Forest inventory update in Canada

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Modern forest management presents ever increasing demands for accurate and up-to-date forest inventory information. The process of inventory update is critical. Inventory update in Canada is examined including update for harvest, burns, insect and disease, silviculture, roads and other changes. The magnitude and requirements of the update task are documented. The procedures used are described and summarized by province in table form. Usage, advantages and disadvantages of current methods (e.g. conventional 9×9 aerial photography, supplemental aerial photography, satellite imagery, and aerial reconnaissance) are examined, new methods discussed and trends highlighted. Also outlined are issues related to the incorporation of silviculture and insect and disease information into inventories and the structure and responsibilities for update.

Key words: forest inventory, inventory update, harvest, burns, insect and disease, blowdown, silviculture, aerial photography, satellite imagery, Global Positioning System, aerial reconnaissance, video

La gestion forestière moderne fait des demandes qui vont toujours en s'accroissant pour que l'information des inventaires forestiers soit exacte et à jour. Le processus de mise à jour de l'inventaire est donc crucial. Cet article examine les mises à jour de l'inventaire au Canada, incluant celles dues à la coupe, aux insectes et maladies, à la sylviculture, aux routes, et aux autres changements. On y documente l'ampleur et les exigences de ces tâches. Les procédés utilisés sont décrits et résumés par province sous forme de tableaux. L'utilité, les avantages et désavantages des méthodes actuelles (p.ex., photographies aériennes conventionnelles 9×9, photos aériennes supplémentaires, images satellitaires, et reconnaissances aériennes) sont examinés, de nouvelles méthodes sont discutées et les courants actuels sont présentés. De plus, certains points saillants reliés à l'incorporation dans les inventaires d'information relative à la sylviculture et aux insectes et maladies; et, à la structure organisationnelle et aux niveaux de responsabilité requis pour ces mises à jour sont aussi abordés.

Mots clés: inventaire forestier, mise à jour, coupe, brûlis, insectes et maladies, chablis, sylviculture, photographie aérienne, image satellitaire, Système de positionnement global, reconnaissance aérienne, vidéo

Introduction

The management of Canada's forest land is primarily a provincial responsibility. Information on the nature, extent, location and condition of the forest is required for effective management. The provinces develop, compile and maintain a forest inventory database to support their management responsibility. The typical forest management inventory in Canada is a stand level inventory. Aerial photography is used to stratify the land base into homogeneous units/stands/polygons. These units are classified and sampled to provide descriptive information and volume sample data. A typical forest management inventory database contains maps, usually stored in layers (e.g. cartographic base, vegetation, administrative layer), the related descriptive attributes (e.g. species composition, age, height, and stocking to describe a forested unit on the vegetation layer), volume estimates, and derived information such as environmentally sensitive areas and operability.

The forest inventory is used to derive a status statement of what is there. It is also used to describe an initial state as the input for future predictions or as a base against which to evaluate management prescriptions. The provincial forest management inventory is used at the stand, management unit, region, provincial and national levels for operational, management and strategic level planning.

Fire, insect and disease infestations, pollution, changes in climate, and human intervention through harvesting and reforestation activities are among the many factors that impact and contribute to change in the extent, structure, health and productivity of Canada's forests. Knowledge of expected and unexpected changes in the forest, as a result of these factors, is critical to continuous and adaptive forest management. As changes occur, they need to be detected and the inventory updated to accurately reflect the current status.

Inventory update may be defined as the process of detecting, collecting, and adding changes to the inventory resulting from disturbances causing depletions (e.g. harvest operations, forest fires), as well as changes to the forest causing accretions (e.g. silviculture operations and forest growth). There are basically two sources of update information: those that can be observed and mapped and those that must be sampled (e.g. remeasurement of permanent sample plots) or modeled in the information system. Changes that can be observed and mapped commonly have clearly defined boundaries and result from human (e.g. harvest, planting) or natural disturbances (e.g. fire, epidemic insect damage). Changes that must be sampled or modeled are usually a result of natural processes such as natural regeneration, growth, compositional change and effects of endemic insects and diseases, and have poorly defined boundaries.

Update information is required for operational, management, and strategic level planning and for reporting purposes; but, for each purpose the update information required, and its resolution and timing, differs. For example, operational planning requires precise site specific observations of change, while management and strategic level planning and reporting require

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both site specific observations of change and changes that must be sampled or modeled and then often extrapolated over entire forest strata or management units. A number of new forces are having an impact on forest inventory. Changing social values (e.g. public expectations, interest and involvement in land and resource management decisions), new government initiatives (e.g. timber supply reviews, new forest practices legislation), and increased use of inventory to provide information to assess environmental issues and non-timber uses of the forest, have all contributed to an increased need to have more accurate, reliable and timely inventory information. This has resulted in more emphasis being placed on inventory update.

Update of a stand level inventory involves both mapping of observed changes and modeling of natural processes. Updating the inventory for natural processes such as growth, stand development and mortality is recognized as a major component of the update program but is beyond the scope of this report. This report examines how stand level inventories in Canada are updated for changes that can be observed and mapped. The report describes the nature and magnitude of the inventory update task, discusses specific requirements in terms of detail, accuracy and timing, outlines the update procedures employed in provincial stand level inventory systems (i.e. who does it, when it is done, how it is done), and concludes with a discussion of current update methods (including data sources), new methods being examined, trends, and some remarks on the relationship between silviculture and insect and disease information and inventory information.

Nature of Problem

In Canada there are 344 million ha of forest land for which management level inventory systems are being maintained. These systems contain 37,792 separate map sheets and databases of approximately 14.4 million forest stands (Table 2) (Leckie and Gillis 1995). Continually there are man-caused and natural disturbances to the forest ecosystem resulting from harvests, burns, blowdown, insects and diseases, silviculture treatments, roads and other infrastructure changes, and land use change. These must be detected, documented and accounted for in the inventory (i.e. inventory update) to support an up-to-date management planning process.

From 1990 to 1992 there was on average 902,120 ha harvested each year (Table 1). Many thousands of cutblocks need to be accounted for each year. For example, British Columbia had between 4000 and 5000 cutblocks in 1992, Alberta averaged 2720 cuts per year from 1990 to 1992, and Newfoundland typically 500 per year. Even a small province such as New Brunswick has approximately 1400 cuts per year; this number has approximately doubled since the early 1980s as individual cutblock size has decreased.

Most new roads that need to be added to the inventory are associated with harvesting operations. There can be hundreds of new roads developed annually in any one province. Ontario, for example, reported that almost 2000 km of new roads were built in 1993, BC 711 km, PEI 90 km and Alberta typically has approximately 1500 km and 300 new roads per year. New Brunswick had 260 new roads but Saskatchewan only three in 1993. There are also a significant number of new seismic lines cut each year in Alberta and British Columbia that need to be mapped and added to the inventory.

There are on average 8,000 to 10,000 fires each year in Canada. All detected fires are documented, and the location and approximate size are recorded. Fires over a minimum size (e.g. 4 ha) are usually mapped and accounted for in the provincial management inventories. An average of 1000 fires over 4 ha in size burn approximately 675,000 ha each year in the provinces. The large number of fires smaller than the minimum size are not accounted for in the inventory. The average area burned, the total number of fires for the years 1990 to 1992, and the number of fires greater than 4 ha in active fire control zones are listed by province (Table 1). Although the area of management inventory does not exactly coincide with the zones of active fire control, this latter number gives an approximate indication of the number of burned areas that need to be updated.

Blowdown can vary from a few isolated trees to significant swaths of damage in the case of tornadoes and winter wind storms on coastal British Columbia. Scattered damaged trees often go unreported or undetected. When significant damage within concentrated areas occurs, the blowdown is usually detected by reconnaissance from light aircraft, documented (i.e. mapped) and the potential volume loss is usually salvaged. When there is salvage logging, the blowdown may not get entered into the inventory; rather the change is recorded as a harvest depletion. The areas and numbers of blowdowns recorded are usually not large (e.g. Alberta typically might update 100 ha in two blowdown areas).

The area surveyed each year for insect and disease damage can be quite large and fluctuate tremendously. There is a constant requirement to detect new outbreaks as well as to monitor existing infestations. For example, in Ontario the area of moderate or severe defoliation by the spruce budworm in the 1980s ranged from a high of 18 million ha in the early 1980s to 5 million ha in 1988. Similarly, the affected area ranged from 16 million ha to 400,000 ha in Quebec. In British Columbia, near the peak of a mountain pine beetle outbreak, there were approximately 300,000 ha of recent mortality in over 9000 separate infestations (Kondo and Taylor 1986). The actual mapping and quantifying of these changes also varies tremendously. Values shown (Table 1) give an average total area per year of insect and disease damage recorded for the provinces.

A large area undergoes silvicultural treatment each year (Table 1). On average for the years 1990 to 1992, 399,330 ha were site prepared, 443,120 ha planted, and 366,200 ha tended or thinned each year. These involved operations on many individual areas. For example, in Alberta in a recent year there were 1600 areas site prepared, 1365 planted and 45 tended, while in BC the numbers of treated areas were 5520, 7060, and 2270, respectively. Different jurisdictions record and account for silviculture activities differently. It is common for activities to be tracked through separate silviculture information systems and not accounted for in the management inventory system. Regardless, activities are usually mapped and documented at the local (District) level and at least summarized at the Provincial level.

