soil productivity and hydrologic function

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Abstract

In British Columbia and elsewhere, governments are evaluating the sustainability of forest practices. This requires the development of sensitive and reliable indicators and their monitoring over time. Conserving soil productivity and hydrologic function is a key aspect of forest ecosystem sustainability. British Columbia's Forest and Range Evaluation Program (FREP) has recently developed a protocol describing indicators and methods for collecting the data necessary to evaluate forest practices. We present five indicators for describing the status of soils on recently harvested areas in British Columbia, along with a brief scientific rationale for including them in the evaluation system, and a description of their intended use for monitoring sustainability. For three of the indicators, we also provide preliminary thresholds to help in determining whether current forest practices are consistent with the maintenance of soil productivity and hydrologic function.

KEYWORDS: *Forest and Range Evaluation Program,* Forest and Range Practices Act, *forest soil disturbance, indicators, monitoring, soil conservation.*

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Introduction

Under British Columbia's *Forest and Range Practices Act* (*FRPA*) the forest industry is responsible for proposing results for the sustainable management of forest resources and developing strategies to achieve those results.[1] The role of government is, in part, to establish default standards, ensure compliance with established results and strategies, and evaluate the effectiveness of forest practices for achieving management objectives. The purpose of British Columbia's Forest and Range Evaluation Program (FREP)[2] is to determine whether regulations (e.g., Forest Planning and Practices Regulation)[3] and forest practices under *FRPA* are meeting the government's objectives for 11 resource values (biodiversity, cultural heritage, fish/riparian, forage and associated plant communities, recreation, resource features, soils, timber, visual quality, water, and wildlife). FREP is part of the results-based forest practices framework in British Columbia. Because the evaluations will be used, in part, to test fundamental assumptions made in the drafting of the legislation and the default standards, improvement and innovation in forest practices over time are expected. In addition, FREP is an important part of government efforts to publicly report the outcome of forest practices occurring on Crown land, and encourages an open dialogue with the public, professionals, and stakeholder groups.

The Forest and Range Evaluation Program is part of the results-based forest practices framework in British Columbia.

For the 11 resource values identified within *FRPA*, the following steps are involved in assessing sustainable forest management:

1. develop specific monitoring and evaluation questions for each value, and identify indicators that characterize important aspects of the resource value's condition;
2. evaluate the status or trends of resource value indicators and determine causal factors;
3. determine whether resource values are being managed in a sustainable manner through proven or alternative forest practices;
4. communicate the results of evaluations to resource managers and the public; and
5. recommend changes to forest and range policies and legislation, where required.

The objectives of this review are to: (1) describe the indicators and stewardship questions used within FREP to evaluate the soil value at the cutblock level, and (2) illustrate how information from soil resource monitoring is being used to improve forest practices and policy in British Columbia.

Protecting Soils Under *FRPA*

The objective set by government for soils in *FRPA* is "without unduly reducing the supply of timber from British Columbia's forests, to conserve the productivity and the hydrologic function of soil".[4] A first step in determining whether this objective is being met is to define soil productivity and hydrologic function.

Productive forest soils do more than produce crops, although many definitions of soil productivity with origins in industrial agriculture refer primarily or exclusively to crop production (Campbell 1978; Gregorich *et al.* [editors] 2001; Brady and Weil 2002). As stated by Yaalon (2000:301), however, ". . . it is as the transformer, regulator, buffer and filter of water, nutrients and other dissolved and dispersed compounds that soils are most important to humankind . . . the soil system, especially its carbon dynamics, is the central link between the physical climate and biogeochemical cycles." It is also clear that in the context of sustainable forest management, the growth of the forest is critical, and includes the production of "crops" such as commercially harvested

[1] SBC 2002, Chapter 69, *Forest and Range Practices Act*. *http://www.for.gov.bc.ca/tasb/legsregs/frpa/frpa/frpatoc.htm*
[2] B.C. Ministry of Forests and Range, Forest Practices Branch, Forest and Range Evaluation Program. *http://www.for.gov.bc.ca/hfp/frep*
[3] Forest Planning and Practices Regulation, B.C. Reg. 14/2004. *http://www.for.gov.bc.ca/tasb/legsregs/frpa/frparegs/forplanprac/fppr.htm*
[4] Forest Planning and Practices Regulation, B.C. Reg. 14/2004, Part 2 Division 1, Section 5. *http://www.for.gov.bc.ca/tasb/legsregs/frpa/frparegs/forplanprac/fppr.htm#section5*

timber, berries, and mushrooms. Soil hydrologic function refers to soil processes that affect the properties, distribution, and circulation of water in weathered surficial materials.

