

EROSION CONTROL

HIGH CONSERVATION VALUE 4, QUESTION 14

Are there forests critical to erosion control?

BACKGROUND

The HCVF Framework for Canada recognizes that forests may be critical for soil, terrain or snow stability, including control of erosion, sedimentation, landslides, or avalanches.

Soil is a critically important resource on forest lands. Soil loss through erosion reduces a site's productivity through loss of nutrients and the ability to hold water. Soil erosion also negatively impacts down-slope ecosystems. Eroded soil washes into streams, rivers, and lakes and creates water quality problems for people, fish, and wildlife.

Soil erosion, including mass wasting, is the most common natural landscape forming process. Over thousands of years, natural erosion wears down mountains and deposits soil elsewhere to form plains, plateaus, valleys, river flats, and deltas. Accelerated erosion can result from certain human land use practices and requires a combination of two factors: Loose soil (resulting from moving water, raindrops, or freezing and thawing) and a physical force (e.g., water, wind, ice, or gravity) that can transport the soil to a new location.

Several factors influence whether soil particles are likely to be loosened or detached and, thus, become vulnerable to erosion. These factors include:

- Force, frequency and timing of precipitation – Intense rains have more power to dislodge and transport soil than gentle rain does. Precipitation on frozen ground is less erosive than on unfrozen ground.
- Amount of vegetation and litter cover – Plants and litter provide cover that intercepts and reduces rainfall impact and slows wind velocities. Vegetation also increases water infiltration into the soil, reduces runoff velocities, filters sediment and contaminants and provides structure (roots) to hold the soil in place.
- Soil texture - silts and sands detach easily, while high clay content binds particles.
- Slope stability

Slope stability is affected by:

- Steepness - Generally, the steeper a slope the more susceptible it is to erosion and landslides
- Aspect – Slope facing into prevailing winds can lead to greater exposure to wind-driven rains, and higher run-off rates.
- Shape - Straight and S-shaped slopes tend to be more stable than concave or convex slopes
- Water content of the slope - Slopes saturated with water due to precipitation or human activities like

irrigation or removal of vegetation can be too heavy to withstand down-slope movement.

- Slope modification- Slopes that are undercut by human activities, such as roads and excavation, may be unstable. Steep canyon slopes may be undercut by the erosive actions of streams. Structures or material deposited on the top of slopes may contribute to an overloading that encourages down-slope movement.

A generally proportional relationship exists between total water yield (runoff) and the extent of forest disturbance (Sahin and Hall 1996). The amount of erosion that occurs is a response to the balance between gravity and the resistance of soils, rock and, vegetation. Activities such as road building and timber harvesting can affect the ability of soils, rock, and vegetation to resist movement.

Avalanches

Avalanches commonly snap tree boles and move debris down slope and into watercourses.

Slope angle is one of the primary factors contributing to avalanche probability. Under most snow and weather conditions avalanches are rare on slopes less than 30 degrees, and are most common on slopes of 35-45 degrees. Slopes steeper than 50 degrees tend to slough snow and not build up a snowpack capable of avalanche. Dense trees and dense, large rocks act as anchors for snow on slopes. A thick, mature grove of conifers can act as an effective anchor for snow while a sparse grove of aspen or other deciduous species has very little effect.

DATA SOURCES

The HCVF Framework for Canada lists the following possible data sources:

