RIC Report 001
Discussion Document

REPORT OF THE TIMBER INVENTORY TASK FORCE ON THE CURRENT TIMBER INVENTORY WITH RECOMMENDATIONS FOR THE FUTURE

APRIL 1992

PREAMBLE

This report is submitted to the Resources Inventory Committee (RIC) by the Timber Inventory Task Force.

The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments. First Nations peoples are represented in the Committee. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report The Future of.Our Forests.

To achieve its objectives, the Resources Inventory Committee has set up several task forces, including the Timber Inventory Task Force. The terms of reference for the Task Force were to review the current Ministry of Forests Inventory Program and to design and plan the development of a new provincial timber inventory process. The Timber Inventory Task Force has completed the critical review of the current timber inventory. This is the full report of that work.

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[1.0] Executive Summary

The terms of reference for the Timber Inventory Task Force are, broadly, to ”design and plan the development of an accurate timber inventory”. The first phase of this project was to ”review the current Ministry of Forests’ Inventory Program”. This report is the summary of that initial process.

A wide review of the inventory program was conducted, ranging from an historical and organizational perspective to specific technical procedures. Numerous experts were interviewed and background papers considered. Observations and suggestions are detailed by inventory phase within this report.

It is concluded that, in general, the provincial inventory processes are fundamentally sound. Given the technology and provincial objectives of the day, the inventory was thoughtfully designed and implemented. Unfortunately the updating and renewal of the system lagged behind the demands of the primary users. Major criticisms presented here centre on uses or applications that were never considered in the initial program design.

Some improvements to procedures, mainly in the ground sample and classification phases, are needed and can be corrected for the next inventory with conventional approaches.

Current technology offers some very attractive advantages in mapping and data handling which should greatly enhance the responsiveness and credibility of the future inventories.

Major opportunities for the next inventory are briefly summarized by program phase.

Inventory Design

The past inventory was designed to provide management unit summaries for key forest parameters such as area and mature volume by broad forest types. For unit planning it was adequate in overall accuracy. More recently, however, local area resource planning has become the norm. The level of accuracy required for these detailed plans could not be provided by the provincial inventory and consequently the program lost credibility in the eyes of some users. In future inventories the key challenge is to design a system that can meet the needs of provincial, regional, and local planners at a reasonable cost. As an absolute minimum, the system must provide planners at each level with a reliable estimate of the accuracy of key resource parameters.

Specialists should begin work on a new inventory design, using sources with expertise and experience from throughout western North America. Special attention must be paid to the questions of data accessibility and standardization, credibility, and clear presentation of the accuracy to be expected. In addition, the ability to validly sample local areas, in order to increase the precision of the overall inventory for local planning, should be a design feature.

As the design process and pilot projects proceed, strong involvement by the Inventory Branch is essential. Expertise to expand and modify the design and procedures over time must be maintained within the Branch. Current initiatives and leadership within the Branch are encouraging.

Map Base and Integration

All forest inventories should be capable of overlay and integration. Currently this is not possible because of the lack of a standard provincial map base. The TRIM base should be strongly supported. It offers the best possibility for integrating and sharing information from different sources. Provincial policy of full cost recovery for the TRIM program may prove to be detrimental to its introduction throughout the Province.

Future inventories should incorporate ecological, vegetation, and topographic criteria in the definition of polygon boundaries. Some data collection for other resource inventories should be anticipated. ”Designing with change in mind” should be a guiding principle.

Database and GIS

It is not surprising that an inventory several decades old would not make full use of computer systems, or fail to anticipate computer databases with modern capabilities. The current database structure needs a thorough redesign along modern lines, with an ability to ”download” information to local planners. Geographic Information Systems (GIS) are an excellent means of augmenting the data not easily gathered during field work, and of combining other inventories and historical information. The GIS should be seamless, to facilitate aggregation or partitioning. In addition, a good audit trail of changes, a static data set over a fixed time period for all users, and the ability to decentralize data access and augmentation would be highly desirable.

Classification and Field Work

The current classification system is an asset. It forms a good basis for the first stage of a new inventory. More attention to some aspects of quality control and data storage are desirable, and it is necessary to use field sampling data to correct the classifications assigned by remote sensing. Current field techniques are acceptable, but could be aided by new technology such as global positioning systems. The basic structure for updating the inventory at intervals is sound; however, the intentions must be followed with action. The prototype pre-inventory analysis system is promising. Work should proceed on this project with an eye to setting priorities in the transition to a new inventory. As part of the re-inventory process former polygon estimates should be compared to actual ground measurements in order to estimate both the former error levels and the anticipated increase in precision.

Reporting and Credibility

The current attempts to report data are commendable. A substantially improved and well-defined relational database would markedly increase the system's flexibility. The philosophy of decentralized access to the data, some degree of decentralized augmentation to the data, and strongly controlled (perhaps centralized) quality control is very desirable.

Credibility is a central and critical issue. Several different sources, all providing essentially the same answer, is the strongest approach to credibility for complicated systems such as a modern inventory and land resource data set. An outside audit by another organization, along with several systems which can quickly provide valid samples of any item of special interest would go far to ensure the important credibility aspect of the next inventory.

[2.0] Introduction

The Forest Resources Commission in its report tabled April 1, 1991 recommended that:

> ”the Government of British Columbia undertake a commitment to complete inventories for all renewable forest resource values using standard compatible systems”
>
> and
>
> ”a Provincial Forest Resource Inventory Committee be established to plan and develop a program for these inventories”
>
> and
>
> ”a Timber Inventory Task Force should immediately conduct a critical review of the present Ministry of Forests’ re-inventory program and report within the next 12 months.”

The Resource Inventory Committee with its eight Task Forces (of which the Timber Inventory Task Force is one) was established in response to these recommendations.

Terms of Reference (Appendix I) for the Timber Inventory Task Force, in summary, were:

> ”to make recommendations to the Ministry of Forests on matters pertaining to timber inventory ... The Task Force will review current inventory programs and recommend standards and procedures for an accurate, flexible and stand specific timber inventory process.”

The findings of the Task Force are submitted in this report. This work is the first of two phases. The second phase is to develop a timber inventory system capable of integrating with other resource inventories.

The members of the Task Force are drawn from Government, Industry, BC Institute of Technology and The University of BC. Together they represent extensive experience in inventory design, execution and analysis.

The members of the Timber Inventory Task Force were:

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Michael Bonnor, Ph.D., Forestry Canada, Victoria
Don Munro, RPF, Faculty of Forestry, University of BC, Vancouver

Task Leader:
Stephen Omule, RPF, Inventory Branch, Ministry of Forests, Victoria

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Kim Iles, Ph.D., Kim Iles & Associates Ltd., Nanaimo

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Ted Lea, R.P.Bio., P.Ag., Habitat Inventory Section, Ministry of Environment, Victoria
Bruce Pendergast, R.P.Bio. (resigned February 1992), Habitat Inventory Section, Ministry of Environment, Victoria
Darrell Robb, RPF, Prince George Region, Ministry of Forests, Prince George
Norm Shaw, A.Sc.T., BC Institute of Technology, Burnaby
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Gerry Still, RPF, Research Branch, Ministry of Forests, Victoria
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The Task Force met in seven sessions, with extensive work being done outside the meetings in preparation and organization. Individuals from fields of direct interest were invited to give presentations, with unofficial written comments or background papers to add detail where needed. The following specific topics were reviewed:

1) General Principles of Good Inventory Design
2) Design Requirements for the Last Inventory
3) TFL Inventory Procedures
4) Forest Classification Procedures
5) Mapping
6) Use of Remote Sensing
7) Historical Summary of Forest Inventory Efforts in BC
8) Wildlife Inventory
9) Operational (pre-harvest) Cruising
10) Scaling Procedures
11) Residue Procedures
12) Silvicultural Surveys
13) Range Inventory Procedures
14) Recreation Inventory Procedures
15) Database Use in Inventory Branch
16) Pre-Inventory Project Analysis

17) Yield Analysis
18) Growth & Yield Measurements, Decay, Growth Projection
19) Endemic and Epidemic Growth Losses
20) Databases for Private Land Inventory
21) Inventory Branch Training and Planning Procedures
22) GIS and Inventory Linkages
23) Local Resource Use Planning
24) Old-Growth Task Force
25) Business Area Analysis for Inventory Branch

The Task Force's findings are based on these presentations and form the body of this report. Within each chapter they are organized as follows: a background statement on the topic

- a listing of advantages of the current system

- a statement of concerns about the current system, and a listing of important principles and suggestions for new inventory.

Readers of this report will notice that, on occasion, there is repetition of topics in the statements of concerns and listing of principles and suggestions. This occurs partly as a result of subject overlap and partly for emphasis.

[3.0] Historical Development

A consultant was commissioned to prepare a review of the historical development of forest inventories in British Columbia (Appendix II).

The first inventories emphasized mapping with attempts to provide improved estimates of area and location of large forest areas with only gross estimates of volume. As the use of aerial photography became practical, mapping precision improved dramatically. Techniques were developed to enable timber classification from aerial photographs and from aerial reconnaissance, and the accuracy of estimates of timber volumes increased.

With the first serious efforts at sample-based inventory, sampling methods and statistical concerns were addressed and computers were used to tabulate and analyze the data. As inventory became more costly, especially in terms of personnel, ground sampling was replaced with computer estimates of volume based on measures and estimates of age and site index. These innovations had not been anticipated in the design of the old inventory and difficulties were encountered in merging information from the new and the old systems.

The recent availability of satellite remote sensing at regular intervals has led to updates of areas obviously removed from the timber base. At the same time, GIS technology is developing, along with modem computerized databases which can hold and report raw and summarized data. Ecological mapping is increasing, and much of the current research uses this for its base.

As with the designs of many systems, the past systems are strong influences on future systems. The technical side of forest inventory can be very difficult to coordinate over a large area with rough terrain for field work. There is a strong and reasonable tendency to work along proven lines.

Historical information, records, field procedures, etc. which have been worked out over decades are not easily changed. The basic question is whether these systems will continue to serve well and evolve naturally into the next foreseeable developments in computers and measurement technology. A great amount of experience is available throughout western North America in natural resource inventory. Timber inventory is the best known technology, and systems that provide good timber resource information can probably be used as a basis for other information needs.

It is important to identify the things that worked well, and also those that did not work well. In many cases, the changes and new requirements could not have been foreseen by the inventory planners. Perhaps we can identify some lessons on the management of change as well as the management of data.

[4.0] Current MOF Timber Inventory

[4.1] Purpose

As stated by the Forest Resources Commission (Background Papers, Vol. 7, 199 1):

> ”The purpose of the existing inventory that has been carried out during the last 30 years was to provide average management unit level statistics. The intended primary use was for calculation of annual allowable cuts. It was also to be used to monitor depletion of the forest from harvesting and wildfires, as well as updates for reforestation.”

TFL holders were expected to inventory their own holdings, and this work was not duplicated by the Province.

[4.2] Overview

Some characteristics of a good inventory are listed in Appendix III. The inventory process is generalized in the flow chart in Appendix IV. The following text should be read in conjunction with the flow chart.

Administrative Issues

Mission Statement

The Inventory Branch Mission Statement sets out broad goals and objectives to guide the development of current and new inventories.

Pre-inventory Analysis

Cost-benefit analyses are undertaken to assess the need for major inventory updates or re-inventories.

Inventory Training and Planning

A special training section ensures that staff are trained and kept abreast of new developments.

Technical Audits

The entire inventory process is subject to audit at any time. Audit is an on-going process to ensure quality control and compliance with standards.

Business Area Analysis

Based on a strategic business plan, information requirements are analyzed, and a high-level systems design and implementation strategy is developed. Short- and long-term plans are prepared and integrated with similar plans from other Ministry Branches to ensure maximum efficiency and eliminate gaps and overlaps.

Phase 1: Forest Cover/Base Mapping

Base Mapping

The first step in the forest inventory is to obtain a base map. This is used for ownership patterns and administrative boundary lines, as well as for field navigation and road access information. In the future, the TRIM database will be used for this purpose. The base map is an important requirement for the eventual combination of separate inventories, and should be common to all organizations.

Polygon Borders

Areas (polygons) supporting forest cover of similar characteristics are delineated, usually on aerial photography. The lines may be original, or based on the same borders as some past inventory. The individual polygons are then transferred to base maps. This process is a major effort, performed on a total of approximately 7000 mapsheets.

Phase 2: Classification and Reporting

Initial Estimates (Classification)

The characteristics of the forest cover for each polygon are estimated. Initial estimates use existing former information, air calls (helicopter views), ground calls (walk-through visits to the stand), previous ground observations (actual measured plots), and any silvicultural or historical records about the area. This phase is important in minimizing the number of new ground observations which will be needed.

Ground Sampling

Ground samples are established in some of the polygons. This is the ”ground truth” process which ensures that any mistakes in the initial classification can be corrected to give valid overall volumes.

Map Production and Reporting

The polygon boundaries, together with all other base map features, are digitized, while the polygon attributes (e.g., classification labels) are entered into the database. The combination of the polygon boundaries and locations with the attributes constitutes the geographic information system which permits analysis of inventory data in relation to geographic location.

Depletion and Other Updates

After the initial inventory, annual updates are required to account for changes due to natural disturbances, harvesting, road construction, etc.

Phase 3: Volume and Size Predictions

Volumes and Sizes

For each polygon, average tree size and volume per hectare are predicted for a variety of species and utilization standards. Reductions for decay are also calculated.