Therefore, we consider a productive forest soil as one that allows forest ecosystems to grow, produce crops, and function with minimal human intervention. A productive forest soil provides:

- a physical environment;
- the ability to retain and supply nutrients;
- moisture-holding capacity;
- the ability to resist, suppress, and withstand outbreaks of diseases and pests;
- resistance to erosion and slope failure;
- desirable pH and buffering capacity;
- biological processes important for ecosystem function and health; and
- the ability to recover keystone ecosystem processes following disturbances within the range of natural variation (e.g., fire and flood).

Under *FRPA*, soil disturbances of concern at the cutblock level include permanent access structures (e.g., roads and landings) and dispersed disturbance in the net area to be reforested (NAR). A protocol to monitor the soil value at the landscape level is currently under development and will not be referred to further in this report. In 2002–2003, the British Columbia Ministry of Forests and Range Soils Team developed a pilot protocol for monitoring soils at the cutblock level in co-operation with the Forest Practices Board for the Board's audit of soil conservation in the Mackenzie Forest District.[5] This protocol has undergone considerable further development and field-testing with the help of district and regional staff and co-operators and is now in the pilot and implementation phase as the *Protocol for Cutblock-level Soil Resource Stewardship Monitoring* (Curran *et al.* 2008). Operational implementation of the FREP monitoring program is carried out by district stewardship foresters with the support of regional and research branch soil scientists and the Forest Practices Branch.

In general, the provisions within *FRPA* and the associated regulations are intended to ensure that forest practices are conducted to:

- limit the area of productive forest land that is occupied by permanent roads, landings, pits, quarries, and trails;
- address the inherent sensitivity of a site to soil-degrading processes;
- limit the extent of soil disturbance caused by harvesting and silviculture activities that negatively affect the physical, chemical, and biological properties of the soil; and
- maintain or restore natural drainage patterns to protect hydrologic function.

Soil Evaluation

Three levels of monitoring and evaluations are conducted by FREP (Province of British Columbia 2005a). Resource stewardship monitoring (RSM), the first line of assessment, provides information on resource status and trends, as well as identifies implementation issues regarding forest policies, practices, and legislation. Effectiveness evaluations (EE) are more intensive than RSM, and determine whether plans and practices are achieving objectives and anticipated outcomes. As a third level of assessment, validation evaluations use scientific methods to assess the assumptions upon which forest management strategies, practices, and standards are based. Therefore, part of RSM and EE is to identify research needs as well as information gaps related to policy implementation, while validation includes research aimed at improving forest practices, management, and policy. Also, it is expected that the legislation and policy will be revised from time to time to reflect new knowledge gained through research.

Development of Indicators

Evaluation is a process of measuring resource value indicators. Indicators must reflect the status of a particular aspect of the soil value, need to be easily measured, and should have scientific evidence to support their use (Curran *et al.* 2005a). The current status of the soil resource, and trends over time, can be evaluated by analyzing quantitative data on indicators of soil condition. In addition, by responding to certain sustainability questions, professionals can provide a more subjective assessment of soil stewardship, which

[5] British Columbia Ministry of Forests and Range. Forest Practices Board. News release November 23, 2004. *http://www.fpb.gov.bc.ca/news/releases/2004/11-23.htm*

may be useful for improving management practices or for gaining information about indicators that still require validation through research.

Uniform criteria that can be summarized quantitatively are well suited for documenting the state of the soil resource at a particular time, and also allow more rigorous comparisons of conditions in areas that may experience different practices (i.e., they are useful for aggregating district and regional information into generalized interpretations applicable to the province as a whole). Quantitative data also permit the assessment of trends and the re-examination of data in light of revised understanding of critical thresholds. For example, if a threshold value for area of the land base in permanent access was revised from 7% (as currently stated in the regulations) to 5%, we could do a better assessment of sustainability using quantitative data than if the data had been qualitative. If a qualitative assessment simply reflected whether the threshold was exceeded, such re-evaluation would not be possible. Questions of stewardship—for instance, whether the total amount of permanent access seemed excessive given the site conditions—require professional judgement that may limit the ability to generalize the information. Stewardship questions, however, provide important context for the quantitative results and could be instrumental in affecting policy or management.