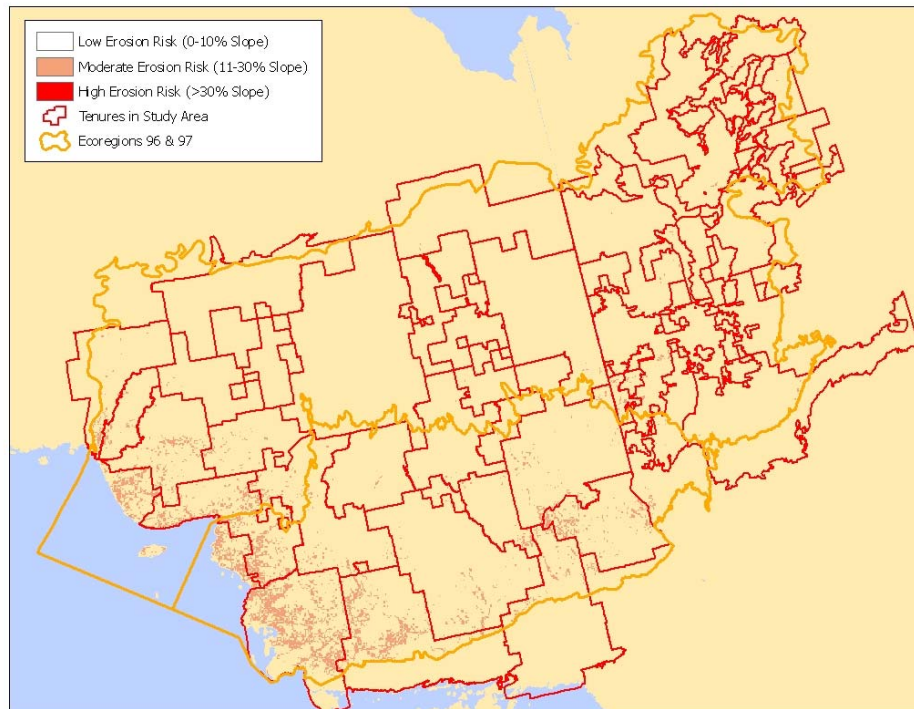
- Maps, remote sensing data, aerial photos, Governmental departments
- Consultation with relevant experts

Additional data sources that would be relevant to addressing the issue of erosion control include:

- Regional guidelines (e.g. Ministry of Natural Resources in Ontario) on physical environment and erosion risks
- British Columbia Watershed Assessment Procedures (http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCC_UIDE/Guidetoc.htm)
- Slope data from topographic maps
- Digital Elevation Models (e.g. USGS SRTM 90m DEM <http://seamless.usgs.gov/>). This dataset has extensive coverage, but its resolution may not be

HCV4 Q14 – EROSION CONTROL

Figure 14.1 Slope analysis of the study area.



suitable for finer scale analyses. Practitioners should make use of the finest scale data available for their land base.)

- Soil landscapes of Canada 1:1 million scale (<http://sis.agr.gc.ca/cansis/nsdb/slc/index.html>)
- Ontario – NOEGTS landform database
- District soils maps (available on-line for some regions; <http://sis.agr.gc.ca/cansis/nsdb/detailed/index.html>)
- Snow, frozen soils and permafrost hydrology in Canada, 1995-1998 (Woo *et al.* 2000)

INTERPRETING THE PRECAUTIONARY PRINCIPLE

Cumulative impacts of various land uses and natural disturbances may result in accelerated soil erosion and mass wasting (Carignan *et al.* 2000). For example, after severe fires, soils are no longer protected by vegetation cover and are subject to accelerated erosion rates. The erosive impact of water on bare post-fire soils is accelerated by even moderate precipitation events. Infiltration rates decrease on bare slopes causing increased runoff and accelerated sediment carrying capacity. The resulting sediment and debris movement into stream channels causes clogging within the channels and mud and debris flows, which scour steeper channel segments and encourage significant deposition along flatter areas of the stream corridor. To compound the hazard potential, soils are subject to slipping or slumping during rainy periods when super saturation may occur. Once super saturated with water, denuded soils lose their cohesive strength and are subject to sloughing.

Under the precautionary principal, we recommend analyses of erosion-prone areas include potential cumulative impacts of forest management actions, other land uses and natural disturbances. Climate change is expected to increase total rainfall, rainfall intensity and soil erosion rates in North America (Nearing *et al.* 2004). To be precautionary, analyses of erosion prone areas within FMAs should be re-evaluated at least once per decade.