Short-Term Planning

The inventory is designed to he accurate for the entire land base, not particular areas chosen for near-term harvest. As areas are chosen for harvest, a separate system of operational cruising is used to confirm the timber estimates. After harvest, the scaled timber volumes and the residue volume remaining after logging are available to confirm the volume estimation procedures of the operational cruise. Since many of the procedures for the operational cruise are the same as for the main inventory, this also acts to confirm the procedures used with the main inventory.

Long-Term Planning

The current inventory is projected forward in time by means of computer growth models. The data for the construction or validation of these models comes from long-term studies. The inventory provides the very important starting value for running these growth models. These long-term predictions form the basis for the calculation of allowable cuts and long run sustained yields.

[4.3] Design

Background and Implications

The inventory design and objectives are critical. Since an inventory will ”live” a long time, a proper design is important. The design will critically affect:

1) The kinds of data which can be summarized and reported by the process.

2) The statistical reliability of the data.

3) The flexibility of the inventory to changes in definition or summary processes as well as additions of new requirements which must be retrofitted to the old structure.

4) The correctness of the process. A valid sampling scheme is essential.

5) The credibility of the system. Errors in design can seldom be overcome. Quality control systems are an integral part of the inventory design.

The current inventory is founded on a stratified random design using fixed-area plot clusters. Stratification is carried out on aerial photographs. The sampling error objective for average strata volumes was ”less than ± 10% sampling error 95% of the time”. This objective was met.

Advantages

1) More kinds of information were taken than were necessary. This allowed a subsequent use of this information in techniques not envisioned at the time the inventory was designed. It also enabled enhancement of estimates based on later research.

2) Provisions were made in the design to ensure quality control. The success of these was not made clear to the Task Force, but efforts were certainly made.

3) The sampling errors for average strata volumes were better dw required, and certainly within reasonable limits. The sampling intensity was adequate to ensure precise answers at the levels for which the design was developed. The amount of bias, if any, is unknown.

4) There appear to be consistent estimates of polygon volumes (but perhaps not species percentages) which can be used as a basis for the first stage of a new inventory. This is an important asset for the next inventory design.

5) The original summary data was kept, and an effort made to project the data forward to the date when reports were issued.

6) For its time, the past inventory was well designed.

Concerns

1) Less than full coverage of the land base resulted in some areas being missed or inventoried by other agencies (e.g., parks, Federal lands, Indian reserves and TFUs). Design differences among these inventories makes their integration very difficult.

2) The original data was degraded by rounding and, by the use of class groupings. There is no inherent problem caused by rounding, except when the original information is discarded, as in this case.

3) Some cultural definitions (such as a category of ”not operable”, or “low volume”) were kept as labels, rather than data. As category definitions changed, Inventory Branch was unable to alter these labels. The original data, if kept, could have been used to change these labels. The job of an inventory is to define ”what is there”, not ”what it means”.

4) There is less confidence in the data than would appear warranted. Clearly, not enough time and effort were spent on ”quality assurance”, even though quality control might have been adequate. Communication to other users about data limitations was not sufficient.

5) Data on polygon boundary and label accuracy is not available, leading to expectations by the users that were not met.

6) There does not appear to be sufficient flexibility in the database for current analysis requirements. This is due to design problems which were unavoidable at the time. The database probably has not been used enough to ensure sufficient error detection, which often comes from frequent use and cross-referencing.

Important Principles and Suggestions for the Next Inventory

1) Statistics for anticipated groupings (e.g., TSA’s, Districts) should be prepared in advance of requests.

2) Increased effort should be directed to the establishment of credibility for estimates and polygon accuracy.

3) Future classifications are important when it comes to implementing change. This is obvious in the case of ecological strata, but there may be others that should be identified also. It is important to get some of this general information from both ground and map sources, even when it is not used immediately. With modem databases, this information is much more useful than it would have been in the past.

4) All species, vegetation classifications, ownerships, etc. should be inventoried. Decisions about ”not of interest” should be made after, not before, the inventory. This does not preclude sampling these types at a lower intensity.

[4.4] Inventory Procedures

[4.4.1] Data Acquisition

Background

The current provincial forest inventory was developed over the last 30 years on a management unit basis. The result was a class-based inventory with the forest cover being described by age, height, stocking, site and species composition classes. This inventory was designed to provide broadly based, average volumes by species and other summarized statistics for each management unit. In 1973, Environmentally Sensitive Areas (ESA's) became an integral part of the forest inventory.

In 1977, in response to a need for more detailed forest cover information, a sub-unit survey was initiated. Instead of a class base, parameters were measured and recorded as continuous variables. At this time the digitization of forest cover and administrative and ownership boundaries was commenced.

No inventories were conducted between 1982 and 1988 because of budgetary constraints.

The process of acquiring data accounts for the major cost and time devoted to an inventory. It is the component which cannot be easily corrected and replaced later, so the proper planning and implementation of this activity is crucial.

[4.4.1.1] Mapping

Implications

Mapping involves two components; the construction of the base map and the delineation of polygons on the base map.

The base map is an important concern. If it is compatible with other sources, it means that much of the information of interest to the inventory and its users can be obtained from other sources. At the least, the other sources act as a second opinion. Every effort must be made to use a base which is standard across other ministries.

Timber polygon data provided to others (by the Inventory Branch) will depend upon the base map. Polygon boundaries are frequently based on natural features, and these will vary slightly by base map. Consequently, the timber polygons will not transfer cleanly to the maps of other users when the base maps are not identical. This problem of ”slivers” where polygons do not match is a serious problem for current GIS systems. Attempts should be made to maximize congruency of boundaries among users.

When mapping of the polygons by the Ministry of Forests (MOF) is draped over the same base map as other users, with useful and stable boundaries to the polygons, other users may well adapt the polygons for their own purposes. This would greatly aid data transfer, especially where the other users also adopted the MOF identifier for that polygon.

Advantages

1) In the last few years, technology has provided many new remote sensing sources for mapping and for updating maps. The accuracy of maps has the potential to increase greatly and for relatively low cost.

2) The Inventory Branch seems well aware of the problems of scale, and have taken steps to ensure that they are not overwhelmed by the 7000+ maps with which they must deal. Most of the mapsheets have been digitized (except for TFL's and parks) and efforts are being directed towards improving procedures.

3) The general direction of mapping technology seems appropriate, and can switch to newer technology or imaging when it is available. Many of the mapping problems which do exist are quite separate from the sampling or database problems, which reduces the coordination and planning effort, and allows the problems to be solved independently.

4) The possibility of reasonably fast turn-around for information needs, coupled with colour-coded map output (and possibly with an overlay to remote sensing information) is a powerful tool. It will go far to establish credibility and answer planning needs. It is likely that the tools for doing this will have to be available, in the future, at Regional/District levels in order to reduce demands on Inventory Branch.

5) Much of the current technical definition for inventory data is available from technical manual sources. It is envisioned that these will become available in electronic form, and be made available as ”pop-up” items in computer databases, or some other appropriate display method.

Concerns

1) There is a variety of methodologies and standards with respect to map updating that is not linked to any obvious policy that differentiates between provisional and final adjustments to a base map. Remote sensing used to update maps is not presently geo-coded, and it is not apparent that steps will be taken to do this. At the same time, it is important to state that the apparent match of remote sensing and maps is quite good, and the process of change detection is working well. Inventory data is multiplied by polygon area, and this accuracy is of concern.

2) There is no indication of source or accuracy of boundaries on the map system. This should be developed as part of the GIS database, since the line information resides on the GIS and updates will likely occur on this system. The presumed accuracy should be stated and some means should be derived to check this. A simple opinion that the lines are accurate in not sufficient.

3) The photos on which the last inventory was based are not always available. There was not a sufficient archiving system.

4) Forest polygons do not presently have globally unique identifiers; they are unique within mapsheets only. This should be changed as soon as possible.

5) Inventory Branch's policy is to use TRIM data where it is available. TRIM production is slow, and despite efforts to coordinate new inventory projects with TRIM production, in

some instances re-inventory has proceeded without it. The cost of TRIM data and technical considerations in converting existing data may prove to be an impediment to its acceptance; however, all users should be encouraged to use TRIM as it becomes available.

Important Principles and Suggestions for the Next Inventory

1) Ensuring that the base map matches that of other users and possible suppliers of data is very important. The TRIM base map is the best option here, and it is very important that it be widely available.

2) Polygon boundaries should be common among layers, when possible, to keep them stable and to make them more useful to others. Software to duplicate line work and polygon borders will also enhance the chance of others matching polygon borders.

3) Display of forest polygons against a variety of other polygons is desirable. This means that the separation of data by layers in the GIS system should be maximized.

4) Each of the forest polygons should have a global identifier which can be transferred along with the polygon location or data. Other users should be encouraged to include this identifier in their databases, rather than to label it themselves.

5) At intervals, an official forest polygon coverage should be issued by Inventory Branch. It would include up-to-date information on polygon shapes which has been fully quality controlled and is not expected to change for 6 months to a year. This ensures that studies done over a short period will get the same answers for the same process. The timber database would also be fixed in the same way.

6) Artificial boundaries, such as mapsheet, are troublesome at best. The GIS system should be ”seamless”.

7) Some indication should be kept on the accuracy of boundaries in the database and on the map. Source is adequate, but some actual estimate of accuracy is better.

8) A system of ensuring that District, Regional and Provincial map bases are identical is needed. This will not be simple, but it is important. The Districts may do much of the work of modifying map information. Quality control is essential.

9) Error detection would be greatly enhanced if the map could be draped over a recent photo. It would be better if this could be done with a stereo pair. Elevation for this process should be derived from the TRIM data.

10) Simple systems for extracting information from the database and drawing maps from this data should continue to be developed. FIR (Forest Inventory Reporting System) is a good example. This will leave Inventory Branch free to concentrate on training, interpretation and special projects rather than simple information requests.

11) Remote sensing standards for depletion update should be defined and a method developed to ensure that provisional updates can be recognized in the graphics files.

[4.4.1.2] Classification

Implications

The classification phase is an important one. Unadjusted classification can serve as basic information for some activities. Often, polygons are not sampled on the ground. In these cases, the raw classification should be a reasonable estimate of stand parameters such as volume and species. In addition, the classified stands can be used to statistically stratify the sample. The classification criteria are sometimes used to estimate stand volumes or the values of other parameters of interest through relationships developed by research efforts.

Advantages

1) The present classified stands, with volumes estimated by the VDYP (variable density yield projection) system and species percentages estimated from aerial photographs, make an excellent basis for the first stage of a future sampling scheme. These preliminary estimates can be used in a sampling scheme such as Ratio Sampling or Double Sampling in order to greatly reduce sample size. The efficiency increase from this system should then be returned to the inventory in the form of greater quality control and precision in ground measurement.

2) The present system provides direct estimates, which are of use even in their raw form. In addition, there is considerable experience with the current system. The present classification system is a real advantage of the current inventory method.

3) There is in-house expertise in regard to photographic classification, and this is necessary to set standards for contractors. There have been clear attempts to do quality control on at least the transfer of information and the consistency of classification. It is important to maintain this expertise.

4) Large-scale changes are handled well enough by the current change detection systems. Growth of stands is probably predicted well enough for updating, but it is not clear how far in the future such projections are valid.

Concerns

1) Some non-forest polygons are insufficiently defined to be of use to other users, and too little information is retained about them.

2) Photo interpretation alone, as a methodology for acquiring the attributes, cannot be relied upon to meet the current standards and specifications of the classification system.

3) There has been considerable loss of original ground sample data, along with its source, quality and location. This data is therefore not available to aid in the next classification of the land base. Some of this loss is permanent – largely due to rounding into classes and input data loss. Some is temporary – such as data only being available on field sheets or other hard copy, or data that is incomplete.

4) MOF ground work is sparse, and this may also be the case with contractors. It is not apparent that values obtained from ground work are correctly used to adjust the inventory.

5) There is too much reliance on reclassification without ground checks, and too much reliance on the assumption that previous ground samples are adequate for use with current classifications.

Important Principles and Suggestions for the Next Inventory

1) Quality control and standards are important, and enough expertise and experience must be kept within the MOF to set these standards. There must be a core of people who do this work on a practical basis. This MOF staff must he familiar with the consultants doing the work and with their field procedures. They should also be involved with field checks.

2) The ”original call” of the polygon classification should be kept, although a ”best current information designation” can also be kept on the same polygon. The original call is important to a number of quality control methods.

3) When the probability of sampling (or using the data from) different polygons is not the same, the expansion factor appropriate to that polygon should be retained, so that estimates can be properly weighted at a later date.

4) There should be a greater emphasis on new technology and field visitations of polygons to enhance the reliability of photo interpretation as a means of classification.

5) The location of data gathered should be noted on hard copy and in a database. This aids quality control, adjustments to the estimates, and further subsampling. This should include the classifier’s name, the source of the data, and any other pertinent information that might be adjusted or subsampled in the future.

[4.4.1.3] Field Work and Sampling

Implications

1) The establishment of plot locations is critical. If an incorrect sample is gathered, there is simply no way to judge the extent of error associated with this mistake.

2) The field measurements are fairly standard and straightforward, but the difficulty lies in ensuring that clearly stated definitions are closely followed. Levels of recorded precision are also important. Data put into classes cannot be recovered to its original precision. If data is summarized into a descriptive class such as ”scrub”, there is little hope of changing that definition later.