The indicators, measures, and stewardship questions presented here are suitable for use 1–2 years after harvesting operations are completed and are therefore proxies for long-term soil productivity. Some indicators of forest productivity, such as tree growth and site index, have not been included because they are more reliably determined after longer time periods. Research efforts, such as the Long Term Soil Productivity Study,[6] are under way to evaluate the linkage between soil disturbance at the time of operations and long-term forest productivity.

The monitoring protocol is organized into five key indicators, each focussing on an aspect related to protecting the soil value under the *FRPA* or in a general stewardship context. The five indicators, a brief rationale for their inclusion, and measures for data collection are discussed. Where an indicator has more than one attribute or component that needs to be assessed, separate measures are provided for each attribute or component.

Stewardship questions provide important context for the quantitative results and could be instrumental in affecting policy or management.

Indicator 1: Lost Productivity Due to Access Construction

Rationale

Permanent access structures, such as main roads, permanent spur roads, landings, and borrow pits, represent either a fundamental change in land use (i.e., conversion of growing site to access), a reduction in productivity (Krag *et al.* 1986b; Megahan 1988) through compaction (Carr 1987, 1988; McLeod 1988; McNabb 1994) and nutrient deficiencies (Carr 1987, 1988), or an alteration in hydrologic function (Megahan and Kidd 1972; Megahan 1981). Roads are often one of the main contributing factors regarding slope stability and erosion or sedimentation issues both on and off the cutblock (Bourgeois 1978; Krag *et al.* 1986a; Sauder and Wellburn 1987; Rollerson 1992; Guthrie 2002; Jordan 2003). Because of these concerns, it is desirable to minimize the amount of permanent access, and to rehabilitate (Plotnikoff *et al.* 2002; Bulmer and Krzic 2003) any temporary access (i.e., access that is not needed over the long term) back into productive forest land.

Measures of percent of cutblock for:

- roads, landings, and borrow pits; and
- rehabilitated access (modified by an assessment of the effectiveness of the rehabilitation).

Examples of stewardship questions related to access construction:

- Does the total amount of permanent access seem excessive given the site conditions?
- Are there portions of the un-rehabilitated access that should have been rehabilitated?
- Do any individual access structures seem larger than necessary?
- Were pre-existing access structures not used that should have been?
- Are there rehabilitated areas where drainage control was not included but should have been?

[6] British Columbia Ministry of Forests and Range. Long-term soil productivity study. *http://www.for.gov.bc.ca/hre/ltsp/index.htm*

Indicator 2: In-block Area Affected or Potentially Affected by Landslides, Drainage Diversion, or Erosion

Rationale

Landslides and other forms of soil removal represent potential or actual losses in productivity (Miles *et al.* 1984; Smith *et al.* 1986) and (or) hydrologic function (Bourgeois 1978; Krag *et al.* 1986a; Sauder and Wellburn 1987; Rollerson 1992; Guthrie 2002; Jordan 2003) and may affect other resource values on and off the cutblock area. We use an estimate of the total area affected or potentially affected[7] to evaluate this indicator because small disturbances can sometimes have large impacts, and some detrimental effects will only become obvious after severe rainstorms or other events.

Disruption of natural drainage patterns can lead to losses in hydrologic function and (or) productivity (Greacen and Sands 1980; Froehlich and McNabb 1984; Kozlowski 1999), and may affect other *FRPA* resource values on and off the cutblock area. High water tables that result from disrupted drainage after machine traffic, for instance, can result in slow seedling establishment.

Measures of area affected or potentially affected by:

- landslides;
- construction and maintenance practices;
- surface erosion;
- drainage diversion; and
- standing water.

Examples of stewardship questions related to landslides and erosion:

- Have harvesting practices or access construction led to, or increased the potential for, mass movement or erosion on the cutblock?
- Have harvesting practices or access construction led to, or increased the potential for, mass movement or erosion off-site?
- Are there areas where measures should have been taken to restore natural drainage patterns but were not carried out?

Indicator 3: Soil Disturbance Hazards, Dispersed Disturbance, Inordinate Disturbance, and Roadside Work Areas

Rationale

Widespread compaction or displacement of the forest floor and upper mineral soil can affect forest productivity and hydrologic function (Greacen and Sands 1980; Smith and Wass 1980; Froehlich and McNabb 1984; Smith and Wass 1994 a, b; Wass and Smith 1994; Startsev *et al.* 1998; Curran *et al.* 2005b; Kabzems and Haeussler 2005), as well as other *FRPA* resource values on and off the cutblock area. Trails are the most common form of dispersed disturbance that are known to reduce productivity (Dykstra and Curran 2000). The effect of roadside work areas on tree growth has not been fully evaluated, even though such areas commonly account for 10–20% of the NAR. Although other forms of dispersed disturbance may not affect early tree growth on some sites, they may cause undesirable long-term effects or make the site more susceptible to erosion.