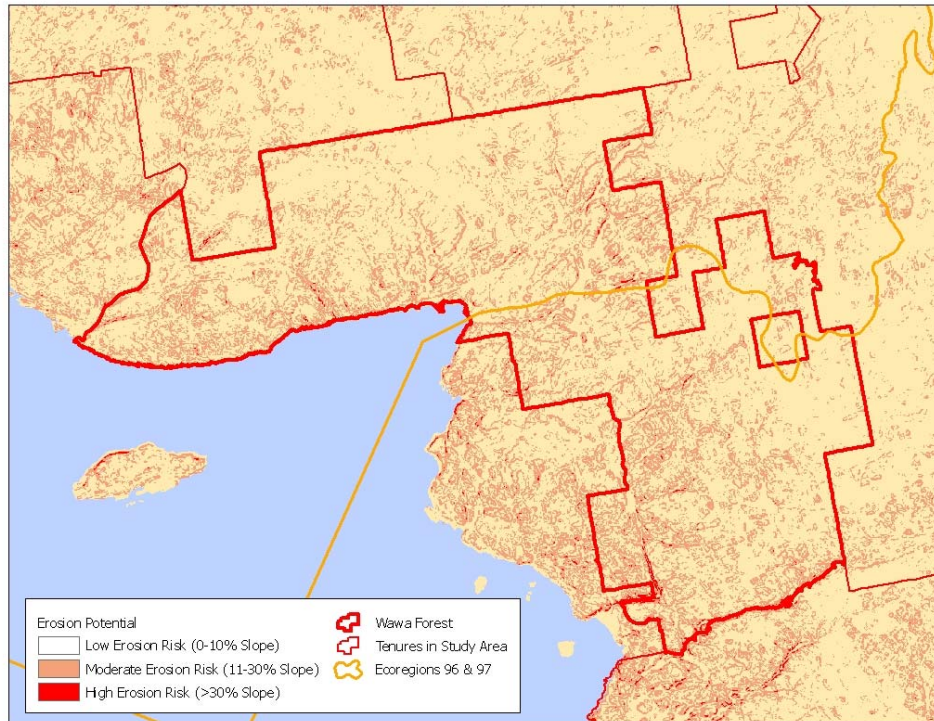
ADDITIONAL GUIDANCE

Spatially modeling erosion and/or flood probability is a common method of identifying erosion prone areas. The flood modeling approaches discussed under Question 13 in this document may also be useful for modeling erosion (see Question 13).

Modeling erosion using the Revised Universal Soil Loss Equation (RUSLE) may also be useful. The RUSLE computes sheet and rill erosion from rainfall and the associated runoff for a landscape profile. It is based on the Universal Soil Loss Equation (Wischmeier and Smith 1978), which incorporates factors for rainfall erosivity, soil erodibility, slope length and steepness, vegetative cover and management and conservation practices. The publicly available RUSLE2 software model (developed by the US Natural Resources Conservation Service) predicts long-term, average-annual erosion by water. While RUSLE2 was developed to be land use independent, note that some researchers question its applicability to certain forest soils and slope gradient characteristics (Gonzalez-Bonorion and Osterkamp 2004). Note also that for some areas of the Canadian boreal region

HCV4 Q14 – EROSION CONTROL

Figure 14.2 Slope analysis of the Wawa Forest.



adequate, fine-scale data may not be available to use this approach successfully for identifying erosion risk areas.

For more information on RUSLE erosion prediction technologies and current software see: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm?action=Go+to+the+official+NRCS+RUSLE2+website

For areas lacking fine-scale data, erosion potential can be mapped based on slope angle by deriving slope from digital elevation models, and erosion potential based on regional guidelines. Figure 14.1 illustrates this example for the study area. Given that there is a lack of fine scale soils data, and that the OMNR guidelines indicate little variability in erosion risk across soil types (OMNR 1997), we based this analysis on slope values only using a 90 m resolution digital elevation model.

It should be noted that while the use of a 90 m or comparable resolution DEM is adequate for analyses at the regional scale, investigations at the level of the management unit should ideally utilized finer grained data. An intrinsic characteristic of slope analyses using DEMs is the decrease in average slopes identified with increasing grid size, potentially leading to underestimations of erosion potential (Montgomery 2003).