There are tens of thousands of changes to the forest landscape per year that need to be detected, mapped and added to the inventory. The location of planned activities (i.e. cuts, roads, and silviculture activities) are known and detection is not a problem. In the case of burns, detection is handled by well organized fire management and suppression infrastructures. The

Table 1. Magnitude of change data for inventory update of harvesting, fires, insect and disease, and silvicultural activities (areas are in hectares)

Item	Province									
	BC	AB	SK	MB	ON	PQ	NB	PEI	NS	NF
Harvesting ¹										
Total area/year	198,706	47,700	17,417	10,093	209,478	267,252	91,690	2,319	36,925	20,538
Clearcut	177,151	42,000	17,417	10,093	186,732	215,415	68,975	1,116	36,313	20,538
Partial cut	21,555	5,700	—	—	22,746	51,837	22,715	1,203	612	—
Burn ¹										
Total area/year	45,714	13,345	174,574	196,000	226,190	182,928	4,946	88	1,335	38,043
Number of burn areas	3,028	1,091	787	514	1,712	944	536	38	510	157
Number of burn areas >10/ha in Fire Attack Zones ²	100	56 ³	42	52	38	26	17	1	7	7
Insect and Disease										
Total area/year ⁴	112,998	614,034	127,434	76,143	293,120	469,310	196,000 ⁵	11,750	4,140	19,515
Silvicultural Activities										
a. Regeneration										
Area planted/year ¹	185,295	32,867	6,105	7,153	78,8500	100,216	19,367	1,009	8,975	3,283
Area natural/year	—	—	—	—	47,900	95,750	—	—	—	—
b. Site preparation										
Area treated/year ¹	141,770	32,154	8,093	6,366	101,654	85,900	13,659	1,265	5,709	2,765
c. Tending ⁶										
Area treated/year ¹	79,920	1,767	1,269	464	81,526	50,409	30,738	8001	9,008	1,637
d. Thinning										
Area thinned/year ¹	38,290	778	193	359	15,119	26,902	14,781	416	4,057	7,765

Note: Missing data either indicates data was not compiled for this report or not available.

¹Three-year average (1990–1992). Source: National Forestry Database (CCFM 1994).

²Number of fires > 10 ha in size within the area of active fire control averaged over 1992 and 1993. Derived from forest fire statistics compiled at the Petawawa National Forestry Institute.

³For both the Fire Attack and Observation Zones.

⁴Area of moderate to severe defoliation and beetle-killed trees, three-year average (1990–1992). Source: National Forestry Database (CCFM 1994).

⁵From New Brunswick Department of Natural Resources and Energy records.

⁶Includes manual, chemical and mechanical weeding and clearing, fertilizing, pruning, drainage, site rehabilitation, mistletoe control and improvement cutting.

detection of insect and disease damage is more problematic, but between the Forest Insect and Disease Survey (FIDS) of the Canadian Forest Service, provincial insect and disease branches, and local field knowledge, most new outbreaks are detected early and known outbreaks are closely monitored. There is no systematic procedure to detect blowdown damage. Detection relies on local knowledge and routine reconnaissance.

Changes do not occur over all the land base (i.e. on each map sheet) each year. Therefore not every map sheet needs to be updated every year. An estimate of the number of map sheets that need to be updated to reflect change activity is provided (Table 2). Requirements are variable, from 10 or 15% to 75 to 80% of the map sheets of a province. On average, approximately one third of the inventory maps need to be updated each year to reflect change activities.

Considerable expenditure of dollars and personnel resources is related to detecting, documenting and adding changes to the provincial management inventories. For example, Saskatchewan, which acquires its own supplemental aerial photography, spends approximately \$125,000 yr⁻¹, \$38,000 on photo acquisition. Quebec spends \$500,000 yr⁻¹ on update photography alone. Alberta, between its annual "Spring Cutblock" mapping and "Land Use Update Program" for roads and land use changes, spends in total \$350,000 yr⁻¹ (\$150,000 on photography). Resource commitments from companies can be large as well. For, example E.B. Eddy Forest Products Ltd. (Espanola, Ontario) spends approximately \$5-6000 on aerial photography yr⁻¹ to update activities on their two management units (12,800 km²). J.D. Irving Ltd. in New Brunswick spends \$60,000-\$80,000 annually for photography and dedicates

approximately 1.7 person years to update forest inventory maps for the 1100 change activities (700 cutblocks) occurring on lands on which they operate.

Inventory Update Requirements

There are several aspects to the requirements for inventory update:

- required cartographic (mapping) accuracy and acceptable errors of omission or commission
- required detection accuracy (minimum levels of disturbance to be detected and mapped)
- frequency and timing (i.e. how often and how soon is update information required)

These requirements are based on forest management planning needs, reporting obligations, established practice, capabilities of available technology, and budgets. Requirements may also vary depending on the type of change being recorded and land tenure (management responsibility). In many cases no definitive requirements have been set.

Cartographic Accuracy

The stated requirements in terms of placement of change activity boundaries on the base map are generally in the order of 20 to 25 m. These requirements are similar to the accuracy of the original forest cover map and reflect a desire to keep the accuracy of the updated information consistent with that of the original map. In addition, it is generally accepted that for forest management purposes, boundaries of forest stands

Table 2. Nature and distribution of change data by province

Item	Province									
	BC	AB	SK	MB	ON	PQ	NB	PEI	NS	NF
Inventory area (000,000 ha) ¹	93.43 ²	38.60	15.88	40.56	59.26	73.08	7.10	0.58	5.31	10.16
Number of mapsheets	7484 ²	4145	1696	4300	10,565	3300	1889	212	2307	1894
% mapsheets each year where a change activity occurs	35 25	30 7	10–15 7	— —	— ³ 10	35 25	— 35	— 87 ⁴	30 —	75–80 —
Concentrated/scattered ⁵	S	C	S	—	—	S	S	S	S	S
Usually follow stand and boundaries	—	No	Yes	—	No	—	No	No	No	No

¹Source: Forest Inventory Mapping Procedures Across Canada (Gillis and Leckie 1993).

²Includes Tree Farm Licences and parks.

³Mapping of change activities takes place at a local level. There are no definite figures available at the provincial level on the percentage of mapsheets affected or the concentration of activities.

⁴Four-year total.

⁵The degree to which activities are concentrated or scattered.

should be placed within ± 20 m of their true location (Leckie and Gillis 1995). With the implementation of accurate digital base maps in several provinces (3–10 m accuracy), there is a tendency to want even higher accuracy. In practice, however, expediency in the use of a particular technology (e.g. supplemental aerial photography, satellite imagery) and budgetary considerations sometimes become the overriding factors, rather than the desired accuracy. At this time, many provinces do not have established cartographic standards for mapping change activities.

Acceptable errors in the total area of a particular disturbance are not well established. Some provinces indicate that a 5% error in the area of a disturbance would be appropriate for cutblocks and blowdown, 5 to 10% for burns and 10% for insect and disease. The accuracy of boundary placement for insect and disease damage is also often less stringent than other disturbances. Much of the insect damage information comes from sketch mapping which has poor spatial accuracy because observers cannot be stand specific in their mapping.

A more relevant measure of accuracy may be the error in boundary position relative to stand boundaries and other features such as roads, streams and lakes. This is particularly true for determining volume depletions, relating the actual to planned cutblock boundaries or setbacks, and locating the cutblock in the field.

Therefore in practice, the final placement of the boundary of a disturbance is influenced by current stand boundaries and sometimes, in the case of harvesting, the boundary of the proposed cutblock. For example, slivers are often created when change polygons are added to the forest inventory map (i.e. small polygons are created between the delineated cutblock polygon and the existing stand perimeter when the boundaries are not aligned). These are resolved by various rules:

- merging with adjacent stands (e.g. New Brunswick — merge if the sliver is < 0.25 ha; Saskatchewan — merge if $<$ minimum stand size)
- maintaining new sliver polygons (J.D. Irving Ltd.)

- not creating them [e.g. having actual boundaries follow planned boundaries unless significant differences exist (E.B. Eddy Forest Products Ltd.)]

Removing slivers will result in misplacement of a change boundary and subsequent errors in area determination.

Detection Accuracy

The requirement to detect subtle or small changes due to harvesting is generally stringent. Three provinces require all cutting operations to be recorded, while the remaining provinces desire all cuts greater than 1 to 3 ha to be updated. Practical considerations, however, sometime override the requirements. For example, Saskatchewan maps cuts > 1 ha, but cutblocks between 1 and 4 ha are delineated and updated only if a label can be placed within them. If not, they are not delineated. Most provinces require partial cuts (selected trees cut or retained) to be recorded regardless of the amount of trees removed while some do not have established standards. Where partial cutting is not common (e.g. Manitoba and Newfoundland), the province does not update for partial cuts. However, partial cut areas would be delineated and interpreted during the next reinventory. Quebec identifies and maps a change if 25% of the tree cover (crown closure) has been removed. Partial cuts, especially those with a small number of trees removed, are difficult to detect and delineate. In certain cases the planned cutblock boundary must be used as the final boundary. This can lead to errors as only pockets within the planned area may have been cut or the boundary is different from that planned. The requirement to identify the level of partial cut varies from just labeling the area as partial cut (PC) to adding a new stand description (e.g. from a ground estimate or air photo interpretation).

There is a requirement to update the inventory for roads. This generally includes all new forest access roads (e.g. primary/permanent access, secondary/non-permanent trail access). Third level access roads (e.g. skid trails) are not usually mapped. In British Columbia, where up to eight classes of roads

are mapped, skid trails are initially mapped. These trails deteriorate over time and are then removed from the map.

The minimum size of burn that is detected and updated varies from one to 20 ha. Generally all burns over these sizes will be mapped regardless of intensity. In some cases ground fires with minimal damage to trees will not be updated. Quebec again requires a 25% loss in tree crown cover before updating. Most provinces indicate a level of burn (most indicate either burn or partial burn). New Brunswick has three classes dependent on the volume remaining and Alberta has four classes based on % loss of crown closure. These four classes can be applied to any disturbance (burn, insect and disease, blowdown, partial cut).

Blowdown is not considered a major update issue. Nevertheless it is considered desirable to update for blowdown areas greater than one to five ha. Most provinces just ascribe a disturbance code designating blowdown to the area delineated. Alberta and Quebec, however, give complete stand descriptions. In practice many blowdown areas are logged and incorporated into the inventory as a cutblock and thus are never updated as a blowdown.