3) There are a number of subtle problems in field work. Inventory Branch has virtually abandoned putting in field plots for the last 10 years, and consequently has less experience in this area than is desirable. Fortunately, there is considerable experience in the Province for solving these problems.

Advantages

1) Inventory in the Province has, until the late 1970’s, always been a centralized process, which has done much to maintain standards. Many of the field techniques are widely accepted, and these techniques have been used in the research and record-keeping systems of other units in the private sector as well as government.

2) Early efforts were well designed for their time. The processes used were well described, and the use of plot clusters and a multi-phase sampling system were appropriate.

Concerns

1) There were unquantifiable problems with sample location. At least in some cases, certainly not all of them, plots were moved to more convenient locations where the field crew believed that the forest was exactly the same. While the field crew did not <u>think</u> that there were any problems with moving plots or selecting plot locations that were convenient, there seems to have been no process to <u>assure</u> us that errors did not occur and accumulate. Even if every polygon sampled became closer to the true value, this process of rearranging plots could still lead to unacceptable overall errors.

2) Classing and rounding data caused problems which could not be rectified, and their effects are unknown.

3) There is no outside mechanism which serves as an audit, credibility check, or early warning system for the inventory. This is part of the reason that confidence is lacking.

4) The objectives and procedures of the multi-phase design (which was introduced at a later date) were not clearly worked out. The mechanisms for obtaining data were awkward, and data storage was not designed as part of the program. The system was not integrated with other levels and objectives of the inventory.

Important Principles and Suggestions for the Next Inventory

1) Ground samples are crucial to ensure unbiasedness and enhance credibility in any of the processes used to establish or to update the inventory.

2) These plots must be placed with a valid sampling system which is well defined and clearly documented. This allows future recompilation options, as well as establishing scientific and statistical credibility.

3) Compatibility of data and quality assurance are important, and should be stressed. Centralization is one very good option for this, and staff training is crucial.

4) Past inventory designs made inadequate use of prior information and ancillary information which could have quickly been gathered. Count plots, Empirical Bayes estimators, etc. should be considered early in the design phase.

5) Decentralization without an excellent training program, protected staff time to do the job, and good quality control, can result in problems.

6) A pilot project, including tests of field procedures, data storage, compilation and reporting is a crucial part of implementing the inventory process.

7) We must not take a narrow view of efficiency or practicality. Flexibility, credibility and generality are also part of efficiency. There are many correct ways to do things, and statistical advice must be quickly available to field crews to ensure that changes are chosen from a correct list of possibilities.

8) The automatic reaction of many people is to put in more plots to solve a problem. More plots is seldom the answer. The provincial sampling error is very small, certainly less than 1 %. The problems are with bias, data storage, local applicability, credibility, etc. Sacrificing these other items (to make more plots available more cheaply) did not serve us well.

9) No significant components should be left out of the inventory. Dead material, non-commercial species and all other components must be accounted for.

10) A common basic set of inventory information and definitions would be highly desirable for all organizations in BC. Such a database could be put together, but would require time and effort by all major players. This would foster eventual standardization without forcing it prematurely, which would not be desirable. Where possible, terms and definitions should follow international and national standards. Codes should be readable, standard, and leave room for future expansion.

[4.4.2] Data Compilation

[4.4.2.1] Volume

Background and Implications

Detailed measurements of stem diameters and shape, defects and quality from data collected in the 1950's and 1960's have enabled the development of accurate equations to predict individual total tree volume of each of the commercial tree species in the Province. In the compilation process, these equations are used to calculate volume per hectare from the ground sample plot data.

Data compilation and storage are important for several reasons. If data are not compiled with correct equations, it is obviously prone to bias, but the key issues here are somewhat different.

Data must be weighted correctly. When plots are not put in by a simple grid pattern with the same intensity everywhere, it is important to properly weight the results - otherwise bias results.

Raw data which is not kept with its full accuracy cannot be recovered. The urge to minimize storage and handling must always be tempered by the possibility that the decision is wrong, and will have to be reversed later. The history of Inventory and the Growth & Yield program contain many examples of this error.

Advantages

1) Field procedures were kept reasonably simple, with good training processes, complete manuals, and good quality control on the measurements themselves.

2) The procedures are well integrated with those of other branches of the Ministry, and the necessary research has been done on taper equations and other technical matters.

3) The current inventory, even if there are technical problems with compilation and data, still provides an excellent first stage estimate for a new inventory.

Concerns

1) There are several procedural differences between the Inventory Branch and other branches. These are not serious differences from a technical point of view, but they are a constant annoyance in terms of cross-checking the data. This leads to a credibility problem.

2) Some of the data cannot be recovered in its original form. This severely limits options for correcting individual estimates or even determining an overall correction for the entire inventory.

3) Many errors were only detected after leaving the field, with no opportunity to check the data directly.

4) The majority of samples are from mature and commercial species.

5) There are no samples for trees less than 7.5 cm dbh and for non-commercial species.

Important Principles and Suggestions for the Next Inventory

1) The current database of single-tree sample information, together with the volume equations currently in use, is sufficient to use without modification in the new inventory.

2) The original data was degraded by rounding and by the use of class groupings. There is no inherent problem caused by rounding, except when the original information is discarded, as in this case. This led to a number of problems, including some probable bias. Original data should always be retained.

[4.4.2.2] Deductions

Background and Implications

Volumes calculated as outlined in Section [4.4.2.1] above are subjected to a series of deductions in order to provide estimates of usable or merchantable volume. These deductions include allowances for stumps of varying heights, tops of varying diameters, breakages of varying kinds, and decay of varying types.

These deductions, if not made in a precise and unbiased manner, have the potential to seriously degrade the reliability of the volume estimates.

Some procedures, such as decay and breakage estimation, are meant to be valid over a large area (a TSA, for instance). Their use by other groups in the Ministry sometimes leads to problems with users who apply them in local areas.

Advantages

1) Most of the volume and decay data previously gathered is useful and as applicable today as it was when it was collected in the 1950’s.

2) The taper equations used to calculate volume deductions for stumps and tops are statistically precise and unbiased.

3) There is good agreement throughout the forest community on standards for recording decay.

4) There is good budget support for this field, a stable and experienced staff, and they are headed in generally the right direction. Recent activities are avoiding any sample selection errors from the past.

Concerns

1) The breakage factors need validation or improvement.

2) If widely applicable factors are appropriate to Inventory Branch, but not adequate for others, who should develop new procedures? How will we ensure that the local factors add up to the overall factors in the long run?

3) There are no outside checks on the reasonableness of the answers for volume deductions. Some kind of outside validation, perhaps using scaled volumes or cruiser - estimated decay, is very desirable.

4) Decay estimation is highly variable, despite the large database upon which it is based.

Important Principles and Suggestions for the Next Inventory

1) Some deductions, such as breakage and decay are inherently difficult, if not impossible, to determine with accuracy.

2) Some independent check should be available for both the remaining standing crop and the currently harvested portion.

[4.4.2.3] Site Quality

Background and Implications

Site quality, the capacity of a specific area of forest land to produce, is often estimated as an index. This index is arbitrarily defined as the height a tree will attain at an age of 50 years.

Forest inventory has two processes which are largely separable:

a) What is there now – a descriptive process.

b) What will be there in the future – a projective process.

The site quality is closely tied to (b), the projection of the inventory from its present state. It is also critical for estimations of future crops which are independent of the present forest. This makes it of central concern for planning.

The ”Long-Run Sustainable Yield (LRSY)” is almost totally dependent on three items:

a) The land base upon which wood is harvested. This is critically dependent on future reductions.

b) The stocking volume and species assumed to occur there in the future.

c) The site quality of the land.

Item (c) is the only one which the field measurements are in a position to affect. In many cases the ”site index” which is used to measure site quality is assumed to include the important parts of item (b) as well.

The characterization of site quality is therefore of critical importance to projections of the forest inventory into the future.

Advantages

1) The inventory already gathers this kind of information, and it is a part of the projection process. The quality control is in place, and much research has been devoted to gathering and using this information.

2) Research Branch has issued site index equations for general use throughout the Province, and all the organizations in the Province are cooperating in making these standards work well.

3) Field measurements for use in building site index equations have been standardized, and the process continues to build a data set which will increase in value and extent.

Concerns

1) Site index as a productivity indicator is designed for even-aged stands. Its use for all-aged and over-stocked stands is questionable. With the potential use of the Prognosis model for Interior stands, a switch to ecological units is probably wise.

2) A distinction must be made between the use of site index equations for their narrow use as height growth estimators and the more general use of site index to indicate productivity and stand growth. It is the latter use which is really in question in the Interior of the Province.

3) There have been serious problems with data handling in regard to site index:

    a) Rounding has led to significant errors and loss of information.

    b) The use of classes, followed by metrication, has introduced further bias.

c) When site index equations change, the raw data has not been available to recalculate the new site index. This has compounded errors over time.

d) The site index equations have not been derived for estimation for older stands. They have emphasized only the younger part of stand life.

4) Site index curves are least accurate at very young ages. This is partly a statistical choice which could be reversed, but the expression of site potential in young stands is simply not yet clear in the stands' early life.

Important Principles and Suggestions for the Next Inventory

1) The correlation of site index with ecological indicators should be encouraged for several reasons:

   a) The production potential of all-aged stands may be more accurately portrayed by ecological indicators than by standing tree measurements.

   b) For young stands, a mixture of the direct estimates from young trees and the more general estimates from ecological class may yield more stable results.

2) The raw information on age and height for field information should be kept to 1 year and 0.1 meter accuracy so that future changes in the site index equations can be accommodated.

[4.4.3] Data Storage and Reporting

Background

The Forest Inventory Planning (FIP) file contains detailed forest polygon information, area statistics for the administrative and ownership boundaries and applicable per hectare volumes by species, along with stand history.

For forest stands, it includes the information at year of measurement or estimation as the original input. It also contains such information as projected values to the current year for stand age, height and stocking class. In addition, there are some derived values such as calculated site index, inventory and growth type groups. For complex stands, the forest cover information is recorded by layers.

This file is used for standard and special reporting of forest inventory statistics within Inventory Branch. An ASCII format of this file is available for clients.

Inventory Branch has developed and distributed user-oriented reporting systems for use on personal computer platforms. These are the Provincial Summary Reporting and the Forest Inventory Reporting systems. They can be used to interactively generate reports and graphics.

[4.4.3.1] Database

Implications

Much of the information from an inventory is derived after the initial field work is done, using the raw data for making calculations, groupings and distinctions which have important uses at that time.

The reporting needs change over time, and the classification and reporting must be redone using the same data. There is ample evidence that nobody can predict these needs far into the future. The assumption must be that recompilation is needed at intervals.

The prompt reporting of summary information goes far to establish the usefulness and credibility of the inventory. Summary data which is on a database is particularly important, since it allows searches for particular kinds of land areas, inventory characteristics and the correlation of information. A well-constructed database, with a ”user-friendly front end” is the reporting choice for the next decade. The use of a mapping system to display database detail is highly desirable, and is a completely separate matter.

Advantages

1) Data storage is being moved to a central database.

2) Many of the data collection and editing problems from the last inventory will be solved using field data recorders.

3) The Inventory Branch is well aware of the problems with the old database designs and is actively pursuing a better system.

Concerns

1) Locations of most field plots can only be determined exactly by accessing original field notes. Plot data cannot be used to characterize areas which have been cut. Polygon midpoint data is sufficient for some kinds of data, but not for all.

2) The database design of the past inventory is inflexible, and completeness of the data is questionable. Expanding the amount of data stored in the present structure is costly and slow.

3) It would be easy to underrate the difficulty of designing a database, filling it with data, and querying it enough to find the problems. It is costly and time consuming to design systems which are easy for the Districts to use.

Important Principles and Suggestions for the Next Inventory

1) The database should be for the whole Province, not just lands managed by the MOF

2) A responsive, well-defined database is important for quality control, quick response, and to widen the useful applications for this data. If a basic set of definitions for the database can be agreed upon by industry and government, it would provide many advantages and lead to eventual standardization of many items. Each organization can then add specific additional items of its own choice to this basic set, while making data exchange and combined summaries possible and rapid.

3) Inventory Branch must ensure that data can be shared among user groups. In particular, the problem it must solve is the movement of data for inventory polygons.

4) Plot locations should be kept as accurately as possible, and documented on the maps of the day. The bearing from a relative location, which can later be clearly identified on new photos and maps, will reduce the problems from eventual map base changes. These locations should be stored as ”hard copy”, as well as in the computer.

5) A well-constructed modern database is key to the process. A committee of people who have technical expertise should begin as soon as possible to design it. Where it is desirable to use a specialist database for speed or other considerations, a simple one using a modern public system should be designed at the same time so it can accept data transferred to it by the main database. Summary data is more essential than raw data for District use and planning.

6) Summary data, for groupings which can be anticipated, should be available on a simple database without the need for a GIS intervention.

7) A mechanism for archiving data after updating is highly desirable. Historical information should not be lost, and all changes should be considered temporary for at least a few months.

8) A quick, simple and flexible reporting system is highly desirable, along with a simple way of illustrating the data.

9) Central control of data and methods is very desirable. The problems of simply keeping records available should not be underestimated. Decentralized control over methods and documentation will create more problems than it solves.

10) Decentralized access to the summary information is important. It keeps the work load on Inventory Branch to a minimum, while encouraging the use of the data. By some method, it would be desirable for the specialists at Inventory Branch to know what kinds of questions are being asked. This would help avoid (well-intentioned) misrepresentation of the numbers.