Figure 14.2 illustrates the same analysis at the scale of a single tenure located in the southwest of the study area, the Wawa Forest. This analysis, while useful in highlighting the general areas of high erosion risk, does

not produce defined HCVF zones delimiting the erosion prone sites.

To determine a mappable distribution of erosion sensitivity, it is more useful to derive threshold levels of erosion risk within defined ecological or management-based units. We derived a threshold for the proportion of Forest Resource Inventory (FRI) polygons at medium and high erosion risk according to the following values:

- > 75% of the FRI polygon is medium and/or high erosion risk; or
- > 50% of the FRI polygon is high erosion risk

Figure 14.3 illustrates the distribution of medium and high risk FRI stands in Wawa forest with these thresholds applied.

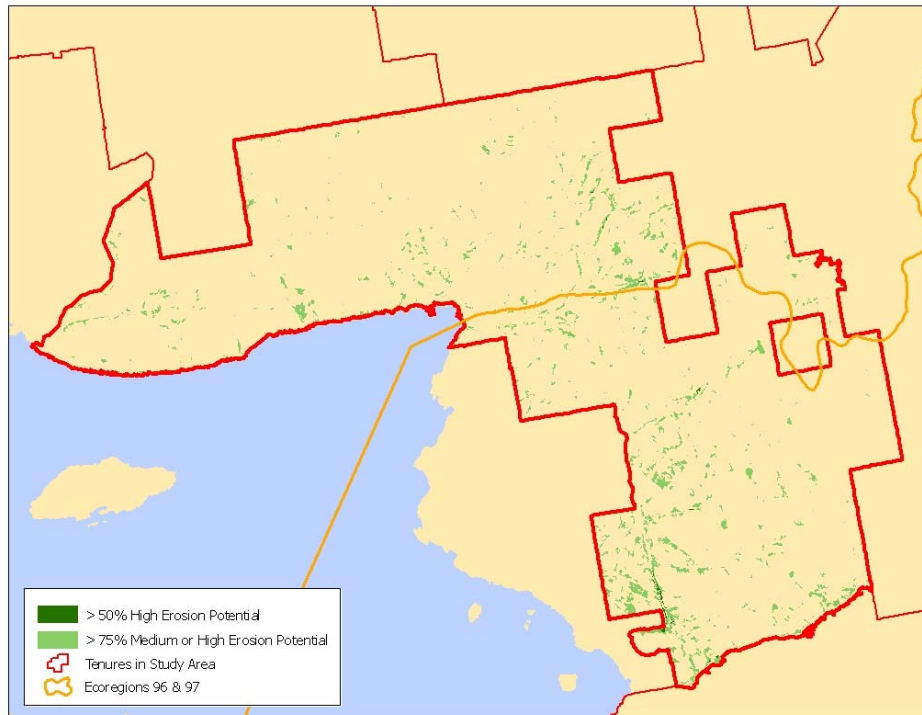
We recommend that management prescriptions vary depending on the amount of medium and high erosion prone slopes. For FMAs with steep terrain, we recommend a similar analysis of slope angles to identify avalanche-prone slopes.

Thresholds

One threshold for a measurable response in water flow as a result of forest disturbance was found to be at forest cover changes at or above a 20-25% (Bosch and Hewlett 1982; Hornbeck *et al* 1993). Under Question 13 in this document we suggest a threshold of 20% disturbance (as defined above) be set for forest practices in all watersheds, and a precautionary threshold of 0-10% be set for HCVFs identified under

HCV4 Q14 – EROSION CONTROL

Figure 14.3 Potential HCVFs defined by FRI polygons which are covered by greater than 50% high erosion potential areas or greater than 75% medium and/or high erosion potential areas.



Question 13. We recommend this threshold also apply with regard to erosion probability.

Stream crossing density – the number of times that roads, trails, pipelines and railroads cross streams – is another potential watershed indicator. Watersheds with many crossings are more likely to have increased erosion, water temperature, angling pressure and temporary or permanent barriers to fish movement. Salmo (2004) recommends a critical threshold of $<0.5/\text{km}^2$ calculated for subwatershed, and target threshold of $<0.32/\text{km}^2$ per subwatershed for the Deh Cho Land Use Planning Area. We suggest a similar threshold is appropriate for HCVFs under Questions 13 and 14 throughout the Canadian boreal region.