The requirements for insect and disease damage assessment are driven by the need to monitor forest condition (i.e. to detect new outbreaks and to monitor the spread and severity of existing infestations). Three types of damage may be distinguished and mapped:

- current defoliation: Depletion of current year's foliage identified in classes based on amounts of red discolouration (e.g. eastern spruce budworm (*Choristoneura fumiferana* (Clem.)), jack pine budworm (*Choristoneura pinus* Free.))
- cumulative defoliation: Loss of foliage, often accumulated from several years of current defoliation
- mortality: Total loss of foliage; but in the case of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) a red or yellow discolouration also indicates mortality.

Hardwood defoliation [e.g. gypsy moth (*Lymantria dispar* L.), or forest tent caterpillar (*Malacasoma disstria* Hbn.)] may result in complete leaf loss, but there could be complete recovery, in the same year in some cases.

Damage areas are usually classified as to the level of damage (light, moderate and severe) with light, for example, representing the minimum visible defoliation (commonly 30% for spruce or jack pine budworm current defoliation). In most cases detection of small damage areas is not important especially once an outbreak has started. But there are cases such as root rot and mountain pine beetle surveys for sanitation cutting where recording small or even single affected trees is important. Newfoundland maps and discriminates four classes of mortality caused by the hemlock looper and budworm (11–25%, 26–50%, 51–75% and 76–100%) as part of its inventory update. However, most provinces do not incorporate insect and disease damage changes in their update mapping.

The requirements to survey and map silvicultural activities are driven by the need to determine if contract specifications have been met (i.e. for payment), and to monitor the results of treatment to ensure proper conditions and regeneration success. Various types of surveys are conducted including those done prior to harvest to establish cutblock boundaries, immediately following harvest to determine reforestation treat-

ment (e.g. site preparation, planting design), at establishment to assess planting quality or to assess adequacy of natural regeneration, following planting/natural regeneration to assess survival and to determine maintenance requirements, following maintenance treatments, and finally to 'sign-off' a silviculture area as satisfactorily stocked, free-growing or free-to-grow (i.e. having met predetermined conditions with respect to species, stocking (stems ha), height, and competing vegetation). Large amounts of information are collected and stored in silviculture information systems. Some of these systems are linked to the management inventory system, but most are not. Silviculture information is problematic in terms of inventory update. Much of the information collected and stored in silviculture information systems is not important from a pure inventory point of view. In most provinces cutblocks are delineated and incorporated into the inventory, but information gathered from silviculture surveys and treatments (e.g. new treatment boundaries and descriptions) does not usually get added to the inventory. This information may, however, be used to help assign a full stand description at the time of reinventory.

Frequency and Timing

Inventory update is driven by three main factors: the need to have up-to-date information at the local level to make management decisions, a desire to keep the provincial inventory as current as possible, and a desire, regulatory requirement or legislative demand to report changes in the forest base on an annual or other basis.

The requirements for reporting changes of various types (Table 3) include the period for which changes are reported, the date on which they are to be reported, who is ultimately responsible for providing the information, and whether the reporting is required by legislation, regulation or established practice. Most provinces have a requirement from regulation or legislation to report changes on an annual basis. Some report changes that occur over the fiscal year (1 April–31 March). The period for reporting is flexible and in practice is the date on which photography is flown (which often is well past 31 March). In the case of Newfoundland, imagery is acquired in August and September after most of the cutting operations are completed and also when insect caused defoliation is complete for that year. This effectively becomes the reporting period for cutblocks, burns and insect and disease mortality level. The time delay for reporting changes is also variable, generally from five to 18 months. In some cases it is sufficient to record and map changes at the local level and to only report changes in summary form to the headquarters or provincial level. In other provinces the changes must be incorporated into the provincial inventory maps and database at the reporting date or shortly after. Silvicultural records are often reported only in tabular form.

Alberta has two update programs, an annual update of cutblocks and burns and a five-year land use update for roads, trails, pipelines, seismic lines and agricultural and industrial clearings. British Columbia updates all map sheets on a two year cycle. Prince Edward Island does not update its inventory annually but at interim times between reinventories. Nova Scotia incorporates update information in the inventory through a series of projects (e.g. of several counties at a time) as resources permit. Other provinces do not have a formal update

Table 3. A summary of provincial requirements for collecting and reporting forest change data

Province	Primary use of change data ¹	Reporting period	Reporting date	Reporting responsibility	Reporting requirement
BC	Inventory maintenance Timber supply analysis	2 year	Nil	Crown	Practice
AB	Inventory maintenance Silviculture treatment	April–March	—	Company/Crown	Regulation
SK	—	April–March	—	Company/Crown	Regulation
MB	—	—	—	—	— ²
ON	Management plan	5 year	—	Company/Crown (District)	Regulation
	Annual report	April–March	April 15 ³	Company/Crown	Regulation
PQ	Management plan	April–March	September 1	Company/Crown	Regulation
NB	Management plan	April–March	July 31	Company/Crown	Legislation
PEI	Management plan Verify volume estimate	5 year	Nil	Crown	Legislation
NS	— ⁴	Nil ⁵	Nil	Crown	Practice
	Planning	April–March	Nil	Company	Practice ⁵
NF	Inventory maintenance Timber supply analysis	Sept.–August	May ⁶	Crown	Regulation

¹Primary use (e.g. management planning, verification, inventory maintenance).

²There is a requirement to report forest management activities on an annual and five-year basis. There is no requirement to map these activities.

³15 April for all change data except cuts and burns which are reported by 15 November, seven months later.

⁴Inventory updated periodically in large blocks as resources permit.

⁵Forest companies operating on Crown Land are required by regulation to report forest change activities.

⁶There is a lag period of 1.5 years between reporting period and reporting date.

program. In these cases, although the inventories may be updated at the district level for management planning purposes, there is no updating of the official inventories at the headquarters level. The inventories become updated at the time of reinventory.

It is almost invariably the ultimate responsibility of the provincial forest agencies to report the changes. However, the responsibility for detecting and reporting change activity is often incorporated into the tenure agreements of forest companies.

Inventory Update Procedures

The procedures used by each province and often different districts and companies within each province vary. However, in many provinces standards and data sources are prescribed. Responsibilities are partitioned or shared among the provincial forest agency headquarters and districts, and the forest industry companies. An outline, for each province and category of change (i.e. harvest, fire, insect and disease, and other features), of the methods (source data and transfer equipment) and the responsibilities for various functions or steps of the inventory update process is provided (Tables 4, 5, 6 and 7). The following sections summarize the general procedure for each of these cases, highlighting exceptions or typical examples.

Harvest

A typical scenario might be that between mid-January and the end of March, district offices provide the Inventory Section at provincial headquarters with the location of all harvest activities for the year. These are known from management plans and local monitoring of logging operations. Generally a 1:50,000 to 1:250,000 scale National Topographic Series (NTS)

map is provided outlining the approximate location of each cut. These maps are then used as a basis for contracting aerial photography coverage or, in the case of Saskatchewan, setting up flight plans for acquiring their own photography. Large companies will also provide the locations of their cutting operations or undertake a similar procedure for contracting photography separately. By March all activities will have been placed on maps and the photo acquisition ordered (contracted). It is generally advantageous to coordinate aerial photography contracting centrally so that a better price can be obtained. For example, New Brunswick and Alberta each coordinate photo acquisition on behalf of most of the large licensees in their province. The cost of photography can also be shared between companies and the Crown (e.g. E.B. Eddy Forest Products Ltd. and Espanola District Office of Ontario Ministry of Natural Resources).

Conventional 9×9 aerial photography is by far the most common data source. It is generally acquired at the scale of the inventory photography and maps. Panchromatic black and white film is the most cost effective. Saskatchewan and Manitoba as well as some districts in Ontario and British Columbia use supplemental aerial photography (SAP) in 35 or 70 mm format. Such photography is acquired at smaller scales (e.g. 1:40,000) than the inventory map and then photographically enlarged to the mapping scale. In general there has been a trend towards less use of SAP in favour of conventional aerial photography. This is due to the need for local/in-house expertise, increasingly scarce resources for conducting the photography and generally better results from the 9×9 photography. However, SAP is still an effective tool especially where expertise and

Table 4. Summary of update procedures employed in provincial forest management inventory systems (harvest)

Methods				Functions ¹									
Prov- ince	Data Source	Format	Time of data collection	Transfer method	Change		Order imagery	Receive source imagery	Interpret/ delineate boundaries	Transfer	Digitize	Update attributes	Confirmation
					Identification	Imagery							
BC	Photography	Varying scales 9×9 70 mm B&W	Spring/ Summer	Mono Restitution	D		R	D	D	D	D	D	No
	Ground traverse	—	—	Sketchmap, epidiascope			H	H	H	Contractor	H	C	
	Satellite images	Landsat TM 9×9 transparency; 1:100,000; bands 3,4,5	Summer	Procom				Contractor	Contractor	Contractor			
		Landsat TM digital-precision geocoded		On-screen digitizing									
		SPOT panchromatic transparency; 1:500,000		Procom									
GPS		—	—	Digital									
AB	Photography	1:20,000 and 1:15,000 9×9 B&W infrared	Spring	Map-O-Graph	D		H	H	H	H	H-drafting	H	R
		1:40,000 enlarged to 1:12,500 70 mm	Spring/ Summer	Sketchmaster	C		H ²	H	H	H	H	H	No
MB	Photography	1:30,000 9×9 B&W	—	Procom	D		D	D	D	D	— ³	— ³	—
		35 mm enlarged to 1:15,840 35 mm enlarged to 1:20,000 B&W; 1:20,000; 9×9	—	Sketchmaster Sketchmaster	D		D ²	D	D	D	D	D	—
ON	Photography	Landsat TM 9×9 transparency 1:15,000 9×9 B&W	Spring/ Summer	Procom Sketchmaster	D		H	H	D	H	H-drafting	H	No
	Satellite images	1:12,500 9×9 B&W	Fall, spring, winter	Sketchmaster	C		H	H	C	C	C	C	R
PQ	Photography	1:24,000 9×9 B&W/colour	Summer	Light table	H		H	H	H	H	H	H	—
		SPOT 9×9 transparency; 1:500,000; bands 1,2,3 Landsat TM 9×9; transparency; 1:500,000; bands 2,3,4	Summer	Procom	—		H	H	H ⁶	—	H ⁷	H ^{6,7}	No
NS ⁵	Satellite images	Landsat TM 9×9; transparency; (90%) 1:500,000; bands 3,7,4 SPOT 9×9 transparency (10%)	Summer/ Fall	Procom	H		H	H	H	H	H ⁸	H ⁸	No

¹Responsibilities for each function include: H, Headquarters; R, Region; D, District; C, Company/Licensee; Contractor.