[4.4.3.2] Geographic Information System (GIS)

Implications

Simply described, a GIS (Geographic Information System) is a computer system capable of holding and using data describing places on the earth’s surface.

There are two main functions of a GIS system. They are quite separate, and should be viewed that way.

1) Creating geographic data (location, neighbors, matching overlays, etc.). This is normally sent to a database, perhaps on a personal computer, which will then summarize the data and work with it.

2) Display of information (color maps, symbols, etc.). This is a very simple function, which can be done on a far simpler and less expensive machine - possibly running on a personal computer.

Only function (1) needs to be done on a full GIS system. The database for the inventory system may be done on the same machine as the GIS functions, but it may also be quite separate. The connection between the GIS and the inventory database is the unique identifier of the polygon involved.

It is clearly an important function of the GIS to overlay different types of information and to provide this information to the database. Considerable time and expense are needed to accomplish this. Still, the more important function will be working with that data. It is therefore clear that the job of the GIS is to feed data out of the system for further analysis.

One of the solutions to the difficulty of the volume of work on 7000 mapsheets is to distribute the data and a simple way of displaying it. The Districts can then do much of the work on personal computers or small workstations, requiring the GIS only for analytical work.

Advantages

1) Some of the GIS problems are really mapping problems, and there are groups inside and outside of Inventory Branch who are working on those. This will free the Branch to concentrate basically on the ”value added” information brought to the GIS by the inventory and other functions of the Branch.

2) There is some movement in the GIS community to automate some of the line entry functions. In addition, expert systems and change detection systems will increasingly put us in the situation of verifying change instead of worrying over every detail of data entry and description. Some work is being done to supply photos and other remote sensing as background displays for the maps. This should reduce time and effort, speed quality control, and reduce duplication.

3) The Inventory Branch seems well aware of the trends in GIS. It will require discipline for managers to balance exploration of new technology with the important work of making current systems work correctly. Effort must be expended to ensure that the system is somewhat separated from the technology which supplies information so that change to newer technology is not too disruptive.

Concerns

1) It is not clear that a good audit trail is available for change within the GIS system.

2) Line entry is a huge problem, but it must not overshadow getting the data out of the GIS onto the database.

3) Data on polygon accuracy and the source of boundaries is not available, and not clearly planned for the near future.

Important Principles and Suggestions for the Next Inventory

1) Several platforms and storage protocols will exist over the next two decades. The Inventory Branch needs to ensure that digitized data can be transferred between machines with minimal expense and loss.

2) The GIS system should be used to add data to the inventory from a set of overlays taken from available sources. This is mainly a GIS/mapping problem, and could be tedious if borders must match.

3) A separation of the functions of database, GIS and map display is important. Often, the problems can be separated and attacked individually. The GIS should not necessarily be the main display mechanism.

4) As the source of data transfer and relationships, the GIS is crucial to cost-effective data handling. As such, it should be considered as a source of data which is just as important as field observations.

[4.4.3.3] Reporting and Data Availability

Implications

Some of these topics are discussed in the previous sections.

Much of the current problem with the inventory hinges on credibility. It is often the case that flexible and quick production of reasonable answers that are well-displayed adds greatly to that credibility. One of the great challenges for the Inventory Branch is to ensure quality control while widely distributing the data. Decentralization of the ability to ask questions, provide summaries and display those results is one of the keys to reducing the workload in Victoria while better serving the users of the data.

The current reporting system, mentioned earlier, is a good example of the direction in which all stewards of data should move. There are questions of confidentiality to be addressed when the Ministry releases data provided to it by private sources. Even when the MOF gathers data, there is some question of propriety, quite aside from the legal question of data ownership.

A good deal of the reporting for the inventory will be done for the purpose of planning. A central question with such data is: how well does it apply to the local area? The Task Force heard many references to errors in the local accuracy of inventory information. In many cases, it would appear that too much was expected of overall averages from the inventory. This appears to be a question of expectation control.

Many of the values assessed in local resource planning problems are much less precise than the inventory data, but there is little anxiety about these because little was expected of them. We must, in future, work harder at stating the precision which should be expected. The default expectation seems to be that high precision is available.

Advantages

1) The data is centrally controlled now. This is a great advantage for quality control.

2) Successful efforts are being made on the mechanics of providing and illustrating data, and there is a clear commitment to provide data to the users through the Districts.

3) Planners seem reasonably sure what they want, and it is mainly a question of access and putting the information into perspective.

4) The topography data needed by planners will be provided by TRIM, but it is not clear how it will be used, and if software is in place.

5) The Task Force reviewed the current summary data reporting system (FIR) of the Inventory Branch, and the following remarks are in regard to this system.

    a) This is one of the rare instances where a clear view of the roles of database, GIS and data presentation has been applied. This system is an excellent example of a number of general principles, and is to be commended.

    b) Reporting time and flexibility are excellent at the levels provided, and other information can be recovered in a longer time interval.

    c) About 85% of the Province can be described and the answers illustrated using a single source.

    d) The system is simple and effective.

e) The personal computer capability is a real advantage. This is an excellent example of central quality control with decentralized access to the data.

Concerns

1) Database management is a new activity. There is every reason to believe that serious problems will occur. Safety of data is of concern. An audit trail on changes is the minimum safety factor.

2) Derived data is too often kept while the original data has been discarded. Rounding and classification were, in retrospect, a mistake.

3) There are many parts of the Province not represented, and data on polygons without significant timber is sparse.

4) Many of the sources of current data have been lost. We do not know how closely a polygon was examined in the process of deciding the label it contains.

5) Previous raw data has been dispersed to Districts, lost or destroyed. It should have been stored centrally, and properly preserved.

Important Principles and Suggestions for the Next Inventory

1) Credibility comes from expectation control and ”truth in advertising”, not just better data. Credibility is partly a question of performance against expectation, not just performance against truth.

2) Availability is a serious concern, and sometimes a great deal more pertinent than accuracy. Perhaps we should give up a few plots and put those resources into data handling. Rather than try to provide data for all uses, perhaps we can simply ensure that other sorts of data are available.

3) We can never anticipate all the needs. We can never get the whole provincial database accurate to the ”local” level, because that level keeps changing. We need to provide a way to signal when a local study needs to be done, and provide the framework and advance information to make such a localized sample efficient. In this regard, perhaps a person who does technology transfer in sampling and local studies should be available from the Branch. This person would need a good background in sampling, Branch databases and good problem identification skills.

4) While data source is useful, it is no direct substitute for direct assessment of accuracy. Some indication of precision is, however, highly desirable.

[4.5] Updating the Inventory

Background and Implications

Inventory update is a process of keeping the inventory current by accounting for large-scale changes in area due to harvesting, insect and disease damage, fire, new roads, and for stand growth, history and treatments. The process is similar to keeping a bank book regularly updated to account for deposits, withdrawals and interest. Inventory update procedures include mapping of disturbance boundary changes using aerial photography and satellite imagery, and revising polygon information based on silviculture records and stand growth models. It is currently done every two years, but it is planned to be done on a continuous basis.

Once the initial inventory is in place, it must be updated by several processes:

a) GIS (see Section [4.4.3.2]) is used to update changes due to harvest, insect attack or catastrophic events.

b) Growth models (see Section [4.6]) are used to project the initial inventory to the present or to some future time.

c) Regular re-inventory of large areas as the initial inventory ages or particular areas are of special concern. This often includes modification of the inventory due to changes in standards (log scaling changes, for instance) or procedures.

It is item (c) which is the topic of this section.

The process can be broadly split into two parts:

1) Pre-Inventory Analysis A pre-inventory analysis is conducted to determine the costs and benefits of a re-inventory.

2) Re-Inventory Process The re-inventory may be only a massive update process or a complete replacement of the old inventory. It may, or may not, establish new polygon boundaries in the process. It is analogous to the re-inventory that takes place in one of several warehouses during the year. The extent of the update is usually determined by the accuracy of the current inventory, including stratification and classification.

Advantages

For the pre-inventory:

1) This well-intentioned approach, which asks what needs to be done (and where) before the process is begun, is very refreshing. User involvement seems to be quite good.

2) Change is slow and careful, and is occurring on areas which are separable and well-defined.

3) There is a consistent process for providing specifications for the project.

4) Retaining polygon boundaries, where possible, is a good idea.

For the re-inventory process:

5) The classified polygons provide a good base for subsampling of the land base during the re-inventory. This should be exploited.

6) The pre- and post-inventory information offer an excellent chance to quantify the improvement made by the re-inventory.

Concerns

For the pre-inventory:

1) There does not appear to be an overall objective for the reliability of polygon classification.

2) For polygons visited in the field, only the classification label is checked; actual volume is not. Therefore, there is no way of assessing bias or the degree of improvement that can be expected from a new inventory.

3) The methodology is not statistically based.

For the pre-inventory process:

4) Too little time is spent in the field by the photo interpreters.

5) The current, rather limited, database design of the F1P files restricts possible improvements and flexibility in the update process.

6) Much of the original data from the previous inventory has been lost. This limits the data available to the interpreter in making the newer classification.

7) MOF ground work is sparse, and consists mainly of interpreters training themselves. The data is not directly used in adjusting polygon volumes.

8) The re-inventory is really a reclassification process, not a statistically designed inventory, and it is not clear that the averages ascribed to these classifications are still valid.

9) It is not clear that the re-inventory process has improved the information in the inventory. ”More current” does not necessarily mean ”more accurate”. Better definition of border locations is not enough to ensure improvement in the quality of the inventory – it is only

one aspect of the problem. While large changes such as harvest or catastrophic loss are included, there may be better ways to locate many borders than by the use of remote sensing.

Important Principles and Suggestions for the Next Inventory

For the pre-inventory:

1) Reliability expectations must be set with regard to polygon classification. Evaluations of the need for re-inventory should be statistically based and include comparisons of current estimates and actual ground information.

2) Ranking for the updating processes should be based on the possible improvement that a new inventory would bring.

For the pre-inventory process:

3) When the probability of sampling (or using the data from) different polygons is not the same, this must be determined and proper weighting procedures used for estimation.

4) Any improvements resulting from the re-inventory should be quantified.

5) This methodology must be improved and statistically based. At least the classification error and bias of the current procedure should be quantified.

[4.6] Projection of Data

Background and Implications

Growth projection comes in two, basically different forms:

a) Short-term projection, for consistent reporting.

b) Long-term projection, for planning.

This comes under the direction of the Growth & Yield program in Inventory Branch when discussing natural stands, and involves Research Branch when we are dealing with the effects of silviculture, managed stands, and the hypothetical growth of future managed stands. These growth effects are important to the economics of managed stands, but the discussion here will mainly be involved with the inventory aspects of the subject.

<u>Short-term projection</u> (the change in the inventory at a small scale, to update it for a few years) is done by projecting the stand growth. This process is necessary to bring data up to the same time period, so it can be reported in a consistent manner. Since inventories are done in different years,

such a correction is necessary even when the inventory is recently completed. As the inventory gets older (by up to 10-20 years), it is “grown forward” from the current date. With a good starting point from the inventory, this process simply cannot go far wrong.

The second problem, long-term growth projections, is more difficult and carries much greater potential for error. This is the method used to produce initial AAC estimates, to provide planning information, and to develop logging plans.

There are two separate issues here:

a) Projection of the current inventory to some assumed point of harvest.

b) Estimation of long-term forest growth for stands which do not yet exist. These stands will be the result of management when the current stands are harvested. This subject has been addressed under Section [4.4.2.3], Site Quality, earlier in the report.

Projection of the stands to harvest can be a substantial problem for forest growth modelers. With a good inventory starting point, this problem is greatly reduced. The key here is to assure a good starting point based on actual ground observations, particularly by the measurement of basal area.

In addition, projections must be kept ”reasonable”, in that they agree with past experience in similar stands. This argues for maintaining records of previous harvests, perhaps from different sources like the operational cruise and the log scaling records.

Depending upon the growth modeling philosophy, the growth “potential” may be estimated, followed by reductions for “Operational Adjustment Factors” and losses not included in the data or the modeling philosophy used to make the projections. This matter of adjusting modeled results is not simple or easy, and falls mostly outside the inventory domain.

Advantages

1) The Forest Productivity Councils in BC have helped to coordinate growth & yield activities across the Province and to develop plans and standards.

2) Coordination and integration of growth & yield with the inventory and analysis components has commenced. A decision to use a single forest stand, i.e. polygon, as the basic area unit is a positive step.

3) The existing database is being reorganized to facilitate efficient processing and access. Obvious steps are being taken to standardize, summarize and do quality control work for the data which is available. While the difficulty of this work should not be underestimated, it is clear that honest efforts are being made in this direction.

4) Resources and expertise sufficient to maintain the present momentum appear to be committed.

5) Ecological classification is proceeding for all PSPs in the Province.

Concerns

1) There is no obvious way for VDYP to obtain the history of stands, and therefore to decide if it should estimate or project differently (e.g., thinned or fertilized stands).

2) ”Ground calls” are not utilized in a formal program of field validation for VDYP. There seems to be no large or coordinated effort to validate the method, though less formal evaluation seems to be comforting.

3) Little use has been made of the Research database, but perhaps that will change as all databases become more accessible.

4) Inventory links to growth models are poor. There is no way to know what the needs of future models will be, but detailed ”research” models will almost certainly require information which must be specially gathered for that purpose.

5) There seems to be a problem with how growth & yield information is used in the planning process. Planners may require more assistance from experts in growth & yield.

