
Establishment of Canada's National Forest Inventory: Approach and Issues

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Abstract.—This paper describes Canada's National Forest Inventory (NFI) sampling design and implementation. It also describes issues related to annualizing the NFI using the approach of the U.S. Department of Agriculture Forest Service Enhanced Forest Inventory and Analysis program as a model. It concludes with an outline of plans to address the inventory annualization issues.

Canada's 10 Provinces and 3 Territories have a forest cover of approximately 418 million hectares, or nearly 50 percent of the country's total land mass. The forests are owned by the 10 Provinces (71 percent), the Federal Government and three Territories (23 percent), and private owners (6 percent). The Provinces and Territories are responsible for forest management, including management inventories. The Federal Government is responsible for the management and inventory of Federally administered forest lands and the compilation and reporting of the National Forest Inventory (NFI).

A new NFI has been designed (Gillis 2001) and is in various stages of implementation in partnership with the Provinces and Territories. The NFI provides accurate and timely national statistics on the extent, state, and changes over time of Canada's forests. This information is expected to support policy development, national and international reporting, and other emerging needs.

Sampling Design

The NFI sampling design is described in detail in the NFI documents available at the web site <http://www.nfi.cfs.nrcan.gc.ca> and published elsewhere (Gillis 2001, Wulder *et al.* 2002). Only a summary is provided here. The target population for the NFI is Canada's land mass, whether vegetated or not. This target

population, and thus the list of sampling units, is assumed to consist of infinitesimal points that are stratified for reporting purposes into 15 terrestrial ecozones (Ecological Stratification Working Group 1996). Ecozones are partitioned into subpopulations called NFI units for estimation purposes. An NFI unit is defined as an ecozone within the boundaries of a Province or a Territory. The partitioning of an ecozone into units is necessitated by differences in sampling schemes and different data collection methods that may otherwise occur within an ecozone.

The overall NFI sampling design is a probability sample of points in Canada, consisting of the following two components:

1. A single systematic sample of points across Canada, with a photo plot installed at each sample point (remote sensing).
2. A simple random subsample of the systematic sample within selected ecozones, with a ground plot established at or adjacent each subsample point (ground sampling).

The photo plots provide the primary source of the NFI data, and the ground plots provide additional information. Local variations in sampling design and data collection methods among the Provinces and Territories are permitted.

The remote sensing component involves a single systematic sample of locations (sampling points) located at the nodes of a national 20 km x 20 km fixed grid over the entire land mass. The grid sample locations are then grouped into ecozones (strata). A 2 km x 2 km permanent photo plot is installed at each sample location (fig. 1). The photo plot is partitioned into polygons or pixels using various classifiers (domains) based on aerial photo interpretation, other remotely sensed data such as the data from the Earth Observation for Sustainable Development (EOSD) project (Wulder 2002), and other data sources. Photo plots are the primary source of the NFI data. Attributes include area, biomass, carbon content, and volume by land cover class in a plot.

About 18,864 planned photo-plot locations exist in the country (table 1). Photo plot data are obtained from aerial photos in about one-half of these locations and from the EOSD data in

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the remaining areas. In the three arctic ecozones and the prairies, only overall area totals (not broken down by classifier) will be obtained. The EOSD data may also be used as auxiliary information in the estimation of areas where both aerial photos and EOSD data exist.

Figure 1.—Example of a 2 km x 2 km NFI photo plot (1:20,000 midscale aerial photograph).



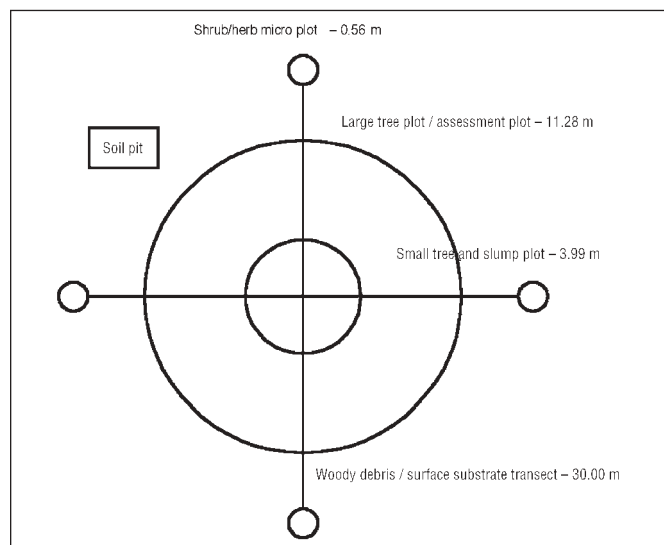
The ground-sampling component involves a simple random subsample of photo plot locations over a Province or a Territory or within an NFI unit. The nominal ratio of forested ground plots to photo plots is 1:10, with a minimum of 50 forested locations per ecozone, and no sampling in the three arctic ecozones. A permanent ground plot is established at or adjacent to the photo plot center, consisting of a cluster of nested circular plots, line transects, and a soil pit (fig. 2). The variables of interest include measurements or descriptions of trees, shrubs and herbs, woody debris, soils, and site. The nominal number of forested ground plots range from 0 to 163 per ecozone and from 0 to 268 per Province/Territory, for a national total of about 1,139 (table 1).