²Acquire supplementary serial photography (SAP) in-house.

³Harvest depletions, fire maps and silviculture information is recorded and maintained at Regional offices.

⁴Only clearcuts are updated.

⁵Applies to clearcuts only. Partial cuts are transferred and digitized from maps provided by District. Boundaries of partial cuts come from traverses acquired by District staff during cut inspection.

⁶Interpretations are cross-referenced with maps of cuts provided by the Districts.

⁷Update information is acquired on a project basis (usually several counties at a time).

⁸Treated as a soft update (change information is maintained in a separate layer and only incorporated with the inventory on special request).

Table 5. Summary of update procedures employed in provincial forest management inventory systems (Fire)

Methods				Functions ¹								
Prov- ince	Data Source	Format	Time of data collection	Transfer method	Change Identification	Order imagery	Receive source imagery	Interpret/ delineate boundaries	Transfer	Digitize	Update attributes	Confirmation
BC	Photography	Varying scales 9×9 70 mm B&W	Spring/ Summer	Mono restitution	D	R H	D H	D H Contractor	D H Contractor	D H Contractor	D H C	No
	Ground traverse	—	—	Sketchmap, epidiascope								
	Satellite images	Landsat TM 9×9 transparency; 1:100,000; bands 3,4,5	Summer	Procom								
		Landsat TM digital-precision geocoded		On-screen digitizing								
		SPOT panchromatic transparency; 1:500,000		Procom								
GPS		—	—	Digital								
AB	Photography	1:15,000–30,000 9×9 B&W infrared	Time of fire	Map-O-Graph	H-Fire	H-fire	H	H	H	H-drafting	H	No
SK	Photography	1:40,000 enlarged to 1:12,500 70 mm B&W	Spring/ Summer	Sketchmaster	H-Fire H-Inventory	H ²	H	H	H	H	H	No
MB	Photography	35 mm enlarged to 1:15,840	—	—	D	D	D	D	D	— ³	—	—
ON	GPS	—	Time of fire	—	H-Fire	H	H	H	H	—	D	No
	Photography	35 mm enlarged to 1:20,000 1:20,000 9×9 B&W	—	—	H-Fire D	D ²	D	D	D	D	D	
PQ	Photography	1:15,000 9×9 B&W	—	Sketchmaster	R-Fire agencies	H	H	H ⁴	H ⁴	Contractor	H	No
	Satellite images ⁵	Landsat 1:12,500 9×9 B&W	—	—	H-Fire	H-Fire	H-Fire	H-Fire	H-contract	H	H	No
NB	Photography	—	Fall	Sketchmaster	H-Fire	H-Fire	H-Fire	H-Fire	H-Fire	H-Fire	H-Fire	—
PEI ⁶	Traverse	—	After fire	Sketch onto map	H-Fire	H-Fire	H-Fire	H-Fire	H-Fire	H-Fire	H-Fire	—
NS	Satellite images	Landsat TM (90%) 9×9 transparency 1:500,000; bands 3,7,4	Fall	Procom 2	H	H	H	H	H	H ⁸	H ⁸	—
NF		SPOT (10%) 9×9 transparency										No

¹Responsibilities for each function include: H, Headquarters; R, Region; D, District; C, Company/Licensee; Contractor.

²Acquire supplementary aerial photography (SAP) in-house.

³Harvest depletions, fire maps and silviculture information is recorded and maintained at Regional offices.

⁴Sometimes contractor.

⁵For special cases where there are large areas burnt.

⁶Not an issue, no major fires since 1962.

⁷Not incorporated into the inventory.

⁸Treated as a soft update (change information is maintained in a separate layer and only incorporated with the inventory on special request).

Table 6. Summary of update procedures employed in provincial forest management inventory systems (Insect and Disease)

Methods			Functions ¹										
Prov- ince	Data Source	Format	Time of data collection	Transfer method	Change Identification	Order imagery	Receive source imagery	Interpret/ delineate boundaries	Transfer	Digitize	Update attributes	Confirmation	
BC	Sketchmap ²	1:50,000	Summer	—	D	—	—	D	— ³	— ³	— ³	—	
		1:100,000			FIDS			FIDS					
		1:250,000	Summer	—	D	—	—	H,R,FIDS	— ⁴	— ⁴	— ⁴	—	
AB	Sketchmap	1:15,000–20,000	Summer	Map-O-Graph	D	H	H	H	— ⁴	— ⁴	— ⁴	—	
	Photography ⁵	9×9											
SK	Sketchmap	colour/colour infrared											
		1:250,000	Summer	—	H,FIDS,R	—	—	H,FIDS,R	— ⁶	H	— ⁶	—	
		1:50,000	Summer	—	H-Protection	—	—	H-Protection	— ⁴	— ⁴	— ⁴	—	
		1:50,000	Summer	—	FIDS	—	—	FIDS	H	H	— ⁷	—	
		1:50,000	Summer	—	H-Protection,D	—	—	H-Protection	— ⁴	—	— ⁴	—	
	Satellite images ⁸	Landsat TM digital enhancement		Procom, 35 mm projector	H-Protection,D	H-Protection	H-Protection	H-Protection	— ⁴	—	— ⁴	—	
NB	Sketchmap	1:150,000	Summer	Map-O-Graph	H-I&D	—	—	H-I&D	H-I&D	H-Inventory	— ⁴	—	
		1:50,000	Summer	—	FIDS	—	—	FIDS	— ⁴	FIDS	— ⁴	—	
		1:50,000	Summer	—	FIDS	—	—	FIDS	— ⁴	FIDS	— ⁴	—	
		Landsat TM 9×9 transparency (90%)	Late summer	Procom 2	H,FIDS	H	H	H	H ⁹	H ⁹	H ⁹	H ⁹	—
		1:500,000; bands 3,7,4											
		SPOT 9×9 transparency (10%)											
	Sketchmap	1:50,000 and 1:125,000	Summer, fall ¹⁰	Manual	H,FIDS	—	—	H,FIDS	H,FIDS	H ⁹	H ⁹	—	

¹Responsibilities for each function include: H, Headquarters; R, Region; D, District; C, Company/Licensee; Contractor; FIDS, CFS Forest Insect and Disease Survey.

²If the insect infestation is under active management the BC Ministry of Forests will undertake a detailed survey, otherwise FIDS will do a broad area survey usually on a 1:100,000 map.

³Not added to inventory but is sometimes transferred and digitized under contract for the District or Region insect and disease groups. Sometimes if it is a large input it is added to the inventory at the District level.

⁴Not included in inventory.

⁵Aerial photography is sometimes used for mountain beetle and spruce budworm damage.

⁶The affected area is harvested and mapped as a cut or the infestation and damage is controlled and not included in the inventory.

⁷Used to calculate growth and yield factors for timber supply analysis in timber management planning; not added to the inventory.

⁸A survey using Landsat TM is done every two to three years. This is used to help determine spray blocks by the Protection Branch (headquarters) and salvage logging in the Districts.

⁹Treated as a soft update (change information is maintained in a separate layer and only incorporated with the inventory on special request).

¹⁰Defoliation surveys are done in mid-summer and assessment (mortality) surveys in the fall.

Table 7. Summary of update procedures employed in provincial forest management inventory systems (Other¹)

Methods				Functions ²								
Prov- ince	Data Source	Format	Time of data collection	Transfer method	Change Identification	Order imagery	Receive source imagery	Interpret/ delineate boundaries	Transfer	Digitize	Update attributes	Confirmation
BC	Photography	Varying scales 9×9 70 mm B&W	Spring/ Summer	Mono- restitution	D	R H	D H	D H Contractor	D H Contractor	D H Contractor	D C	No
	Ground traverse	—	Summer	Sketchmap, epidiascope Procom								
Satellite images		Landsat TM 9×9 transparency; 1:100,000; bands 3,4,5		Procom								
		Landsat TM digital-precision geocoded		On-screen digitizing Procom								
		SPOT panchromatic 9×9 transparency; 1:500,000										
		—	—	Digital Map-O-Graph	H	H	H	H	H	H-drafting	H	R ⁴
GPS	Photography	1:40,000 9×9 B&W	Summer									
AB ³	Photography	1:40,000 enlarged to 1:12,500 70 mm B&W	Spring/ Summer	Sketchmaster	C D	H ⁵	H	H	H	H	H	No
SK	Photography											
MB	Photography	Sometimes 35 mm	—	—	D	D	D	D	D	— ⁶	— ⁶	—
ON	Photography	35 mm enlarged to 1:20,000 1:20,000; 9×9 B&W	—	—	D D C	D ⁵ C	D C	D C	D C	D C	D C	—
Satellite images		Landsat TM 9×9 transparency										
	PQ	Photography	Spring/ Summer	Sketchmaster	D	H	H	D	D	H-drafting	H	—
Photography		1:15,000 9×9 B&W										
	NB	Photography	Fall, spring, winter	Sketchmaster	C H	H C	H C	C H	C H-Contract	C H	C H	C R
GPS ⁷												
PEI	Photography	1:24,000 9×9 colour infrared	Summer	Light table	H	H	H	H	H	H	H	No
Satellite images		SPOT 9×9 transparency; 1:500,000; bands 1,2,3										
	NS	Landsat TM 9×9; transparency; 1:500,000; bands 2,3,4	Summer	Procom	—	H	H	H ⁷	H	H	H ⁸	—
		—	—	—								
N/A												

¹Includes roads, trails, rights-of-way for pipelines and power lines, and seismic lines.