6) There is a current problem with making sure that all PSP data is readily available in a standardized summary form. This problem is being addressed.

7) The availability of detailed, ground-based inventory data for input into the models is of high concern. The use of non-traditional data sources, such as operational cruise plots, needs to be pursued.

8) There is evidence that some Ministry branches consider data proprietary. Data sharing amongst Ministry branches should be encouraged and facilitated.

9) Inventory Branch currently relies heavily on contractors. Caution should be exercised to ensure that the Branch maintains a permanent staff of expertise to enable high quality growth & yield development and analysis work.

10) Progress in dealing with managed stands has been slow; more coordination between Inventory and Research Branches should be encouraged.

11) Information is lacking for stand dynamics in natural stands.

Important Principles and Suggestions for the Next Inventory

1) Emphasis should be given to measuring tree and stand variables (e.g., crown dimensions and diameter distributions) which most models indicate can improve the accuracy of overall estimates.

2) Efforts should be concentrated in second-growth stands, mixed species stands, uneven-aged stands and managed stands.

3) It may be possible to integrate more precise Ecological Classification into the re-inventory process, making it available for future projections. As a temporary measure, map estimates of ecological units can be used either as an adjunct to plot measures or as a separate sample system.

4) Temporary plots are often later used in ways not anticipated. They should be set up so they can be relocated and remeasured in the future.

5) Second-growth stands are important for any inventory, particularly for productivity measurements that so strongly affect long-term growth projections.

6) Site index questions vs. ecological approaches may require some major splits in procedures between even and uneven-aged forests.

7) Projection of the inventory is an important consideration. Getting a static snapshot is not good enough. Some attempt should be made to estimate the amount of difference which growth models show when they are started for the <u>same</u> point. The difference from ”bare groun& includes separate assumptions and should be done as well, but it is of less interest from the inventory aspect.

8) Many of the systems in the MOF and the government in general should be able to correlate their answers with other sources. An attempt should be made to keep one or two comparable answers within all organizations. One suggestion would be to keep gross volume of live and dead trees 17.5 cm and larger, without any reductions at all.

9) Some mixture of site quality estimators should be considered in young stands.

[4.6.1] Endemic and Epidemic Growth Losses

Background and Implications

Insects and diseases cause mortality, reduced growth and wood quality deterioration. Epidemic losses are caused by catastrophic events such as an outbreak of spruce budworm, while endemic losses occur on a reduced, but regular, basis. Ideally, the inventory tracks the amount and causes of endemic losses to assess the potential for increased fibre production and quality if control measures are indicated.

Currently, epidemic losses are included in inventory updates; however, little is being done with regard to endemic losses.

This is not necessarily a problem. There are several ways to deal with this, and they are actively discussed in the growth & yield community. Similarity of data definitions and coding are some of the simple, but important, details.

The Task Force reviewed current plans regarding the gathering of growth loss information. It is the combined effort of several groups in the Province. The effort of providing a clear ”adjustment factor” for these effects is fairly recent, and will not be easy. Our concern was simply for the general direction for the overall effort.

Advantages

1) Several systems are already in place to track epidemic pest outbreaks.

2) Research Branch is in the process of setting up growth plots to track the effects of pests. We do not need to do anything about that.

3) The inventory plots will likely be too far apart to provide useful data on pest infestations, but may give some information useful for background studies in incidence or correlation with other parameters, providing that the information is available on a good database design.

4) Inventory Branch is already working on the standards which will be necessary for gathering this data from multiple sources.

5) The Technical Advisory Committee of the Forest Productivity Councils is attempting to ensure standard gathering of damage codes for future use. This will not solve the problem of past measurements.

6) The profile of this issue has been raised because some growth modeling is seeking to specify the potential growth, and then adjust downward to “Operational Adjustment Factors”. The advantage is that if falldown can be attributed to a cause, the impact of that cause and effect can be assessed. One problem is that these effects may not be independent.

Concerns

1) The exact use of the information to be gathered is not clear. It is very difficult to use this kind of data clearly and appropriately. A pilot project would really help here. The group who wants to use this data should assume that it is already available and try to make use of it in order to fix ideas and procedures (better yet – the raw data should be simulated and the summarization and interpretation process attempted).

2) Pest incidence is typically clumpy in stands. It is not obvious how this problem could be dealt with.

3) Crews may have to be specially trained to give consistent information in line with MOF standards on pest data.

4) Many data sources, such as TFLs, all use their own codes for past work.

Important Principles and Suggestions for the Next Inventory

1) Diameter distributions should be available from the raw data or the summaries.

2) Plans should be made to overlay historical information, such as pest incidence, on the location of sample plots. This requires actual locations of information sources.

3) The inventory data, and possibly the growth from that description, will be adjusted by damage and pest information. This should be designed into the use, storage and reporting of the data, if possible.

4) Methodology should be developed for acquisition of endemic pest loss data and its prediction.

5) Pest risk and hazard rating systems should be improved.

6) Growth models should include the effect of pest losses.

[4.7] Yield Analysis and Harvest Planning

Background

Planning activities undertaken by the MOF and others are the largest single outlet for inventory data. The process (yield analysis) for determining an AAC relies heavily on forest inventory, growth & yield and timber management and silviculture assumptions, in addition to other resource inventories and management constraints.

Harvest planning, commonly projected on a 20-year horizon, makes use of the same data to identify feasible geographic locations upon which to base detailed 5-Year Development Plans which specify cutblocks, buffer strips, roads, and harvesting methods.

Local Resource Use Plans, which are developed when multiple resource values and proposed management practices may be in conflict, require the most detailed information available.

Advantages

1) Social aspects are included along with the natural resource information.

2) The planning process combines several disciplines, and may provide a focus for the importance of standardization in measurement systems.

Concerns

1) The process is not particularly well defined. This is not a criticism - it is simply the nature of local planning activities.

2) The setting of allowable cuts has been virtually de-coupled from the analytical processes of inventory and growth. This is likely to cause a credibility problem which cannot be solved.

3) The process of allowable cut determination is mysterious enough that it invites credibility problems.

4) There seems to be a problem with localizing broad categories of data for local situations. Part of this problem is that nobody has known what precision to expect with this data.

5) Long-range planning means that areas which have been cut have a potential yield as important as. the areas still uncut. Samples from both types need to be handled correctly. Young stands need to be assessed for productivity.

Important Principles and Suggestions for the Next Inventory

1) The whole forest land base (including cut and uncut areas) is important for long-term planning. Inventory planning should ensure that efforts are properly directed to both.

2) Current deficiencies of models which require a great deal of aggregation should not tempt us to provide broad categories. Short-term processes should change to humor longer term processes, not the reverse.

3) The structure of the inventory should allow localization of broad types to a particular area.

[5.0] Other Timber Inventory Processes

Background and Implications

An overall provincial timber inventory presently must be assembled from several different sources. For crown forest land outside TFL's, the Ministry of Forests' inventory program applies. Other organizations have developed timber inventory data in conjunction with their management responsibilities. These inventories include significant amounts of private land, in addition to crown land, and can be more intensive than the provincial MOF inventory. For example, TFL and private land inventories may contain additional information such as vegetation and biophysical mapping.

The basic inventory processes are similar in both MOF and industrial inventories. However, because of minor differences, such as in classification definitions, combining the inventories can be very difficult. Such incompatibilities limit the feasibility of producing an overall inventory by combining existing inventories except perhaps for very broad, general purposes. In some cases, differences in map bases and GIS systems exacerbate this problem.

A number of other branches and agencies collect data that contribute, or have the potential to contribute, to the inventory. In some cases, however, the sampling framework for these activities is quite different, thereby creating compatibility problems.

[5.1] TFL Inventory Processes

Background and Implications

One of the obligations assumed by TFL holders as part of managing a Tree Farm Licence is to develop and maintain a timber inventory. This was an essential element in bringing the licensee lands under forest management. These inventories began in conjunction with the granting of TFL's (then Forest Management Licences) in the 1950's and have evolved over the years as methods, standards and technology have changed. In general, TFL inventories are more intensive with emphasis on ground sampling and localized growth & yield. Linkages with the provincial inventory have become closer over time. However, differences in design, technique, definitions and systems have limited information exchange.

It should be pointed out that while TFL inventories may be different in standard than those of the MOF, a strong review and approval process by the MOF has long been in place.

In order to assess TFL inventory processes, specific inventories of the following TFL holders were reviewed:

- Western Forest Products Ltd.
- MacMillan Bloedel Ltd.

- Pope and Talbot Ltd.
- Weldwood of Canada (Cariboo) Ltd.

The comments in the remainder of this section reflect combined impressions from these reviews.

Advantages

1) Some diversity has fostered change in inventory techniques and practical research and development. The use of these techniques on the ground has provided insights which would not otherwise be available.

2) Much of the history information about forest stands is available from the TFL holder (but not in a consistent format or with standard definitions). Some history systems are linked to the inventory information, and at least are on the same map base.

3) The company cruising staffs have some of the most intensive experience and training in the Province, along with consultants who regularly do this work.

4) The close association of company research and growth & yield groups with their inventory groups has led to advantages for all of them. This. mixture of experience and viewpoint has led to better data standards and definitions – an easier task in a smaller organization.

5) Some of the strengths of the industrial sector inventories were:

    - Strong ties to planning systems.
    - Long-term commitment to growth & yield plots.
    - Consistency in technique and definition.
    - Changes held in suspense until the quality control is done.
    - GIS links were useful, practical and tested.
    - Polygon size was small enough for operational use.
    - A large percentage of the polygons were ground sampled.

Concerns

1) It is virtually impossible to combine the TFL inventory data with provincial information, due to:

    - Differences in data definitions.
    - Differences in classification.
    - Database differences.

Mapping problems include:

- Slivers created by different map bases and boundaries.
- Ownership boundary differences on the map base.
- Compatibility of GIS systems.

2) Some inventory definitions have been lost, changed at unknown dates, or are just incompatible with current MOF uses. This is particularly true when inventory was not centralized or done with permanent crews.

3) Data and technique changes are difficult, since they involve many parts of the organization, historical records and even tax or other legal implications.

4) Transfer of map and attribute data is a problem between TFL holders and the MOF. Some types of standardization are desirable, without the rather heavy-handed approach of strongly limiting hardware and software support.

5) There is some duplication in MOF data requirements. It would be beneficial if these could be decreased.

6) Problems with uneven-aged growth modeling are difficult, and must be addressed by the MOF in some way. While the inventory can describe the stand now existing, growth potential and expected harvest remain a problem. Perhaps such estimates should be constrained by historical harvest data. At the very least, a range of historical harvest amounts should be available, then the modeler might argue that they are moving along the upper level due to increased silviculture, better protection or some other line of reasoning.

7) Is ”one age” for all-aged stands really sufficient? Are there other indicators of maturity or structure which are important to use?

Important Principles and Suggestions for the Next Inventory

1) The experience of company inventory staff is an asset when it comes to field technique development.

2) The provincial inventory should be independent of ownership boundaries, and not plan to merge data with private sources. It may be possible to use the private data source as an estimate of stand type before it is visited, or as a separate overlay.

3) A common basic set of inventory information and definitions would be highly desirable for all organizations in BC.

4) Central control and permanent staff are a great advantage, over the long run, for any organization.

5) Field work often suffers in the budget process. One of the problems is loss of knowledge about standards and the change of these standards (worse yet – both together).

6) We should consider broad definitions of all-aged stands.

[5.2] Silvicultural Surveys

Background and Implications

Silviculture surveys are done to plan and prescribe silvicultural treatments and to monitor their results.

In most cases, silviculture surveys look at young immature stands in the 0-15 year age range to determine stocking and to provide a new inventory label, or polygon description, following harvesting.

The free growing survey, which is required to be done within the latest free-growing date, relieves a major licence holder, or the Ministry under the Small Business Forest Enterprise Program, from obligations of the Pre-Harvest Silviculture Prescription.

Silviculture surveys also look at older immature stands in the 15-25 year age range to determine treatment options after free-growing or to provide a revised inventory label following treatments.

The Pre-Harvest Silviculture Prescription survey determines the method of harvest and the treatments required to regenerate the harvested area, but does not result in a change of inventory label.

Advantages

1) This separate system is available to cheek the inventory values.

2) The data is available at younger ages than would be the case with operational cruise data.

3) There is (apparently) near compatibility of methods, but it is not clear that this is true, and it will be some time before the details are well known.

4) The harvest database would be an interesting check against projected inventory numbers.

5) Much of the detailed ecological data will become available for stands not visited by the inventory (although the operational cruise will have been done). This could be compared to the estimated information from large-scale ecological maps.

Concerns

1) Some potential database problems may be underrated. The system may be unduly complex.

2) Differences in procedure, compilation and definition are bound to cause problems when comparisons are made with the two sets of numbers.

3) Just as with cut-cruise comparisons, the data available are from a selected set of the population. They can be expected to show different relationships and values.

Important Principles and Suggestions for the Next Inventory

1) If possible, polygons should be the same in different systems. Then, only the data and its structure needs to be specific to the user. In this case, the cut blocks are common to both inventory and silviculture. Every effort should be made to have them formed from a common set of polygon lines.

2) Definitions beyond the ordinary interest of inventory should still be looked at, to ensure that Inventory Branch can use the results if another branch decides to take a different approach. A well-considered approach will likely be accepted by others who lack expertise or time to consider the problem.