Measures of:

- areas of inordinate disturbance (i.e, areas larger than 0.2 ha with 30% or higher disturbance, or smaller areas if there is a high risk to other *FRPA* resource values);
- dispersed soil disturbance;
- roadside work areas; and
- rehabilitated areas (modified by an assessment of the effectiveness of the rehabilitation).

Examples of stewardship questions related to soil disturbance in the NAR:

- Do any of the soil disturbance hazard ratings appear to have been incorrectly determined in the planning stage?
- Do any of the standards units[8] appear to have been mapped incorrectly, or are there complexes that have not been recognized?
- Does there appear to be more dispersed soil disturbance in the NAR than necessary?
- Does there appear to be more soil disturbance within the roadside work areas than necessary?

[7] Area potentially affected is an estimate determined using the professional judgement of the surveyor.

[8] "Standard units are one or more parts of a cutblock for which part or parts there is only one of each of the following: (a) soil disturbance limit, (b) regeneration date, (c) stocking standard, (d) free growing date, and (e) free growing height for each species that contributes to establishing a free growing stand on the cutblock" (Forest Planning and Practices Regulation, B.C. Reg. 14/2004, Part 1, Definitions. *http://www.for.gov.bc.ca/tasb/legsregs/frpa/frparegs/forplanprac/fppr.htm#section1*).

- Considering a range of factors, including safety and efficiency, does the amount of area occupied by skid trails and temporary access structures and (or) the disturbance associated with these structures appear excessive?
- Are there disturbance types present that should have been rehabilitated but were not?

Indicator 4: Green Tree Retention

Rationale

Soil organic matter and the activity of organisms that utilize soil are important factors affecting the productivity of forested sites (Powers *et al.* 1990; Jurgensen *et al.* 1997; Worrell and Hampton 1997; Marshall 2000). The living roots of mature trees sustain a diverse community of soil organisms and processes so there are numerous reasons, including the maintenance of commercially harvested mushrooms (such as pine mushrooms and chanterelles), to be concerned about the removal of all living, mature trees from cutblocks (Amaranthus *et al.* 1989; Bader *et al.* 1995; Kranabetter and Kroeger 2001; Hammond *et al.* 2004). Although insufficient research exists to establish critical limits or thresholds for different ecosystems or even to predict whether dispersed or aggregated retention would meet most ecosystem needs, it is recognized that these are important aspects of soil stewardship that need to be tracked over time.

The following data collected during stand-level biodiversity FREP monitoring are used in the analysis and interpretation of cutblock-level soil FREP monitoring.

Measures of:

- wildlife tree patches by percent of cutblock; and
- green trees retained by number, species, size, and wildlife tree class.

Examples of stewardship questions related to green tree retention:

- Given the site and surrounding landscape, does it appear that there are insufficient mature forests close enough to provide inoculum for organisms recolonizing the cutblock?
- Does the variety of green trees retained fail to represent the variety of tree species common to this landscape?
- Does it appear unlikely that the measures taken to retain standing green trees (e.g., wind-proofing) will be successful?

Indicator 5: Dead Wood

Rationale

Organic matter (e.g., forest floor and dead wood) is a key driver of ecosystem processes. These materials act as important reservoirs of on-site nutrient pools and hydrologic function (e.g., water relations for trees). Consequently, loss of organic matter can affect site nutrient levels and long-term timber production (Powers *et al.* 1990; Jurgensen *et al.* 1997; Worrell and Hampson 1997; Kranabetter *et al.* 2006; Hope 2007). Disturbance to the forest floor is addressed by Indicator 3 and dead wood is addressed by Indicator 5. With the exception of forest fires, which would remove some biomass in a natural forest, the energy and carbon stored in wood, branches, twigs, and foliage would be utilized by saprophytic organisms and contribute to total site organic matter. In a forest harvested for wood, much of the standing biomass is removed and made unavailable to the saprophytic community. In addition, dead wood is habitat for a variety of organisms, including saprophytic fungi that provide competitive exclusion of pathogenic fungi (Chapman and Xiao 2000). Although we cannot yet provide meaningful thresholds or critical limits for dead wood retention, especially since these will differ among ecosystems, it is clear that dead wood is an important aspect of soil conservation that must be monitored.

Coarse dead wood data collected during stand-level biodiversity FREP monitoring are used in the analysis and interpretation of cutblock-level soil FREP monitoring.