²Responsibilities for each function include: H, Headquarters; R, Region; D, District; C, Company/Licensee; Contractor.

³Land use update: roads, seismic lines, transmission lines, and land use changes are updated at least every five years. Areas of high activity are updated on a more frequent basis.

⁴Forests (Regions) add silviculture changes at this time.

⁵Acquire supplementary aerial photography (SAP) in-house.

⁶Harvest depletions, fire maps and silviculture information are recorded and maintained at Regional offices; not added to the inventory.

⁷Road location and boundaries of silviculture activities (primarily spacing).

⁸Interpretations are cross-referenced with maps provided by Districts.

access to provincial or company aircraft are available. Satellite imagery is being used routinely in Newfoundland, British Columbia and Nova Scotia.

Most photography is acquired in the late spring or summer. In New Brunswick leaf-off spring or fall imagery is preferred. This gives better definition of the boundaries of partial cuts and indeed better clues for their detection (e.g. skidder trails are visible). Fraser Inc. prefers winter photography with snow on the ground for better detection and boundary delineation of partial cuts. Photography can also be acquired at different times over the year to evenly distribute the workload on personnel involved in inventory update (e.g. J.D. Irving Ltd. acquired photography for silviculture activities in the fall and for harvest in the spring).

Once photography is acquired it generally takes three to eight weeks to be processed and delivered. Photography is generally received by the group which ordered it, quality checked, documented, sorted and then distributed (from headquarters to districts and companies). A number of copies of the photos may be ordered. For example, copies may be required for provincial headquarters, region and district offices, as well as several for the company (e.g. company's headquarters and district offices). Copies are ordered at the time of acquisition or after the photos have been screened, and only the ones centered on the cutblocks ordered. Interpretation is either done centrally at headquarters or in the districts (Table 4 indicates an even split). In Ontario the large FMA companies are generally responsible for their own interpretation, transfer and digitizing. Fraser Inc. and J.D. Irving in New Brunswick also conduct their own update and provide the digital update maps to the province.

Since the Inventory Sections at provincial headquarters are in most cases ultimately responsible for the inventory and in general are often the only group with adequate GIS capability, the task of digitizing or drafting the final updated map is with headquarters. Attributes are usually entered at the time of digitizing. Some provinces have a formal or informal procedure for confirming change, often involving local field staff. This confirmation would normally occur before boundaries are digitized and added to the inventory. Many provinces, however, do not have a confirmation process. British Columbia, which has digital mapping capability at the district level, will be implementing a continuous inventory update (BCMOF 1995). The update will be done locally and the update files transmitted to Headquarters. Headquarters will conduct a periodic independent audit.

The attributes interpreted and entered for a given change can range from a simple cut designation (e.g. C, clearcut, PC, partial cut) to a complete new stand description. Clearcuts with few residual stems are usually given a cut designation with no description. Assigning attributes to partial cuts can be a problem. The best photography for delineating the boundaries of partial cuts (i.e. leaf-off, black and white) is also the poorest for interpreting residual stand attributes, especially species composition. There are a number of solutions including adding a partial cut designation (PC) to the original uncut stand description, adding a PC without a stand description, and a complete new description with a PC. The descriptions can come from rules of thumb based on what trees are typically removed from a given stand type, a description of stand attributes from aerial reconnaissance, an on-ground description of residual stand

attributes at the time of cutblock inspection, and structured plot surveys within the partial cut area.

Burns

Burned areas are updated using similar procedures. However, in 1/3 of the provinces they are part of a separate process with separate aerial photography and different responsibilities for the various functions (Table 5). The fire management or suppression groups based out of headquarters have a major role in updating for burns in some provinces and are usually involved in at least identifying areas of burn that need to be updated. Generally during fire suppression and immediately following the fire, perimeters are mapped. Sketch mapping, aerial photography and GPS mounted in helicopters are used. When appropriate, this photography is used for inventory update (e.g. Alberta). In other cases, photography at different specifications than that for cutblock updating is used (e.g. New Brunswick acquires aerial photography of the burned areas as a special project of the Fire Branch in the fall). Newfoundland uses Landsat TM or SPOT imagery. British Columbia also makes use of satellite data (mainly Landsat TM imagery).

Fire management groups will often map the blackened area to indicate the fire perimeter. In the case of low intensity fires, the forest stand, especially at the perimeter, may not be destroyed or significantly altered, but would be mapped by the fire management group as blackened area. In such cases, the change boundary reported for forest inventory and the disturbance boundary mapped by the fire management group would be different. The disturbance boundary may not meet the criteria of forest inventory.

The attributes given a burn range from a burn designation with date, to burn with a severity rating, to a number of classes based on residual volume or percent loss of crown closure.

Insect and Disease

Although insect and disease damage is surveyed and mapped in every province, it is not typically added as an update to the inventory (Table 6). The information is used for decisions regarding control programs and harvest scheduling, and sometimes to derive growth and yield factors for timber management planning. Sketchmapping from light aircraft onto 1:50,000 to 1:125,000 scale maps is the most common method of mapping. In most cases this mapping occurs over infested areas. However, when spruce budworm was severe, New Brunswick routinely mapped defoliation over the whole province. Currently with only low levels of budworm, only parts of the province are sketchmapped and reconnaissance aerial observations are done over the rest of the province. The location accuracy of sketch maps is generally poor and it is difficult to relate boundaries directly to a specific stand. In Saskatchewan and Alberta where infestations are commonly smaller and tightly controlled, aerial photography (e.g. 1:15,000 colour) is often used. In addition to the formal surveys, the company and district foresters generally acquire a good sense of damage conditions through local knowledge and reconnaissance flights of their area. This knowledge leads to damage areas being incorporated into harvest operations. The harvested area is then added to the inventory as a cutblock rather than as a damaged stand.

Estimates of growth loss, mortality and risk of future mortality by defoliating insects can be derived by digitizing and

overlying defoliation from successive years. In the case of pine beetle, mortality is mapped using tree colouration. Newfoundland does a mortality estimate using satellite imagery.

Roads and Other

Most provinces update for roads, transmission lines, and seismic lines at the same time and using the same procedures as cutblocks (Table 7). Newfoundland and PEI have no formal update system for roads. Alberta updates its inventory for roads, seismic lines and trails every five years in what is termed the "Land Use Update" using black and white 1:40,000 photography. Approximately 1/5 of the inventory area is updated each year.

Initiatives of company and district foresters are leading to the adoption of Global Positioning System (GPS) methods for mapping roads. Post processing of differential GPS using a permanent station nearby and a mobile unit on a truck is proving to be an effective method. The survey is done during normal travel of the roads.

Roads are generally classified into two to four categories depending on specific engineering criteria (e.g. grade, material, expected life). This information is either acquired from management plans or interpreted from aerial photography. Roads are usually treated as line features in the data base, but in some provinces are polygons. In New Brunswick, for example, if a road is permanent and therefore taking land out of production it is made into a polygon.

Blowdown

Blowdown is normally identified by local reconnaissance flights for other purposes. Occasionally a large blowdown area will be photographed at the same time as harvest operations. Efforts are made to salvage harvest significant areas of blowdown. As a result they are incorporated into the inventory as a cutblock rather than a blowdown.

Silviculture

Silvicultural activities fall into three main categories: site preparation, planting and tending. Detailed information on these activities is acquired at the local level, generally through on-the-ground surveys, and stored in a separate silviculture system. In some cases the inventory can be linked to the silviculture information by including in the inventory, polygons of separate silviculture activities with attributes describing the silvicultural activities in detail.

Site Preparation

A prescription for site preparation is established prior to harvest or during a post harvest inspection (walk through). The site preparation perimeter is usually mapped and recorded by local foresters on the update photography and map or on a "working" inventory map. This boundary is not incorporated into the inventory.

For example, a site preparation survey is a legislated requirement in British Columbia. The site preparation prescription laid out in a pre-harvest silviculture prescription (PHSP¹) is surveyed following the treatment. The results of this survey

must be reported to the district manager within 60 days following treatment.

Planting

The regeneration prescription is prepared usually following harvesting. A survey may be conducted of a harvest area to determine if planting is required, what to plant, where and how much. Update photography is used to guide the regeneration plan. In British Columbia for instance, there is a pre-harvest survey (PHSP) to determine the most appropriate harvesting system for each ecological unit. The manner in which a stand will be harvested, regenerated and tended through time is dictated at this time.

Stand development is monitored through a number of field surveys:

1. *Establishment* — This survey normally takes place at the time of planting to check the quality of work. It can be a formal sampling system or a simple inspection. This usually forms the basis for payment.

2. *Survival* — This usually takes place soon after planting (one-two years) to determine survival. This survey is also used to assess the success of natural or artificial seeding. The results may indicate a need to replant or requirements for maintenance.

3. *Maintenance* — A maintenance survey is conducted around year five to determine stocking and species composition, to assess competition, and to determine the need for replanting, thinning or other tending.

4. *"Sign-off"* — Finally, there is usually a formal survey to determine if an area is sufficiently stocked of acceptable tree species and that those trees are free growing. Sometimes the maintenance survey at five years is used for this purpose.

The use of these surveys varies from province to province (Table 8) and several of the surveys may be combined into one.

There are several scenarios of how planting and regeneration is incorporated in inventories. One simple and common scenario has an area being cut, designated as cutblock, and remaining as cut until reinventory. Another scenario has a block being cut, the cutblock boundary delineated, added to the inventory, and specified as cut (CC or PC) and assigned the year of cut. When the area is planted it is given a PL designation with species planted and year. The boundaries of the cutblock and the plantation are often the same. At the time of the maintenance or sign-off survey the stand attributes are changed again to reflect current conditions (e.g. PL black spruce 90%, aspen 10%, height 2 m. stocking of 80% and age of five years). Normally new polygons would not be created. This stand designation would remain until the area is reinventoried with new photography and photointerpretation. At this time silvicultural records would be used to help the interpretation, especially for age. Any scarification or stand tending would not be recorded in the inventory, although there may be pointers in the inventory database to a history record or the silviculture information system which contains this information.