Ground plots are only established in forested locations that are classified as either “Vegetated Treed,” as locations with the potential to be classified as Vegetated Treed, or as locations that have been harvested. Nonforested ground plot locations are tracked over time and plots will be established when these locations become forested. Inaccessible plot locations are replaced with suitable subjectively selected matches, and difficult-access plot locations are subsampled.

Table 1.—Number of planned and outstanding (to March 2004) NFI photo and ground plots by province and territory.

Province or Territory	Photo plots					
	Ground plots		Aerial photos		Satellite imagery	
	Design total	Outstanding (03/04)	Design total	Outstanding (03/04)	Design total	Outstanding (03/04)
Alberta	166	166	1,656	1,656	0	0
British Columbia	268	50	2,414	100	0	0
Manitoba	96	28	950	698	665	482
New Brunswick	19	0	194	0	0	0
Newfoundland and Labrador	40	23	391	234	588	398
Northwest Territory	136	104	0	0	1,945	1,500
Nova Scotia	14	4	141	0	0	0
Nunuvut	0	0	0	0	287	287
Ontario	203	193	1,523	1,123	970	237
Prince Edward Island	2	0	12	0	0	0
Quebec	150	150	1,494	1,494	1,781	1,781
Saskatchewan	45	30	561	219	1,067	600
Yukon	0	0	0	0	1,225	225
Total	1,139	748	9,336	5,524	9,528	5,510

Figure 2.—*Layout of the NFI ground plot (the dimensions refer to plot radius or transect length).*



Implementation

The NFI is an interagency partnership project with decentralized implementation. The Provinces and Territories define the number and distribution of photo plots and ground plots in their jurisdictions, and collect and provide data to the Canadian Forest Service (CFS). The plots are installed and assessed following national photo interpretation and ground sampling guidelines. The program is implemented through bilateral agreements between the Federal Government and the Provincial/Territorial Governments. The Federal Government develops and maintains standards, procedures, and data infrastructure; provides data on Federal land; and conducts data analysis and reporting. The NFI project is coordinated by the CFS with guidance from Canadian Forest Inventory Committee (CFIC), a grouping of forest inventory managers and experts representing the Provinces, Territories, and the Federal Government (CFS, Parks, Agriculture and Agri-foods, and Environment).

To date, approximately 40 percent and 34 percent of the photo plots and ground plots, respectively, covering eight Provinces and one Territory, have been established. A pilot project is underway in one Province, and planning activities are ongoing in two Territories. The NFI plot establishment phase is expected to be completed by December 2006, allowing for a remeasurement to start in 2007.

The NFI plot establishment activities (over 5 years), including design, data collection, and systems development and management, are estimated to cost CAN\$13.7 million. The annual maintenance, including remeasurement, systems management, compilation, analysis, and reporting, is estimated to cost CAN\$2.4 million.

Annualization

The first NFI report based on the new design should be completed in 2006. It will include statistical tables and maps for key attributes by terrestrial ecozone. The key attributes include those identified by the CFIC and related to the Canadian Council of Forest Ministers Criteria and Indicators reporting. To meet the NFI objective of providing information in a timely fashion, annual NFI reports will be produced that also include estimates of change over time. The following issues related to annualizing Canada's NFI in a cost-effective and statistically defensible way must be addressed:

1. **Re-inventory sampling strategy.** How applicable to the NFI is a rotating panel model, such as that of the Enhanced Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture Forest Service? What are the implications of adding more plots or variables at a later time? How do we capture changes due to disturbances in the population over time?
2. **Plot remeasurement.** Can remeasurement intervals be varied by geographic areas (e.g., North versus South)? Is it acceptable to measure only some attributes in only some plots? How will remeasurement of destructively sampled plots (e.g., microplots clipped for shrub/herb biomass measurement) be performed?
3. **Change estimation.** How applicable is FIA's moving average estimator to our NFI? Should growth models, the Kalman filter, or other mode-based estimation be incorporated into the estimation? What is the impact of changes in strata definitions and boundaries over time on the estimation? What is the best procedure for estimation in NFI units with few plots or no plots?

These and other questions were discussed at a 2-day CFS workshop in Victoria, British Columbia, in March 2004. Workshop participants included biometricians from the FIA program, the CFS scientists and NFI staff, and representatives from the Provinces and Territories. The workshop concluded with several options and recommendations for consideration by the CFIC at its next meeting in June 2004 in Dawson City, Yukon. Methods for photo plot and ground plot remeasurements will then be developed in the light of the recommendations from the CFIC.

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