Measures of:

- coarse dead wood by number, species, decay class, diameter, and length; and
- fine dead wood by fuel loading category.[9]

Examples of stewardship questions related to organic matter retention:

- Does it appear that measures to conserve coarse dead wood should have been carried out on the site but were neglected or ineffective?
- Does it appear that measures to conserve fine dead wood should have been carried out on the site but were neglected or ineffective?

[9] To assess fine dead wood under 7 cm diameter, we used Schedule 7, Forest Fire Prevention and Suppression Regulation (B.C. Reg. 148/96). *http://www.for.gov.bc.ca/tasb/legsregs/archive/fpc/fpcaregs/ffirepre/ffpasrs7.htm#Sch-7*

Data Collection and Interpretation of Sustainability

Sites are normally selected using simple random sampling which allows for: (a) defensible results, (b) estimates of sample error and confidence limits, and (c) objective determination of sample size requirements (Province of British Columbia 2005b). In some cases, targeted sampling may be employed to address specific geographic areas, licensees, or other criteria to meet operational needs.

We expect that much of the quantitative data can be determined from high-definition digital photos of cutblocks in conjunction with field-checking by trained staff using protocols described in Curran *et al.* (2000) and the protocol for cutblock-level soil monitoring (Curran *et al.* 2008). The assessment of the stewardship questions likely requires the involvement of experienced forest soil scientists and (or) qualified professionals with local or regional experience. For example, determining whether the amount of permanent access appears excessive may require an understanding of expected traffic loads, the need for switchbacks in small cutblocks, slope conditions, or other factors (Curran *et al.* 2008). Information generated from the stewardship questions determines the causes of changes in the quantitative soil indicators. This information is essential for improving policy and management practices.

Some soil disturbance is a normal part of all timber harvesting operations, and some forested ecosystems require disturbance for regeneration. In other cases, too much disturbance or certain kinds of disturbance are detrimental. To create an evaluation system, however, we need to decide at what point problems may occur. Therefore, we propose preliminary thresholds for Indicators 1–3 (i.e., access, landslides/erosion and drainage, and soil disturbance) to help determine whether harvesting practices conserved soil productivity and hydrologic function in a particular cutblock (Table 1). These thresholds are preliminary because they reflect a blend of scientific experience and operational reality. They are indicative of good management practices and of levels of disturbance that are not expected to result in significant loss of productivity or hydrologic function. For Indicators 4 and 5 (green tree retention and dead wood), there is insufficient scientific evidence and management experience to specify thresholds. An abundance of scientific evidence acknowledges the importance of these indicators, therefore monitoring is required to create a database documenting the current

TABLE 1. Thresholds of soil disturbance to help determine whether timber harvesting practices conserved soil productivity and hydrologic function

Indicator	THRESHOLDS, SCORES, AND SOURCE		
	Acceptable	Soil conservation objectives may not have been met	Source of thresholds
1. Percent of the cutblock area occupied by unproductive soil as a result of access construction			*FRPA*, FPPR[a], and best management practices
a. Simple topography and slope less than 30%	5%	> 5%	
b. Complex topography or slopes greater than 30%	7%	> 7%	
2. In-block area affected or potentially affected by landslides, erosion, or drainage diversion occurring from roads, landings, or trails	0 m^2	≥ 200 m^2	Practical limit for measurable, mapable area
3. Occurrences of inordinate soil disturbance	0	≥ 1	Best management practices
a. Percent of the cutblock area affected by concentrated and dispersed soil disturbance in the NAR			
i. Sensitive soils	≤ 5%	> 5%	*FRPA*, FPPR, and best management practices
ii. Non-sensitive soils	≤ 10%	> 10%	
b. Percent of NAR affected by forest floor displacement	< 20%	≥ 20%	Best management practices
c. Extent of roadside work areas (RWA) disturbed	< 25%	≥ 25%	*FRPA*, FPPR, and best management practices

[a] FPPR: Forest Planning and Practices Regulation

The data collected will be used to evaluate the status of soil productivity within recently harvested areas, track changes, and facilitate improved management practices.

state and trends of these sustainability indicators and to assist with indicator validation.