Problems arise when there are different treatments within the same inventory polygon, for example, if an area is only partially treated (e.g. refill planted or thinned). A single cutblock

¹Legislated requirement for all cutblocks.

Table 8. Summary of monitoring procedures for regenerating stands (natural and plantation) from establishment to incorporation into the provincial management inventory system

Province	Survey				Disturbances resulting in new inventory polygons		Full inventory description
	Establishment	Survival	Maintenance	Sign-off	Added to inventory		
BC	Pre-cut survey to decide forest management prescription for cut block ¹ Planting quality assessment (optional)	Year 1–2 following planting (optional)	Year 4–7 stocking survey ¹ Inventory label is defined	Year 7–15 ¹ Inventory label is defined	Cut Plant Thin	Cut Plant Thin	Sign-off
AB	Pre-cut survey Post cut survey to confirm treatment Planting quality assessment	Year 3 (optional) plantation assessment	Year 4–8 establishment	Year 14 (8–14)	Cut	—	Reinventory
SK	Planting quality assessment	—	Year 3–5	NSR survey ²	Cut	—	Reinventory
MB	—	—	Year 7	— ³	—	—	Reinventory
ON	Planting quality assessment	Year 1–2 (optional — includes assessment for remedial treatment)	Year 5	Year 5–15	—	—	Reinventory
PQ	Plantation density ⁴	—	—	Year 8 (year 10 for natural regeneration)	Cut Plant Thin	Cut Plant Thin	Reinventory
NB	Pre-treatment survey Planting quality assessment	—	Year 5 growth and yield, and remedial treatment	—	Cut Plant Thin	Plantation Thinning ⁵	Reinventory
PEI	Planting quality assessment	Year 1–2 (includes assessment for remedial treatment)	—	Year 5	Cut Plant	Plantation	Reinventory
NS	—	Year 1	Year 4 Year 7	Year 10	Cut	—	Reinventory
NF	Planting quality assessment	—	Year 5 (ad hoc — Plantation only)	Year 8–12 ⁶	Cut	—	Reinventory

¹Legislated requirement.

²Aerial reconnaissance survey conducted of all cutover/regeneration areas at year eight–10 to assign a class of regeneration. Ground surveys are conducted in questionable areas.

³A free to grow survey at 14 years should be in place by 1996.

⁴For natural sites an establishment survey is done year four.

⁵Thinned areas assigned a thinning code; stand description does not change.

⁶Survey of regenerating stands to assign growth classes (also assess stocking).

boundary may be split numerous times (i.e. into small polygons of the different treatments) before it is incorporated back into the inventory. Questions arise as to which polygons get added to the inventory and which ones are combined, or whether all small polygons are combined in the end into one stand type. Most provinces are just beginning to address this situation. Provinces with detailed silviculture information systems in place are maintaining the small polygons of different treatments within the silviculture information system and have not addressed whether they will be combined into one stand type in future.

Stand tending

There is usually a survey before and after a tending prescription. At the time of stand tending such as thinning, new stand attributes may be specified to reflect the change in stocking and species composition. This information would come from a post-tending survey or just the expected results from the treatment. The information is maintained in the silviculture information system or history record but is not usually incorporated into the inventory.

Discussion

The methods used to acquire change information for inventory update purposes can vary by province and within a province. Responsibility for update mapping also varies (e.g. provincial forest district or forest company). Organizations are constantly looking for more efficient and effective methods. The implementation of management inventory on GIS has provided an opportunity to employ new technologies to capture and document change information that are compatible with the digital nature of the inventory database.

The following section examines methods currently being used and new methods being considered to detect and collect changes to the management inventory resulting from disturbances causing depletions. Trends are highlighted. Incorporating changes to the inventory as a result of silviculture activities and insect and disease damage is also discussed. The section concludes with a brief discussion of the organizational structure and other issues surrounding inventory update.

Current Methods

The current methods for updating the inventory include the

use of conventional (9×9) aerial photography acquired at various scales, supplemental aerial photography (35 mm or 70 mm) enlarged to map scale, satellite imagery (transparencies), field surveys (traverses), and aerial reconnaissance and sketch mapping techniques to capture update information (boundary and attribute).

Conventional 9×9 Aerial Photography

Conventional 9×9 aerial photography acquired at the inventory map scale (1:10,000–1:20,000) is the most common method for updating. This source data is the most expensive medium [e.g. in New Brunswick costs are \$83.00 per cutblock (includes stereo coverage of the block)]. The common practice is to photograph only the disturbance (i.e. usually one or two stereo pair(s) is acquired for each cutblock). Approximately the same mapping accuracy as the original mapping can be achieved (in the order of 20 m depending on scale). In practice, however, it may not always be achieved due to poor quality photography and the use of lower order transfer tools (e.g. sketchmaster). In general, the quality of update photography is not as good as the inventory photography. There are tilt problems associated with the update photography (likely due to the aircraft making sharp turns to fly over the site and not waiting for the plane to stabilize before taking the photographs). This media provides the highest detail/detection capability of all methods. The detection and delineation of partial cuts, however, can be a problem. Timeliness is not usually an issue, although bad weather has been known to cause delays in photo acquisition resulting in subsequent delays in annual reporting. The time period from acquisition to receipt of the photographs can pose problems. There is often a desire to receive photographs quickly so that they can be used for other purposes. For example, Alberta requires photographs prior to the summer to plan silviculture activities; so they pre-plan flight lines based on proposed cuts, and then make changes to these flight plans based on the submission of maps with the actual locations of the cuts by the districts. In this way they are able to acquire the photographs early, map disturbances and have the photos available for the summer to plan their silviculture activities. Photo processing of the update photography early in the spring is generally quick as there are fewer demands for photography at this time.

Interpretation of openings is fast and easy, but transfer and digitizing takes time. For example, Fraser Inc. takes six-eight weeks for delineation (not full time); four-six weeks for transferring; and two weeks for digitizing for all updates (typically 400 cuts and 100 silviculture activities). Photography is also the most versatile of the media used for update; it provides the highest spatial detail and is routinely used for other purposes (e.g. silvicultural planning). Because field people are familiar with aerial photography, there is a high demand for the photographs or similar hard copy imagery. Photography also provides a permanent record and means of checking or verifying location, shape and size of change activities. This method could be improved upon by demanding better quality photography and using higher order transfer equipment to transfer change boundaries.

Conventional 9×9 photography is also acquired at smaller scales (1:30,000 – 1:40,000) to cover and map changes over broad areas. This scale of photography is used to map fire perimeters (e.g. 1:30,000 in Alberta) and land use change (e.g. 1:40,000

in Alberta). Small scale photography (1:60,000) is also being examined by Fraser Inc. for updating disturbances on their freehold land in Maine (USA). The chief advantage of such smaller scale photography is cost. Estimates range from 1/3 the cost (comparing 1:40,000 to 1:15,000 in BC) to 1/4 the cost [comparing 1:50,000 and 1:12,500 (Leckie 1990)]. Using appropriate techniques (e.g. analytical stereo plotters) it should be possible to achieve the same order of mapping accuracy as base maps for features with distinct boundaries (5–10 m depending on scale). These techniques are expensive, but there may be a viable trade off between cheaper photos versus expensive transfer techniques. The detail or detection capability is still good; many of the silviculture interpretations can be done at this scale. Mapping of partial cuts will, however, be a problem. The lack of detail results in problems with the detection and delineation of partial cut boundaries and interpretation of residual stand attributes. Timeliness is not likely a problem, although it may be more difficult to acquire small scale photography than inventory scale photos (it requires higher flying altitudes and hence more problems with clouds beneath the aircraft and more costly pressurized aircraft may also be required). The smaller scale photograph also provides a good permanent record of change activity, especially as an overview.

Supplemental Aerial Photography (SAP)

Supplemental aerial photography (SAP) is another method used by a number of organizations to acquire change data for inventory update. Photography is usually acquired in 35 mm format at different scales and enlarged to map scale, but 70 mm format is also used. This medium costs less than the conventional 9×9 map scale photography and can be particularly inexpensive if the agency doing the update has its own aircraft (e.g. Saskatchewan). The photography is acquired at a smaller scale and enlarged to inventory scale. The quality of photography is not as good as conventional photography (due to aircraft attitude and motion, exposure control, and camera quality). This generally will limit the achievable accuracy. The detail or detection capability is generally adequate despite the inconsistent quality of the photography. Timeliness is excellent. This method is under the complete control of the forest agency; it is usually controlled locally so advantage can be taken of openings in the weather to acquire cloud-free photography. Photo processing, especially 35 mm film, is generally quicker than contract 9×9 photography. The enlargement to inventory scale for ease of interpretation and transfer can, however, add a time delay and expense. Access to a plane, usually one with a camera port, is required for this method. Expertise is also required to obtain good quality photos. The SAP is adequate for other uses (e.g. silviculture planning), especially if it is enlarged to map scale, and it provides a good permanent record of the location of change activity.

There is a trend away from using SAP toward contracted conventional 9×9 photography. A number of reasons have been given for switching. These include:

- to obtain better photo quality and improved accuracy with the conventional 9×9 photography
- to free-up scarce staff time to work on other functions
- to reduce the need to have staff with aerial photography expertise

- to reduce the costs and inconveniences of having to run a photo acquisition and enlargement program.

It is generally thought that resources would be better utilized by contracting the acquisition of photography and concentrating staff efforts on interpretation of change activities and describing the residual forest cover.