3) Data collected by Silviculture and Inventory Branches may differ for the same area. The silviculture data is from a selected source (the complement to the standing timber) and should be expected to show differences. How will the discrepancy be examined?

[5.3] Operational Cruises

Background and Implications

Operational cruises represent an important part of the short-term planning process for both the forest industry and Small Business Enterprise Program. Cruises represent a substantial cost amounting annually to from 12 to 15 million dollars. This program is necessary to provide detailed stand-specific data that the provincial inventory was never intended to provide. Small areas available for harvest are delineated in 5-year plans and an intensive sampling effort is undertaken (in the range of one sample plot per 2 to 4 hectares) to provide volumes by species and grade information as well as terrain attributes influencing harvesting. These data are used to help partition the total provincial stumpage charge among harvesting units. In some instances, the data are used to strengthen inventory data, but mostly not.

Valuation Branch controls this process and while there are similarities with the approach used by Inventory Branch, differences exist. Furthermore, there is no assurance that comparability can or will be maintained as utilization standards shift.

Operational cruises provide the most direct means of comparison between standing and scaled volumes. However, such comparisons are confounded by estimation of residue levels. Similarly, the cruise data can be compared with inventory data, but the different sampling frame and differences in compilation introduce nearly insurmountable uncertainties.

Advantages

1) A huge number (nearly 300, fully measured, ground plots) are installed every working day in British Columbia. These are all processed in a common way, and offer a resource of considerable value. There is no doubt that there are possible problems with the selection of these plots, but perhaps that can be overcome.

2) Methods for plot measurement are standardized.

3) Because so much of this work is done by consultants, there is a real interest in making the procedures consistent and correct everywhere in the Province.

Concerns

1) Time constraints are reducing the utility of the reports for AAC purposes.

2) Summary reports on a management unit basis are not available.

3) Objectives of the system are in a state of flux and methodology has been volatile.

4) Procedures give results that are incompatible with inventory.

Important Principles and Suggestions for the Next Inventory

1) Stand volume is one number in a whole system of numbers and data uses. Some thought must be given to providing answers in terms that can be compared with other users' information.

2) Where possible, everyone should bend a bit toward common definitions, or at least provide answers based on one common definition for each important variable. Having a commonly acceptable standard toward which everyone can move is highly desirable, even if they move slowly toward that goal.

3) It may be possible for all forest inventory groups in the Province to agree on a framework of well-defined information which everyone can report upon and transfer to others. This should be clearly designed and well worked out, but every user should be encouraged to keep data in the way it serves their own system at the same time. If a database system could be designed to hold both types of data (standard and user defined), and be used by everyone

in the Province, this would be a great advantage. Even attempting such a goal would iron out many problems shared by different groups.

[5.4] Residue and Waste

Background and Implications

The close utilization policy introduced in 1966 required that residue and waste be measured. The emphasis for sampling at that time was primarily cut control. Measurements for utilization were performed only when waste was considered flagrant. During the 1980’s emphasis shifted from cut control to the enforcement of utilization standards. Current policy requires that all harvested areas, on most tenures, be sampled within 60 days of completion of primary logging.

It should be pointed out that the term ”waste” is a technical term with a long history, and does not always indicate errors made in the logging process. In fact, some of the wood which is technically considered ”waste” is removed during logging. The concern here is with the process of measuring the volumes of wood left on the logged area.

Advantages

1) By virtue of its history and development, it follows many of the conventions of scaling.

2) Many of the people doing this work have cruising experience, and also a scaling background. This offers the opportunity to bring these disciplines closer together when needed, yet maintain clear differences when that is desirable.

Concerns

1) The process is not well funded, and time constraints are causing difficulty.

2) Attempts to simplify the system, and the fact that it is moving away from the cut control orientation, are leading to difficulties. It is important to have procedures that can compare (scale + residue) for volume, species, decay percentage and a number of other parameters. Such comparisons must at least be available on a sampling basis, so procedures should be developed for this purpose. The current system is cumbersome, changes regularly, and does not lead to values which are comparable with those from Inventory Branch.

Important Principles and Suggestions for the Next Inventory

1) As with scaling, procedures should be at a more general level, if possible, than the inventory alone needs. Residue is one of several systems which offer the possibility of acting as an early warning system for local problems. At the very least, it is needed as the missing link that balances the scale figures.

[5.5] Scaling

Background and Implications

Provincial policy requires that timber harvested from crown or private land be scaled in accordance with the Forest Act and the scaling regulations. This information is the basis for asserting government financial interest and administering provincial cut control.

Scaling of timber evolved from simple tree counts to a complex system of measurement and grading. Two systems in use today are piece scaling, used primarily on the Coast, and weight scaling, used primarily in the Interior.

The scale has the potential to supply several sorts of information which can verify the inventory data. As well as species and volume, the decay percentage could also be supplied. While these numbers may not be directly and precisely applied to the inventory, they serve as a comfort mechanism when the comparison is reasonably close.

Scaling is traditionally held as the ”truth” against which an inventory should be compared. There are many technical reasons why this is not the case, but the details are of small importance. This argument is not as strong with comparisons to the operational cruises, which are specific to the logged area. Even here, there are reasons why differences should be expected.

Advantages

1) The process is well defined, data collection is automated, and the process has well-accepted quality control, accreditation processes and training systems.

2) The process allows new data collection by temporary category. This can be done at either the check scale level or for sections of the wood supply. This allows short-term studies, and random or targeted quality control procedures.

3) The accounting process is worked out to the point where it would allow compilation based on various supply areas. Even if the accuracy of the accounting process is open to question, the structure is an advantage.

4) The check scaling system is a real opportunity for testing new procedures, establishing small-scale samples and gaining feedback on a trial basis. A sampling scheme to draw such a sample should be available.

Concerns

1) There are some differences in procedures between scaling, residue and cruising. These probably cause less of a problem than they do anxiety. When two procedures cannot be directly compared, the tendency is to assume the worst.

2) It is very limiting to have no indication of both net and gross volume in cruising, scaling and residue. This greatly limits the comparability of the systems and the ability to spot problems in the factors used, records kept or procedures instituted.

3) Scaling is a very traditional field. While the consistency in the field is one of its strong points, it also limits the speed and acceptance of change.

4) Scaling is essentially a sampling process, but Valuation Branch seems to have limited access to statistical and sampling advice.

Important Principles and Suggestions for the Next Inventory

1) The scaling system should be used as a check on expected wood flows and other inventory projections. Realizing that there are many reasons that the cruise should not match the (scale + residue), it could still be valuable to have an automatic system operating which gave the comparisons for volume, species, grade, decay, etc. over a large geographic region. The cruise methods must be compatible enough with the scaling system to allow this.

2) Net and gross scale, at least on a sample basis, should be available when necessary, and certainly should be available when items of interest arise. This means that the procedures and data processing should be in place before they are needed.

3) Where there are differences in measurement systems, a serious attempt should be made to gather data in a general enough way that it can humor either processing system. Procedures should be put in place in anticipation of later coordination and comparisons.

[6.0] Administration of the Inventory

[6.1] General Comments

A successful Provincial inventory program must be linked to a well-defined administrative process. The components of such a process should include:

a) A statement of objectives that addresses needs at the provincial, TSA, watershed and municipal levels.

b) A business area analysis which defines the roles of the Branch, the Regions and the Districts.

c) A pre-inventory analysis process which involves input from clients and users.

d) A training section.

e) A technical audit group.

During the past 15 years, the administrative fabric of the inventory process has been threatened by a series of events:

- Decentralization within the Ministry.
- Regional and District reorganization.
- Budget freezes.
- Privatization.

The Forest Resources Commission recognized the problem and recommended changes. Special initiatives and projects which are currently underway are described in Section [6.2] following.

[6.2] Specific Programs

[6.2.1] Inventory Training and Planning

Background and Implications

Inventory Branch has put in very few field inventory plots in the last decade. Many of the experienced staff have moved on. In addition, the Branch has added many new staff members with no previous inventory experience. There is a serious need for training, and for the anticipation of future developments in the Branch.

Any new inventory will last a long time. Errors due to lack of training and quality control will re-occur. There will be a great need to develop career path specialists to direct the work inside the Branch and to set standards and policy for consultants outside the Ministry. In addition, other specialists must understand the structure of the new inventory, and know how to modify, interpret, recompile and add to the next data set.

Inventory Branch recognizes these problems and has already instituted a new and greatly expanded training program.

Advantages

1) The deficiencies have been recognized and a program is being developed to remedy them.

Concerns

1) Non-Branch groups are often the first to actually try procedures and to learn the lessons from them. How will the Branch learn the pertinent lessons?

2) How will innovation be encouraged without sacrificing necessary consistency?

3) Photo interpretation certification, though well intended, can be superficial.

4) Training is no substitute for experience and judgment. It is also necessary to anticipate changes in the profession.

5) Outside influences and connections are desirable. When possible, MOF staff should be mixed with other people during training. MOF-only sessions may invite tunnel vision.

6) It would be easy to slip into training for Branch needs, not for client needs. It is important that training not just be oriented to Branch procedures, but to general principles and future options.

7) There is no formal analytical process which has set the dollar requirements for the inventory. While $l/ha is not a small amount, it certainly is not large compared to the anticipated expenditure from Silviculture, for instance. Even planning activities will eventually amount to a considerable expense in comparison to the overall inventory.

Important Principles and Suggestions for the Next Inventory

1) Distribution of information on computer files (such as E-mail or word processor disks) will aid in cross-referencing and the transfer of exact definitions.

2) In addition to the training, a record of that training is desirable.

3) Training (or familiarization) for District and Regional staff may be on current procedures and standards - but there must be a career path for professionals who wish to deepen their general experience, judgment, and insight.

[6.2.2] Business Area Analysis

Background and Implications

The Business Area Analysis is a major planning tool within Branches of the MOF. It focuses on planned development in the next few years, and acts to coordinate several groups who might otherwise be moving apart.

Some of the options for performing a new inventory may be constrained by the current business area analysis. For example, staffing and equipment development of the Branch are a part of this program.

Advantages

1) The intent to give Districts access to (and responsibility for) the data is good. The databases can be reconciled at intervals, and an ”official base” issued at 6-month or yearly intervals.

2) Integrating the GIS and the relational database is a positive move, provided that the linkage does not result in slowing down both systems. Much of the work can be done as entirely separate functions.

3) The effort on training is excellent, particularly with the current lack of field experience of new staff.

4) Budget support and administration seem to be strong points with the current Branch structure.

5) The philosophy of ”problem definition first, data gathering second” is very astute. Our problems are often that we have too much questionable data under poor control, not that we have too little data.

6) A seamless database is clearly desirable, as is one without missing areas for TFLs, parks, etc. even if the data is sparse within those areas.

Concerns

1) Maintaining the advantages of centralized quality control and procedures while the system access and updating are widely distributed will require hard work, good relations and

accurate forward planning. By the time a problem is noticed, it will often be too hard to fix. Anticipating problems and fast attention to District concerns must be a major effort.

2) Quality control on data change with a decentralized system is complex. A major problem is correction to the database involving one parameter which also effects others. For example, a change in the number of trees/hectare for the 12.5 cm + utilization level will result in a change for all lower utilization levels. In addition, there may be other values (diameter distributions, average diameters) which will all be affected.

3) It will be hard to develop and maintain expertise in the Districts. This is particularly true without career path development.

Important Principles and Suggestions for the Next Inventory

1) While the Branch intends to manage change, some of that change could well be managed by others. Perhaps maintenance should be a local problem (with tools and techniques provided by Branch). The inventory should focus on the starting point of all of this. Updating is often a higher priority than re-inventory.

2) Within the MOF, underlying data quality and integrity concerns cannot be offset by surface appearances - that will just result in credibility problems. On the other hand, fast response and good presentation certainly help with public perceptions.

3) While data may be kept in a central location for quality control, small subsets of the information should be available for PCs and workstations in the same basic formats, with the same apparent software functions.

4) Career paths should be developed.

5) Where possible, polygon boundaries should be common among clients and users. This can facilitate the transfer of data and result in improved efficiency not only among MOF Branches, but also among Ministries.

6) Data from any source should be accompanied by an indication of its reliability and quality.

[7.0] Integration of the Timber Inventory with Other Types of Inventory

Background and Implications

The current timber inventory integrates other resources information using Environmentally Sensitive Area (ESA) designations on forest cover maps. ESA's reflect the environmental, technological, social and economic constraints in force at the time of inventory. They are designed to supplement a resource database that is necessary for integrated forest management at various levels of planning intensity.

ESA's are identified through photo interpretation, ground investigations, helicopter flights, and data provided by other resource agencies and public interest groups.

The question of when to combine different resource inventories (at time of data capture or after this process) is one which depends upon the techniques used by the sampling system and the training needed by field crews.

[7.1] Wildlife Inventory

Background and Implications

The present Wildlife Habitat Inventory was developed from the Canada Land Inventory (CLI) program of the late 1960's and early 1970's. It resides with the Habitat Inventory Section of the Wildlife Branch, BC Ministry of Environment, in Victoria. The program considers ecological components in the landscape including climate, soil, surficial material, topography, vegetation and animal habitat use, with the intent of classifying and mapping ecosystems. The main uses are to assess current suitability and potential capability of the land to support particular animal species and to identify enhancement and other management opportunities.

The wildlife program manages for 630 species of terrestrial vertebrates found in BC. Forest inventory information, mainly in the form of cover maps, is a prime source for ecological mapping. However, the present timber inventory and forest cover mapping lacks many of the ecological factors that are required to assess animal capability and suitability. Information on snags and down material would be a useful addition to the timber inventory.