At the cutblock level, sustainability is then evaluated, in part, by comparing the quantitative values for the indicators to the threshold values. The use of these thresholds allows the evaluator to rapidly determine whether harvesting practices conserved soil productivity and hydrologic function on a particular cutblock. The threshold values provided in Table 1 can be used to guide such decisions, along with consideration of the responses to stewardship questions related to each of the indicators. The threshold values are based on management experience supported by ongoing scientific research, and may need to be adjusted to reflect new practices or research findings. For example, while the threshold for permanent access is set at 7% of the cutblock area (FPPR), recent information shows that this value may already be too high—most harvested blocks in British Columbia are completed with less than 7% permanent access—and a value closer to 5% may be more appropriate. Other threshold values, including dispersed soil disturbance, partly reflect what is considered achievable with good practices.

Exceeding the threshold for any indicator suggests that harvesting practices may not be consistent with the objective set for soils by government in *FRPA* (i.e., to conserve the productivity and the hydrologic function of soil without unduly reducing the supply of timber from British Columbia's forests). The stewardship questions can be used to confirm such a suggestion. As a general rule, confirmation that soil objectives have not been met is indicated when (a) the value for the indicator exceeds the threshold, and (b) a positive response is returned for one of the stewardship questions related to the indicator.

For cutblocks where thresholds were not exceeded, and no stewardship questions received a positive response, it is likely that harvesting practices achieved the soil objectives. If a response to a stewardship question does not confirm the indicator score, or a positive response is returned for a question without the indicator value exceeding the threshold, then the evaluators need to use their professional judgement. Where it appears that soil objectives have not been met, future monitoring may need to be carried out to determine longer-term effects on soil productivity and other *FRPA* values.

Improving Forest Management and Policy

The data collected during cutblock-level soil monitoring will be used to evaluate the status of soil productivity within recently harvested areas, track changes, and facilitate improved management practices. All three types of monitoring (extensive RSM, intensive EE, and validation) contribute to this process. Information from RSM, using the indicators described here and collected at the forest district level, will provide managers with a status report and the raw data for evaluation of soil value trends at the provincial level. Information from EE, particularly the response to sustainability questions, will assist with the interpretation of RSM information and elucidate options for alternative management approaches or practices that may resolve problems. Finally, the focus of validation or research efforts is, in part, directed by information derived from RSM and EE, and the results are used for developing better approaches for conserving soil productivity and hydrologic function. In general, activities in RSM are carried out at the district level, while EE and validation are directed primarily at the regional and provincial levels. Despite this, all activities would benefit from enhanced co-ordination of monitoring and research at the provincial, national, and international levels.

British Columbia's FREP evaluates whether forest practices are meeting not only the intent of the current objectives in *FRPA*, but also determines whether forest practices and *FRPA* legislation and regulations are meeting government's broader intent for the sustainable use of resources. Therefore FREP results also determine whether changes to legislation or regulations are needed to ensure sustainable use of the forest resources and, if so, to guide the refinement of policy.

Summary

A monitoring system has been developed for evaluating soil productivity and hydrologic function in British Columbia's forests. Guided by the framework within FREP, a series of indicators have been developed and a monitoring protocol devised to quantitatively track changes in soil status. Use of the quantitative indicators

and protocol can provide important information for evaluating soil sustainability in relation to proposed thresholds for British Columbia, and to elucidate trends resulting from forest practices. A continuous process of evaluating the scientific basis of the indicators and validation monitoring will guide efforts to improve the monitoring system, and make it responsive to new knowledge. The indicators described here should help managers and policy-makers determine whether current harvesting practices are consistent with the conservation of soil productivity and hydrologic function based on current understanding of soil and ecosystem processes and forest practices. Through co-ordinated efforts at the district, regional, and provincial levels, the monitoring framework will provide information that will indicate whether British Columbia's objectives for soil productivity and hydrologic function are being met, and a mechanism for improving the provisions within *FRPA* in response to new research findings.

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Test Your Knowledge . . .

Monitoring the effects of forest practices on soil productivity and hydrologic function

How well can you recall some of the main messages in the preceding Research Report? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Under British Columbia's *Forest and Range Practices Act*, the role of government is to:
   A) Propose results for the sustainable management of forest resources
   B) Develop strategies to achieve proposed results
   C) Evaluate the effectiveness of forest practices for achieving management

2. The Forest and Range Evaluation Program:
   A) Is another enforcement form of forest practices regulations
   B) Helps determine whether changes to legislation or regulations are needed to ensure sustainable use of the forest resources
   C) Carries out applied research on sustainable forest management

3. Thresholds are not provided for dead wood or green tree retention because:
   A) Insufficient research exists to establish thresholds for different ecosystems
   B) Dead wood and green tree retention are not needed to sustain forest soil

ANSWERS

1. C 2. B 3. A