Satellite Imagery

Satellite imagery is also used to delineate and map change information for update purposes. Satellite imagery (Landsat TM or SPOT multispectral or panchromatic) is usually acquired in transparency or film print format at a scale of 1:500,000 to 1:1,000,000. The satellite imagery is projected to register it to the inventory map at the map scale using a Procom II device. Change activities are interpreted and transferred directly to the inventory map sheet. The cost of image transparencies for Landsat TM ranges from \$1800 for a precision corrected quarter scene (82 km × 88 km) at 1:500,000 to \$2600 for a full scene (184 km × 176 km) at 1:1,000,000². The cost for SPOT data is \$2800 for a precision corrected (multispectral or panchromatic) full scene (60 km × 60–80 km) at 1:500,000². This source data is the cheapest update medium; one scene will often cover many change activities. While the accuracy of this method is still open to discussion, it is certain that this method cannot meet strict requirements for 1:10,000–1:20,000 mapping. The general consensus on the use of satellite data is that it is certainly possible to detect and delineate clearcut boundaries but not to the level of detail nor with the level of confidence required for accurate mapping. Mapping of partial cuts and the interpretation of residual stand attributes are also major problems with satellite imagery. The use of satellite imagery is contingent upon cloud-free imagery being available for the time period desired (e.g. Newfoundland would like one ≤ 10% cloud cover summer image per year). A special device is required to project and register images to allow for the delineation and transfer of change activities onto inventory scale maps. Although the images provide a good overview of activities for foresters, they are not sufficient for many other uses (e.g. planning field activities) and, as such, according to J.D. Irving Ltd., it is not worth the cost to purchase images solely for overview purposes. The images do, however, provide a good record of change activities.

There are a number of miscellaneous issues regarding the use of satellite images for update. High quality, clear satellite data is required to increase the accuracy of boundary line delineation. Previewing the data for quality, however, can be a problem; haze or thin cloud are not always apparent using the current previewing system. It is often necessary to view full resolution and multiband imagery to guarantee freedom from haze or thin cloud. One does not want to pay for the data if there is haze. Ownership of satellite data is another issue. In order to improve overall efficiencies, it is important to share data between provincial agencies and forest companies or among forest companies. Current agreements on the use of satellite data do not accommodate the sharing of data among different organizations. There are concerns about the stability of satellite data both in terms of future availability and consistency

(i.e. wavelengths). Most organizations have examined the use of satellite imagery for inventory update and, while most agree that there may be other applications for this technology (e.g. regeneration monitoring), and that it may be useful as a check on ground based methods, many have not accepted it as an effective update method.

Field Surveys

Field surveys or traverses are another, less common method of capturing change information. These involve a field crew surveying the perimeter of the change area (disturbance) by means of compass and chain methods. The main cost of this method is getting the crew to the field and the time required to physically survey or walk the boundary. Costs are high if a special trip to the site is required for this activity. If mapping can be done during a trip to the site for other purposes it is much more cost effective. The accuracy of this method hasn't been thoroughly tested but is felt to be acceptable. The detail visible or detection capability depends on the type of disturbance and whether the boundary is clearly distinguishable. For example, clearcut boundaries are usually well defined and quite easy to survey from the ground, although residual patches of forest within the clearcut can be time consuming to survey. On the other hand, partial cut boundaries are not always clear and may be very difficult to survey using ground based methods. The timeliness of this method is excellent. A map of the change area is available immediately following the survey. There is no permanent record or visual means to verify the location, shape and size of the disturbance.

Global Position System

Global positioning system (GPS) technology is being introduced to replace the compass and chain field surveys. The accuracies achieved using this method are often better than the accuracy standards for the creation of the original map. The detection capability is to a very fine resolution. As with the field survey, a GPS survey can be done when required. This method requires a GPS receiver, a differential station and post processing of data. As with the traverse method there is a need for some kind of visual confirmation (i.e. photography or satellite image). Problems arise with this method and traditional compass and chain techniques when the boundary of the disturbance is not followed (e.g. going around wet areas) or if the boundary is not well defined (e.g. not mapping all areas of residual or remnant stands). Partial cut disturbances can be quite difficult to map accurately using this method. Practical considerations may be the deciding factor for whether this method is appropriate in any given situation (e.g. does a company or forest agency want to utilize its field staff in this manner? Is the field staff visiting the site for other purposes? Is someone required (by law) to walk the boundary of the disturbance?) For example, in British Columbia there is a requirement to walk and flag the boundaries of all cutblocks prior to harvesting. In this case, GPS could be used to get the boundary of the planned cut. The cost of acquiring the GPS information could then be imbedded in the cost of flagging the boundary.

GPS technology is being used on a regular basis to update road information. Roads that are updated using GPS make good control for later georeferencing of photography, satellite or other imagery.

²Costs as of April 1995.

GPS units mounted in helicopters are also receiving some use to map the boundaries of major changes (e.g. cuts, fires and even some insect damage).

Aerial Reconnaissance

Aerial reconnaissance is a method used by local foresters to monitor activities in their area. It is a critical component for detecting unexpected changes such as blowdown and early problems with insects and disease. For example, foresters with Fraser Inc. annually fly their entire area in a block pattern to assess scheduled harvest blocks, disputed cutblocks and the results of silviculture activities, and to detect recent budworm infestations. Sketch mapping techniques are used to note and map changes. Sketch mapping is also the mainstay of national and provincial insect and disease mapping programs. The costs associated with this method are low. For example, in New Brunswick the cost of the annual spruce budworm defoliation survey is in the order of \$0.0035 ha⁻¹. However, when large areas are involved, expenditures on aerial observation can, nevertheless, be considerable (in northern regions of BC \$60, 000 to over \$100,000 are spent some years). The detail visible or detection capability is very good. The timeliness of this method is also good and does not depend as much on weather conditions as photography, an important feature considering some damage symptoms only last for a few weeks (e.g. budworm). Results using this method are immediate. A major problem, however, is poor geometric accuracy (e.g. damage from most insect and disease surveys cannot be related to the stand level). Experienced personnel are needed to provide consistent and good quality work. This method does not provide a permanent record or means to check results. Some use is being made of video imagery as part of the aerial reconnaissance to provide a permanent record of specific locations of interest for later review.

New Methods

Organizations are continually searching for better ways to capture and document change activities. New technologies that are compatible with the digital nature of the inventory database are being investigated for inventory update. These include digitizing conventional aerial photography, direct acquisition of digital photography (e.g. using digital frame cameras), the use of video cameras, and the use of digital satellite imagery.

Digitized Aerial Photographs

Digitizing conventional photography and using the image as a back-drop to GIS information is a method being considered by organizations whose inventories have been fully implemented on GIS. Conventional aerial photographs are scanned (digitized) to create digital image files. The image files are geometrically corrected (i.e. georectified or orthorectified) to register them to the GIS based forest inventory maps. The perimeter of the change activity is digitized directly ("heads-up" digitizing) from the geo-corrected backdrop image onto the forest cover type layer in the GIS. Image files may also be pieced together to form an image mosaic map. These are useful for visualizing change activities over a larger area or activities that cross more than one photograph.

Low resolution desktop digitizing equipment is inexpensive and digitizing requires a minimal amount of time. Georectification

is an added task in the process, but the transfer and digitizing steps are eliminated. This is a key advantage considering that transfer and digitizing are a large component of the update or any mapping procedure. For example, in inventory map production, labour costs for transfer and digitizing can account for approximately 22% of the overall map production costs [from data of Leckie and Gillis (1995)]. While the accuracy is tied to the geometric correction, accuracies of ± 20 m are consistently achieved using 1:20,000 photography (e.g. E.B. Eddy Forest Products Ltd.). Lower resolution digitizing results in poorer detail. For example, E.B. Eddy Forest Products Ltd. digitizes 1:20,000 scale photography at 150 dpi (dots per inch). The resolution achieved at this scanning rate is 3 to 4 m as opposed to the original resolution of the photograph (20 to 30 cm). However, the resolution remains adequate for mapping clearcuts and new roads. Higher resolution digitizing requires more computer storage and could result in problems with screen real estate (i.e. displaying sufficient area of coverage at full resolution). For example, at the original resolution of 30 cm, only a 300 m $\times$ 300 m area could be displayed at one time on a 1000 $\times$ 1000 screen. The end-to-end update mapping system should be faster than conventional systems using photography in analogue format as the transfer and digitizing steps are eliminated. The photograph provides a permanent record of the change activity, and the digital format provides a good reference to information on the GIS.

This method is similar to what most people are used to; a hard copy photograph is available at high resolution for use in the field (i.e. planning silviculture activities), and a soft copy (digital format) permanent record is available at low resolution as a back-drop to GIS information and for future use. Additional advantages to this method include: the option to orthorectify images, the capability to display multiple layers of other information easily (e.g. stand boundaries, planned cut block boundaries), and the ability to use arcs from the planned cutblock when digitizing the true cutblock boundaries. The potential also exists to use remote sensing techniques (classification algorithms) to automate the procedure. The automatic classification works reasonably well, but requires visual confirmation. This option would be useful where local knowledge is not available.

Digital Frame Cameras

Digital frame camera technology offers advantages similar to those for digitized photographs. Photography is acquired in digital format, geometrically corrected and entered directly as a back-drop to GIS information for heads-up digitizing of change activities. The resolution of the digital frame cameras is not the same as the conventional photograph. This technology currently offers low resolution and narrow swath width. Approximately the same resolution and swath width that was achieved by E.B. Eddy Forest Products Ltd. digitizing their 1:20,000 scale photography (3–4 m), is achievable with digital frame cameras. The production of a hard copy can be a problem. Printing photo quality hard copy images can be expensive, but may be required. Poorer (printer) quality hard copy will not be sufficient for many field uses. However, copies can be printed as often and at whatever scale is required. In addition, GIS map information (e.g. stand type lines) can be added to enhance the image information content prior to printing.

Video Cameras

Video technology is also being examined as a potential method for acquiring change information for inventory update. This technology offers the same advantages as digitized photographs and the same disadvantages as the digital frame camera. The resolution of the video camera, however, is even lower than the digital frame camera. There is an added step with the video camera of searching for the desired frame and "grabbing" it; the search can be time consuming unless the video image is marked at the time of the flight. The equipment, however, is inexpensive, versatile and can be used on other aerial reconnaissance missions. As with the digital frame camera, there can be a problem with the production of hard copy products for field use. Video technology is being examined by Fraser Inc. in New Brunswick. The video camera, mounted inside the company's helicopter, is linked to GPS for referencing video frames and cutblocks. A video of change activity is acquired on tape; individual frames are then "grabbed" from the tape, converted to image files in the computer, georectified to the map base in the GIS, then change activities are digitized and entered directly into the system. The Company is satisfied with the results, although they point out problems in achieving flying altitudes high enough to give the swath width required to map an average disturbance. Wider field of view lenses can resolve this problem but also lead to lower resolution.