Advantages

1) While climate is not yet a part of the timber inventory process, the other three major criteria – topography, soil/terrain/bedrock, and vegetation – are clearly of mutual interest to both timber and wildlife.

Concerns

1) How will a digital terrain model be obtained in order to add topographic characteristics to the inventory? Presumably, the TRIM project will provide basic information, but is the software available to ask questions based on this data and to provide ”theme” output on the GIS system?

2) Will ground crews be able to obtain the necessary information on plant communities from the ecological classification system which will also serve wildlife purposes? Since many of the polygons will not be visited, will the characteristics be well enough correlated for the information to be reliable?

3) More detailed categories of Wetlands, Alpine, Grassland, etc. can be discriminated through satellite imagery or air photo interpretation and labeled more closely by classifiers, but will they need to be visited? If so, will the timber inventory handle this, or should it be done separately? In this case there could be a clear division of responsibility, but how will the information quality control be coordinated for forestry stands which also include wildlife information?

4) Wildlife habitat inventory involves ecological habitat units which do not match with the polygons mapped for timber inventory.

Important Principles and Suggestions for the Next Inventory

1) The land base and the ecological unit base underlie any inventory. Care must be taken to describe these items in a way that is compatible for merging separate databases and to make reasonable label discriminations even when timber is not present on the polygon.

2) The new inventory should be able to match map bases so several items can be combined with the timber inventory, and so any classifications available can be verified during field work. If possible, this means having preliminary estimates for these items before ground work (or photo work) is applied to an area. Specifically:

   a) Topography - from a digital terrain model.

   b) Climate information - from some outside source.

   c) Soil information and geology - from an outside source.

   d) Land use information and non-timber categories.

   Use of the same map base is highly desirable for obtaining this data.

3) Ground sampling should be designed to acquire or verify:

   a) Vegetation information useful. to other disciplines.

   b) Animal use and suitability.

[7.2] Recreation Inventory

Background and Implications

The mandate of the Ministry of Forest's Recreation Program is to manage and protect recreation resources on Provincial forest land. Identification of recreation opportunities and features within this land base, is the goal of the Recreation Inventory. This is done by identifying natural amenities such as lakes, mountains, etc., along with some man-made, historic and cultural artifacts, and some abstract amenities such as viewscapes, hiking and siding experiences. Carrying out a recreation inventory involves five basic steps:

1) Determining what features have recreation value to the public.
2) Identifying and recording features and amenities location.
3) Determining the sensitivity of the feature to commodity resource development.
4) Determining the present state of development and indicating a present or potential use.
5) Digitizing the information as a layer on 1:20000 FIP maps.

One important goal of the Recreation Branch is to inventory recreation values and to digitize information on all 7000+ mapsheets in the Province. Once completed, this database will be used in all levels of planning.

Advantages

1) The process seems fairly flexible, and standards for describing areas also seem to be well described in the recreation field.
2) There is full coverage of the Province, although not the same level of completeness of data is available everywhere. It is tied to the Canada Land Inventory system and the structure appears to allow a decentralized administration.
3) A link to inventory information has already been attempted.

Concerns

1) Sources are variable, bringing with them all the problems of variable line and point location and of variable data precision.
2) There are quite limited data fields in the current system.
3) There does not seem to be a good way to ask questions of the system.

4) Only 14 of the Districts are digitized, and only about 1/3 of the Districts have a good recreation inventory.

5) The level of update is variable across the Province.

6) The system seems to allow large personal biases in the interpretation of data - and these may not be subject to improvement or change at a later date.

Important Principles and Suggestions for the Next Inventory

1) The timber inventory must anticipate matching up with line and point data from other sources, even if inventory only uses polygon information.

2) Resolution and source are part of any information system, and the date of information should be provided in many cases.

3) More information is needed if this data is to be used for spatial planning.

4) Confidential information is a problem, both in gathering and distributing the data.

[7.3] Range Inventory

Background and Implications

Range inventory, which began in the 1930’s, consists of four major components:

1) Range improvement mapping (fences, water development, logging, etc.).

2) Administrative boundaries (units, pastures, etc.).

3) Weed mapping.

4) Range type mapping.

Data is collected about vegetation communities and forage production. Development of vegetation-based range ecosystem guidebooks is being considered.

Attempts have been made to relate forage production to forest cover polygons and forest classification; however, the correlation is not sufficient for estimation of the forage resource. Range inventory requires information on the total land base, not just forested areas.

Advantages

1) General range types use existing forest cover polygons. It may be an advantage to have different groups gathering the information.

2) There has been no large commitment for ecological range inventory at present, so change is not as disruptive.

3) The range inventory is inclined to use the ecological approach, which is an advantage, and fits in well with the forest inventory approach. Attention to soil polygons fits in well with several other inventory considerations.

4) There appears to be a good link with wildlife concerns.

5) There is an attempt to indicate yield - similar to the forestry concept of site index or yield class.

6) Some of the main attributes of a range analysis seem to have been developed and well considered.

Concerns

1) Forest cover classification labels cannot be used to refine forage production estimates because there is no useful correlation between forest cover and forage production.

2) The current data is not fully entered into computer form and available.

3) The system seems oriented toward map symbols, rather than computerized data which can be used for a variety of purposes.

4) The range inventory system needs substantial work before it is complete and well developed in terms of definitions and measurement.

5) Provincial coverage is not complete, and it is not clear how this data will be updated.

Important Principles and Suggestions for the Next Inventory

1) If a new, range vegetation-based inventory is initiated, range and timber may become separate polygons. Coordination will be required to ensure compatibility.

2) Range information should be coordinated with wildlife needs.

3) In so far as possible, ecological mapping should be used for this and other inventories.

4) Although annual plant production estimates (biomass) are complex to measure, attempts should be made to provide for them in the future.

5) The range inventory probably will have to be linked to another base in order to be completed and updated.

6) Non-forested units need to be better delineated and labeled. This is especially important for wetlands, grasslands and alpine areas. Processes for updating this information must be developed.

[7.4] Old-Growth Inventory

Background and Implications

Old-growth forests in BC represent a wide range of spiritual, ecological, economic and social values. The attributes contributing to these values are complex and in many cases, difficult to measure. A strategy has been developed to identify, and conserve in a wild state, representative areas of old growth. Also, certain attributes of old-growth must be identified and maintained in the managed forests to support species with varying degrees of dependence on old growth.

The old-growth strategy expects to draw heavily on the inventory and has proposed a three-year program to improve resource inventory information.

Advantages

1) Considerable work has been done with this topic, and a central group is available to assist with the details.

2) Their approach is much the same as we anticipated - sieve the land base to identify potential areas, then test for specifics in the field.

3) They have preliminary estimates now, and are working for more accurate estimates using the current Inventory Branch classification.

4) They already have specific data requests, and these seem to be about what we would have suggested.

5) Considerable guidance is available from the U.S. experience in struggling with this issue.

Concerns

1) No firm definition is likely in the short term, and it will probably change over time.

2) There is no sampling technique for determining ”Old Growth”, and none is likely in the near future.

Important Principles and Suggestions for the Next Inventory

1) High-profile items will come up before another inventory is made. We must be prepared to add these items to the existing base.

2) Sometimes the best that can be done is to estimate the percent of land in a category and the area it might fall within. Geographic location cannot be estimated except in isolated instances. Perhaps we also need to know that areas are not in a particular category. For example, the database should state ”Old-growth [Yes, No, Unknown]", not just [Yes or blank].

[8.0] Client Needs: Present and Future

1) Inventory Program's clients are primarily District staff. However, there are many other users of the Inventory Program products. These include:

   a) Other branches of the Ministry of Forests (e.g., Valuation, Integrated Resources).

   b) Other BC Government Ministries (e.g., Environment, Lands and Parks, Tourism, Economic Development).

   c) Federal government agencies (e.g., National Forest Inventory Statistics, External Affairs, Native Affairs).

   d) The private sector (resource-related corporations, companies and consultants, environmental organizations, press, general public).

2) The users obtain inventory products mainly through the Forest Districts. The main products are:

   a) Forest inventory digital data (maps and associated attributes), regularly updated.

   b) Standard provincial, regional and TSA reports on status of the provincial resource.

   c) Standard and special inventory reporting systems (FIR and PSR).

   d) Special products, e.g., Vancouver Island's forest map.

   e) Loss factors for valuation purposes.

   f) The Variable Density Yield Projection System (VDYP).

   g) Permanent and temporary sample plot databases.

3) Uses of these products include:

   a) Broad planning (satellite imagery).

   b) Operational planning (harvesting).

   c) Land use planning.

   d) GIS analysis (TSA and Local Resource Use Plans).

   e) Generation of statistical reports.

   f) Compilations of net volumes and grades.

   g) Updating and projecting forest inventories for yield analysis.

Future clients will continue to be the Districts, as well as the general public and other present users. Additional users in the future will include international organizations such as the United Nations agencies.

Future clients will want to be able to easily integrate data from a variety of sources, and to different levels of complexity. To meet these and other future information needs will require a good database design.

[9.0] Recommendations

These recommendations arise from the statements of ”concerns” and ”suggestions for the next inventory” itemized in each section of the report and should be considered in that overall context. They are grouped in the major phases of the provincial inventory as diagrammed in the flow chart in Appendix IV and outlined in Section [4.2] Overview.

Administration Issues

1) The Province should institute at least one entirely separate audit of the major inventory parameters, to assure the public that any future inventory is acceptable.

2) Inventory Branch should make sure that career paths are developed which will retain practical expertise in the technical aspects of inventory within the MOF. The use of consultants should not be seen as a substitute for such staff.

3) Any pilot projects for the design of the next inventory should be used as an opportunity for the Inventory Branch to design and assess the administrative procedures to be used along with the technical processes. Clear processes of communication, quality control, and correction mechanisms are essential.

4) A committee of well-qualified individuals should proceed with the design and testing of the next inventory, augmented by specialists in the mechanical aspects of the processes (such as field plot installation or mapping).

5) The inventory design group for the new inventory should follow well-accepted and credible procedures, and see that the general framework is laid out for professional review. The system should be simple to audit in whole or in part. The ground samples must be placed by a valid sampling scheme, and more informative estimates of sampling error must be provided.

6) A system must be designed which will allow more accurate estimates of stand parameters on localized areas, and this method of valid sampling for increased accuracy should be readily available from Inventory Branch. A similar sampling scheme should be designed for anyone wishing to check the accuracy of the inventory figures.

7) The next provincial inventory should cover the entire land base, without exception. It should be more oriented toward describing overall vegetation types, as well as obtaining timber information. Differences in regional conditions should be considered, and different techniques used when necessary. Cultural definitions should be avoided.

8) The user involvement for the proposed pre-inventory analysis is good. The pre-inventory should verify the accuracy of current estimates of polygon volume by actual ground measurements, and use some reclassified polygons to estimate the probable increase in the

accuracy of any re-inventory process. Using this ranking, if a re-inventory is called for, the changes made by the re-inventory process should be reported after the project is completed. It should not simply be assumed that the process provided better data.

9) There is a need for a more formal plan for deciding appropriate expenditure levels on the next inventory. It would be better to do the project by parts, each of which was adequate, than to do a less than adequate project on the whole Province.

10) The system should allow for decentralized entry of data, but with some amount of central quality control. As soon as data is checked for quality control, it should be dispersed to users who can analyze it themselves. Questions of confidentiality should also be considered by the Branch, and methods of estimating the accuracy of fine entries should be developed.

Phase 1: Forest Cover 1 / Base Mapping

11) The TRIM map base is essential to the integration of future separate inventory efforts. It could account for large savings in this respect, and should he as widely used as possible. Consequently, the Province should arrange for it to be easily and widely available, and consider the prospect of making it available free of charge. If organizations wish to participate financially, it should be in deciding the order of mapped areas. Once mapped, the data should be available at no charge.

12) The inventory polygons on the map base should have boundaries which are as universally useful and stable as possible, using topography and ecological features as well as stand characteristics to accomplish this. This will promote the use of common boundaries by different users. Each of these polygons should have a permanent and unique identifier tied to the inventory database as well as to the GIS system.

13) The current classification method is satisfactory, with only a few changes. Other sources of remote sensing should continually be explored, with the systems designed so that changes in data source would not be overly disruptive. The ability to ”drape” maps over remote sensing data should be augmented, and line and polygon accuracy should be incorporated into the database. The original classification for the polygon should be retained, even if better estimates are later incorporated. More informative estimates must be gathered on non-forest polygons.

Phase 2: Classification and Reporting

14) Field procedures should be well-documented, pilot-tested and widely reviewed by the inventory community before implementation. It is very important that the systems be successfully implemented in several areas before they are tried throughout the Province. The procedures should be archived as well as the original data which they produce. Where possible, the name of the person doing a body of field work should be recorded.

15) The database should be officially released at intervals, and remain stable during that period. It should then be permanently archived, at least as ”hard copy”. The polygons and the database should have the capability to be transferred to personal computers.

16) Field and office procedures should be available in computerized (word processor) format, and consideration should be given to describing all procedures in video format as well as traditional manuals. Original materials and records should be archived in ”hard copy”, as well as computerized format. Locations of field plots should be noted in the database and on maps of the period, and the proper weighting of the plots should also be permanently recorded.