Related HCVF questions/areas of possible overlap

- Question 12 – drinking water supplies
- Question 13 – forest areas important for flood control and drought alleviation
- Question 16 – forest areas important for agriculture or fisheries

SUMMARY OF RECOMMENDATIONS

- Include potential cumulative impacts of forest management actions, other land uses and natural disturbances analyses of erosion-prone areas.
- Consider basing an analysis of erosion and avalanche risk on slope angle derived from a DEM.
- Vary management prescriptions depending on the amount of medium and high erosion prone slopes.

LITERATURE CITED

- Archibald, D., W. Wiltshire, D. Morris and B. Batchelor. 1997. Forest management guidelines for the protection of the physical environment. OMNR. 42 p.
- Carignan, R., P. D'Arcy and S. Lamontagne. 2000. Comparative impacts of fire and forest harvesting on water quality in Boreal Shield Lakes. Canadian Journal of Fisheries and Aquatic Science 57:105-117.
- Gonzalez-Bonorion, G. and W. Osterkamp. 2004. Applying RULSE 2.0 on burned-forest lands: An appraisal. Journal of Soil and Water Conservation 59(1): 36-42
- Montgomery, D. 2003. Predicting landscape-scale erosion rates using digital elevation models. Comptes Rendu Geoscience 335 (16): 1121-1130
- Nearing, M., F. Pruski and M. O'Neal. 2004. Expected climate change impacts on soil erosion rates: A review. Journal of Soil and Water Conservation 59(1): 43-50
- Sahin, V., and M. Hall. 1996. The effects of afforestation and deforestation on water yields. Journal of Hydrology 178.293-309.
- Salmo Consulting Inc. 2004. Deh Cho Cumulative Effects Study. Phase I: Management Indicators and Thresholds. Prepared for Deh Cho Land Use Planning Committee, For Providence, NWT. 151 p. Online:

HCV4 Q14 – EROSION CONTROL

http://www.dehcholands.org/reports_cumulative_effects_report.htm.

Wischmeier, W. and D. Smith. 1978. Predicting rainfall erosion losses- a guide to conservation planning. Agriculture Handbook No. 537. US Department of Agriculture, Washington, DC.

Woo, M., P. Marsh and J. Pomeroy. 2000. Snow, frozen soils and permafrost hydrology in Canada, 1995-1998. Hydrological Processes. 1591-1611

METHODOLOGY

Figures 14.1, 14.2, 14.3, 14.4

Sources

- SRTM 90 m Digital Elevation Model. USGS. <http://seamless.usgs.gov/>; Note this dataset was utilized do its availability and widespread coverage. Analysis done on individual tenures should take advantage of the finest scale DEM available for the land base.
- Global Forest Watch Canada. Forest Tenures in Canada.
- Environment Canada & Agriculture Canada. Terrestrial Ecoregions of Canada.

Methodology

- The SRTM 90 m DEM was converted to a grid of percent slope and clipped to the Study Area

(Terrestrial Ecoregions of Canada, Ecoregions 96 and 97)

- The percent slope grid was re-classified to illustrate the erosion risk classes cited in Archibald *et al.* (1997) to create Figure 14.1
- Figure 14.2 illustrates the same grid of percent slope viewed at the scale of the Wawa Forest
- The “hotspot” analysis of the Wawa Forest area was performed using a neighbourhood analysis of the percent slope grid using a circular neighbourhood with a 1 km radius to calculate the mean value at each cell creating Figure 14.3
- The slope grid for Wawa Forest was reclassified to “medium” and “high” erosion potential classes, using the above thresholds. This was done to facilitate the conversion of the grid to a polygon coverage.
- The polygon coverage of erosion potential was then intersected with the Forest Resource Inventory polygons for Wawa Forest, and the resulting layer was used to tabulate the proportion of each stand which fell into medium or high erosion classes. This information was used to symbolize Figure 14.4.