Digital Satellite Imagery

Satellite digital data is another method that has been used and is still being considered in some organizations for inventory update applications. Digital satellite data has a number of advantages over the transparency format including not requiring digitizing of the delineated boundaries, and the ability to use the image as a back-drop to other GIS information (e.g. inventory stand boundaries, planned cutblock boundaries). Digital satellite imagery must be geometrically corrected. This can be done commercially or in-house using image analysis software. If disturbance mapping is the only application for the imagery it may be best to conduct a series of geometric corrections of local subareas around each change activity, rather than correcting the entire image. This can be done relatively quickly, is locally more accurate and requires less computing power and storage.

The potential also exists with digital satellite imagery to use automated remote sensing techniques (classification algorithms) to save time in interpreting changes. Automatic classification works reasonably well (major changes such as clearcuts and burns can be easily classified), but a visual confirmation is required. The advantage of classification is that boundaries can be acquired automatically, saving delineation/digitizing time.

Silviculture

There is a wealth of detailed information collected on silvicultural activities. For example, cutblock boundaries (openings) are often further stratified for silvicultural purposes, and specific activities are planned for the different strata within the opening. This information is collected during field surveys and used for contract management and reporting purposes, to plan future treatment activities, to assess performance for remedial treatment, and to ensure compliance with regrowth stan-

dards. The data is not included in the provincial inventory; rather it usually exists in a separate database. It makes sense for this information to be kept separately; but, it is important to recognize that this information is also meaningful for inventory and management decision making. Therefore, there should be direct links between the silviculture and the inventory databases. The problem is to determine at what point, to what level of detail and how should the silviculture information be brought into the inventory.

A rules based system could be used to generate labels (inventory information) on opening polygons from the silviculture information system. These rules would create new polygons based on different activities within the original opening polygon. One simple scenario could be that following a disturbance (cut) the opening boundary would be captured and a common polygon would be created for both the inventory and silviculture databases. A cutblock label would then be generated from the silviculture database and applied to the opening (e.g. Clearcut -1994). If the opening is stratified and each stratum is given a separate treatment (e.g. planted to a different species), the silviculture database would be used to generate the new inventory polygons and to assign plantation labels to each polygon. Following the maintenance survey, the silviculture data could be translated into inventory information and the label updated to reflect the survey data. If remedial action is required following the maintenance survey, inventory information would not be generated until the action is completed. The label again would be updated from data gathered during the sign-off survey. At reinventory, the polygon boundary would be maintained and silviculture information would be used to help generate a complete description. Problems arise with this scenario due to the myriad of possible rules and combinations that may occur (e.g. polygon splitting to accommodate partial treatments) and minimum inventory polygon sizes.

Changes to the forest cover derived from the silviculture database, along with detailed silviculture data, could be added to a working inventory at the district (soft update) in a form that would be useful for planning, reporting and decision making. The information could then be rolled-up in a standard format at regular intervals to update the provincial inventory (hard update).

Insect and Disease

Most provinces do not include insect and disease damage in inventory update. Many insects and diseases cause ephemeral changes to the state of the forest (e.g. changes lasting two to three years). For example, many of the defoliating insects (e.g. gypsy moth, forest tent caterpillar, budworms) cause serious defoliation for several years but mortality is not necessarily significant. Where mortality is not significant, the impact on the inventory is in terms of growth loss and sometimes altered wood quality. On the other hand, insects and disease can cause significant mortality. As a result, programs are in place to detect and monitor damage in order to predict the risk of mortality, significant growth loss and wood quality degradation. The information they provide is used to plan control programs, to alter harvest scheduling and for long term management planning (e.g. information is often incorporated into growth and yield estimates used in wood supply analysis). The information from detection and monitoring programs is usually held

separately from the inventory. It can be related to the inventory and used in conjunction with the inventory. However, because much of the damage information is derived from broad area aerial sketchmapping, the damage information cannot be reliably related to specific stands. This creates a problem for incorporating this information formally into the inventory, especially at the stand level.

The basis for decisions regarding control programs and harvest scheduling varies. They can be based on complex analyses of past damage history (survey information), rules regarding susceptibility, field sampling of insect populations and other factors. Often, however, the information base for these decisions is local knowledge of conditions gained through regular damage surveys, special aerial reconnaissance missions or ground surveys.

Where significant mortality occurs or is imminent, logging usually takes place. The logged area is then mapped and added to the inventory as a cutblock. The history or cause of disturbance in this case could be lost.

The ephemeral nature of insect and disease damage requires this change activity to be handled in a different manner when it comes to inventory update. Changes to the forest cover resulting from insect and disease damage could be incorporated into the inventory as a separate overlay (soft update) so that damage information could be related to individual stands in the most pragmatic manner. Damage information could be maintained as part of the stand history so that it could be accessed on a stand-by-stand basis through the inventory. In this way, this information could be more effectively utilized to assess stand development for planning purposes, to assess stands or areas at risk, to plan control programs, and to provide insect and disease statistics. This information would only be mapped as part of the inventory (hard update) when change is finished (e.g., mortality level, area logged) and the disturbance attribute would recognize the source of damage as well as the salvage activity. For example, the label C(S)-I (budworm) would represent clearcut (salvage) activity following insect caused mortality (budworm).

Update Issues

The organizational structure surrounding inventory update varies among jurisdictions. This is due to different philosophies regarding the use and collection of update information, practical considerations and larger organizational structure factors (i.e. organization of government departments and company operations).

Within provincial forest agencies, the responsibility for harvest, fire, insect and disease, and silviculture information are commonly in different branches of the forest organization. The documentation of this information takes place at different levels within the organization (district/local, region, headquarters). A summary is given (Tables 4-8) of the responsibilities for the various aspects of update. Documenting of silvicultural activities is handled at the district (local) level. Fire is usually centralized at the region or headquarters level; sometimes there are separate programs for mapping fires for inventory and fire management purposes. Documenting changes as a result of insect and disease damage is generally centralized, although district staff are aware of local problems. The responsibility for documenting harvest activities is variable between district and headquarters level and is often

shared. The district monitors the logging operation for compliance with various regulations (e.g. utilization, road construction) while the headquarters is often involved in documenting the activity in terms of mapping.

There are many arguments and reasons for conducting inventory update under different structures and responsibilities. For example, GIS capability (hardware, software and expertise) is not common in local offices, so the function of mapping and adding change activities to the inventory data base has remained a function of headquarters or has been contracted. Another issue is quality assurance of the official inventory. Traditionally headquarters has been responsible for the integrity of the inventory and therefore has had a tendency to conduct many of the update tasks. Also, there is a question of whether local staff should be burdened with the update task, especially the added responsibility of inputting the update into the GIS.

On the other hand, knowledge of conditions and actual change activities is greatest at the local level, so update could possibly be done with less error if done locally. Also, since update information is mainly used locally for planning purposes, an argument could be made for maintaining the inventory locally, or to keep an up-to-date working inventory rather than an up-to-date official inventory. Taking on the update function may be a good way to introduce GIS and to develop expertise in the districts. With modern electronic communications technology and as GIS capability is gained locally, it is possible to update the 'official' inventory locally (e.g. district level) on a continuous basis. This would likely require a quality control step or audit (checking) system to be implemented at the headquarters level.

Various types of data are collected on a continual basis for management purposes at the local (district) level. For example, cutblock boundaries may be established (flagged) and revised numerous times before they are finalized (painted). Each time the boundary is modified new information is gathered. Detailed descriptions of ephemeral changes (e.g. the extent of an insect infestation) are also collected on a continuous basis. It is important that the forest manager have this information so that timely decisions can be made regarding alternative courses of action (e.g. where and when to proceed with insect control programs). Much of this data is relevant to forest inventory. One way to overcome the timing/frequency requirement for up-to-date inventory information is for the district to maintain a working inventory. A working inventory would consist of the latest version of the "official" provincial inventory as a base layer accompanied by individual layers of information representing different activities. These would be created on a continuous basis as activities occurred. The relevant inventory information could be combined with the official inventory and then rolled-up on a regular cycle or as needed to accommodate the provincial update program. The working inventory is also useful in providing information for management purposes where the provincial inventory is not updated on a regular basis.

Sometimes in the cases of harvesting and other changes, the boundaries may be mapped or inspected several times for different purposes by different groups. For example, a cutblock may be mapped preharvest, during or immediately after harvesting for cut inspection, later for silvicultural treatment prescription or contract payment, and again for updating the inventory. Different boundary definitions are sometimes used

(e.g. the drip line, the cut stump, or boundary tree stems). When such situations occur there is opportunity for rationalizing the processes so that the boundary (e.g. post-cut boundary) is only mapped once with one definition and an accuracy suitable for all uses.

The use of contract services for specialized tasks such as transfer and digitizing will likely change in the future as new technologies are introduced into the process. For example, the use of a technology with geocorrected digital imagery and heads-up interpretation/digitizing eliminates the transfer and digitizing functions and therefore the contracting of these services.

Forest companies also have a responsibility for inventory update. Most major tenure holders (forest management agreement holders) are responsible for updating the inventory for change activities on Crown land within their agreement area. This is usually done in cooperation with the provincial agency. For example, the company may be required to provide a map in either digital or analogue format and a photograph of change activities to the provincial district office. A company will often maintain their inventory on freehold land to the same standards as the provincial inventory. Currently government forest agencies generally conduct the update for small company operations. In future for all forest tenure (large or small forest companies and indeed all logging operations) it could be the logging companies that will have the responsibility for updating the inventory. This could result in the creation of a consulting business to do the update for the small logging companies.

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