17) The use of site index, based on ”top height”, is a desirable technique. The inventory should anticipate the desire to correlate such site quality measures with ecological measurements, and explore better methods for Interior all-aged stands. The resolution of problems with using site index curves on older age classes should be a priority. A geo-referenced database with good ecological mapping and descriptions will also be helpful in this regard.

18) The Inventory Branch should establish a group to design and build a database for the next inventory, and coordinate the definitions as widely as possible. Outside experience should be utilized, and the system should be built and tested with the same group. This should begin as soon as possible. In addition, it should be set up in anticipation of the transfer of this data to a personal computer database for the analysis of particular small areas. A unique polygon identifier is the basic link for all data.

19) A ”seamless” GIS system should be utilized, and it should maintain some indication of the accuracy of the line entries. Systems should be quickly developed which will allow a user to specify an area of interest on the database or the GIS, then transfer the data into another computer for processing, along with enough of the GIS information to display characteristics in a simple manner.

20) The philosophy behind the current reporting. system is excellent. The current reporting system (FIR) should be expanded as the database makes more information available.

21) The MOF should explore the possibility of defining a framework for a database that both private and government sources could agree upon for storing and reporting inventory data in the same definitions. Such a database should also allow organizations to store data in the same database using their own definitions. It is hoped that such a system would eventually lead to standardization. At the same time, the MOF has much to learn from the successful integration of GIS and inventory made by several companies. This source of ideas and philosophy should be explored by Ministry specialists.

22) Inventory Branch should explore the possibility of transferring the harvest block polygons used by Silviculture to their own system along with pertinent data on those polygons. Systems of comparing and sharing silviculture data with current inventory data should be designed.

23) There is a great need to enhance the field experience of the Inventory staff and contractors, and to put them in contact with experienced technicians in this discipline. They should visit organizations who are success stories in various kinds of programs. A selected group of inventory specialists should participate in the design of the future inventory. There is far too much reliance on the assumption that previous ground samples are adequate for use with current classifications. There should be a greater emphasis on new technology and on field visitations of polygons to enhance reliability of photo interpretation as a means of classification.

24) As well as widening and generalizing the descriptions of polygons, it would be desirable to gather information on wildlife, recreation, range, and other special designations such as ”Old-Growth”. Appropriate specialists in these disciplines should be invited to monitor and review the design of the new inventory to ensure that these needs are met. At the same time, perhaps serving members of the Task Force could attend relevant meetings involving these subjects.

25) Client service should concentrate on fast turn-around for providing data, clear ideas of probable data accuracy, anticipated systems which clients can operate themselves, and ancillary information sources to verify the correctness of the data. Clear efforts to establish credibility from several outside sources is essential.

Phase 3: Volume and Size Prediction

26) Scaling should be prepared to gather both net and gross measurements, at least from a valid sample over a large area or for complete small areas. The mechanics for such a sampling scheme should be designed.

27) The residue and waste program should be able to estimate the amount of wood from the inventory which was left behind after logging in a manner compatible with inventory and valuation cruising.

28) Yield analysis and growth modeling procedures should be sorted out among the various Branches. The validity of approaches to yield prediction should be overseen by specialists in that field who have clear academic and experience credentials for this work. Until the problems of applying projection techniques are solved, a loss of credibility can be anticipated.

29) The present system of making deductions to inventory volumes is basically adequate, but there is a serious need for continuous ”credibility checks” of these numbers from outside sources. The scale and residue are two such sources, but all branches of the Ministry should try to keep one definition of area volume which would be directly comparable to any other such estimate. Presently, small procedural differences constantly frustrate such efforts.

30) Volume prediction is an important problem. The use of the VDYP system to estimate initial stand volumes is acceptable, provided that it is monitored for accuracy based on ground samples compared to VDYP estimates. Where the estimates are not unbiased, adjustments should be made. A sampling scheme for doing this should be designed. More MOF staff should be personally involved in the construction of the yield prediction systems.

31) The current program for establishing permanent plots and other efforts to establish the ”operational adjustment factors” seem appropriate. A geo-referenced database with good ecological mapping and descriptions will also be helpful in this regard.

32) Inventory Branch should explore possible incorporation of operational cruise plots into the inventory design for local areas.

33) Efforts should be made to get specific estimates of residue and waste comparable to inventory standards.

Timber Inventory Task Force Terms of Reference

Ministry of Forests

Inventory Branch

November 1, 1991

Draft 3.1

1 Introduction

The Forest Resources Commission (FRC) in its report *The Future of our Forests* recommended that a Timber Inventory Task Force be set up to “design and plan the development of an accurate timber inventory”. Included in the report was a further recommendation to “conduct a critical review of the present Ministry Forests’ Reinventory Program and to report within the next 12 months”. The Provincial Forest Resources Inventory Committee (FRIC) will establish a Timber Inventory Task Force (TITF) to implement the FRC recommendations.

2 Task Force Terms of Reference

2.1 Terms of Reference

Reporting to FRIC, the Task Force shall make recommendation to the Ministry of Forests on matters pertaining to timber inventory, which includes forest classification, growth and yield, and loss factors. The focus will emphasize purpose, methodology, and standards and procedures of timber inventory in the province of British Columbia.

The Task Force will review the current inventory program and recommend standards and procedures for an accurate, flexible, and stand-specific timber inventory process. The review and recommendations will apply to all provincial Crown land regardless of tenure. Specifically, the terms of reference are:

1) Review the current Ministry of Forests’ Inventory Program. The review shall address:

a) Design requirements;

b) Inventory methodology;

c) Growth and yield;

d) Site productivity;

e) Decay, waste and breakage (loss factors);

f) Forest classification procedures, standards, cultural definitions such as NSR (not satisfactorily restocked) and “operable” forest land, and site attributes such as old-growth characteristics and biodiversity;

g) Database and data standards.

2) Design and plan the development of an accurate timber inventory process, as follows:

a) Requirements definition;

b) Develop and recommend pre-inventory analysis procedures;

c) Develop and recommend flexible, but statistically sound inventory methods to provide an accurate timber inventory to meet client needs for site-specific planning; The need to integrate the timber inventory with inventories for other resource values will be fully recognized in the design;

d) Recommend size of inventory units;

e) Develop and recommend technical standards for an inventory program;

f) Address the issue of using cruise, scale and other data to support the inventory process;

g) Develop and recommend decision support tools to generate client-defined inventory reports, to assess statistical accuracy of a client-defined unit inventory, and to determine appropriate sampling methods to improve the accuracy of the unit inventory;

h) Recommend the appropriateness of the application of the inventory information of a given standard of accuracy, complete with examples of what it can and cannot be used for;

i) Test the recommended standards and procedures for field application;

j) Provide demonstrations to ensure the recommended inventory standards and procedures are interpreted correctly;

k) Suggest options for appropriate technology, staffing and training requirements for implementing the recommendations.

The Ministry of Forests will evaluate the TITF recommendations for implementation within the Inventory Program.

2.2 Process

The Task Force will coordinate its work with FRIC to ensure that FRIC's standards are incorporated into the TITF recommendations.

The process will be modular in nature and will fit in with the development of other resource inventories under the review of FRIC. It should be considered as the first of two phases of developing multi-resource inventories. The second phase will be to integrate the various resource inventories. The Task Force will consult with the staff of the Ministry of Forests and other government ministries and agencies (such as lands, parks, and tourism) to ensure proper linkage and integration of the timber inventory with other resource inventories.

2.3 Work Plan and Timelines

The Task Force will proceed in order as follows:

1) Inventory Program Review 5 months

a) Review1

- Characteristics of a good inventory design.
- Overview of current inventory process.
- Past inventory techniques and problems.

- General shortcomings of past inventory.
- Report on the current inventory process.

b) Determine information about Inventory clients

- Who are the clients?
- What are the client needs?
- Are client needs being met?
- How do the clients use the products?
    - How much are the clients willing to pay for products?
    - What demands are placed on the inventory program?
    - On what areas of the inventory program are the demands placed?

2. Design and test timber inventory process 12 months

- General principles and philosophy of inventory design.
- Future needs.
- Present assets and limitations.
- Linkages to other inventories.
- Overall approach to new inventory.
- Field testing.
- Report and produce documentation on the new inventory process.

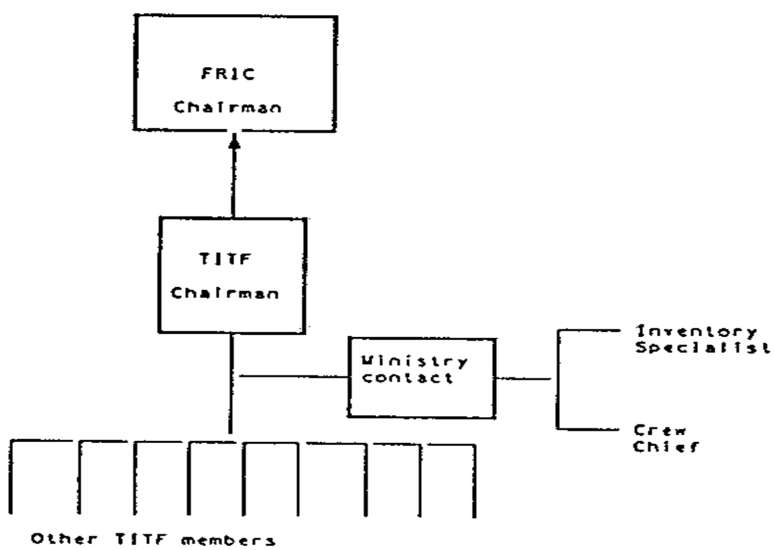
Item 1 can be started immediately, but item 2 will not be started until the other Task Forces addressing cultural/amenities inventories (e.g. recreation, tourism, archeology, wildlife, watershed, and geological) and the FRIC master plan are in place.

3 Task Force Program

3.1 Members

TITF will consist of a total of 12-14 technical experts chosen as individuals (not representatives) from the Ministry of Environment, Lands and Parks; the Ministry of Forests; the forest industry; forestry consulting firms and individuals; and the University of British Columbia. In addition, a 3-person field crew will be established to test and demonstrate the recommended procedures.

3.2 Structure and Responsibilities



Responsibilities are as follows:

- Chairperson: sets agenda; controls time allocated to discussion topics; calls for opinions or concesus as required; insures that minority opinions are expressed.

- Members: review, discuss and recommend current methods and field applications; consult with their peers.

- Inventory Specialist: summarize discussions; prepare technical reviews and initiatives for discussion; analyze field trials; arrange for experts to advise the Task Force.

- Ministry Interface: Ministry of Forests project leader and contact on technical matters.

3.3 Meetings

The Task Force will meet for 1 day every 2 weeks or as required

3.4 Budget

An appropriate budget will be provided by the Ministry of Forests to cover meeting costs, all out-of-pocket expenses and fees for non-government members and invited experts.

Appendix II

An Historical Summary of Forest Sampling Designs in British Columbia

A Report to the B.C. Ministry of Forests

Inventory Branch

Timber Inventory Task Force

James S. Thrower, Ph.D., R.P.F.

February 3, 1992

Acknowledgements

I gratefully acknowledge the contributions of several individuals and thank them for their assistance in this project. Much of the historical information of what actually happened is not documented and without the help of these persons I could not have determined the circumstances of these events. Mr. Jerry Jelinek and Mr. George Allison (both retired from Inventory Branch) were very helpful in describing the methods used in the first major inventory from 1951-1957. Mr. Imre Spandli (Inventory Branch) was very helpful in describing in detail the methods and procedures of the most recent inventory from 1961 to 1977. Mr. Jack McLellan (Inventory Branch) was very helpful in describing all the events from the end of the first major inventory to the present and also spent a great deal of time reviewing this manuscript.

Table of Contents

INTRODUCTION

Forest inventory sampling methods have changes dramatically in British Columbia since the first attempts to quantify the timber resources in the early 1900's. Initially, inventories did not involve sampling in the usual sense but were compilations of any available information including rough guesses of volumes and areas. Often surveys of many become broader in scope and increased requirements of statistical reliability, improved aerial photography and computer technology, and improved aerial and ground access.

The Province is now preparing to re-design and undertake another inventory of the forest resources. Undoubtedly this inventory will be more intensive and more sophisticated than former ones and include factors that were not of concern in the past. More emphasis will likely be placed on non-timber resources. The Timber Inventory Task Force has been formed to advise on the technical aspects of the new inventory. Part of the process is to review the former inventories. This report is presented as part of this review and is concerned only with the sampling designs used in the previous forest inventories.

This report was prepared from discussions with individuals who were involved in the last two major inventories starting in 1951, and from a wide variety of published and unpublished historical and technical documents. The scope of this report is limited to the sampling designs used for estimating volume and does not consider sampling for decay or growth and yield. Include are various notes and comments that relate to general factors and conditions that may have affected what actually occurred. Unfortunately, this report was prepared under severe time limitations and thus not all possible sources of information were reviewed. However, this report should contain the major components of the sampling designs of the previous inventories. Hopefully, this is sufficient information for the Task Force to interpret the objectives of the previous inventories and the sampling designs used in attempts to achieve them

The history of inventory sampling in the Province is not always entirely straightforward. Often many programs were conducted simultaneously at various stages of development. I have tried to simplify the situation by discussing the sampling designs and other events in specific time periods. Sometime this is appropriate and other times it might result in slight confusion of misrepresentation of the events.

The body of this report contains two major sections. The first gives an overview of four major periods in the history of inventory in the Province. The second discusses the historical trends in the inventories, and possible affects of future developments on inventory sampling designs. This is followed three appendices. Appendix I is a table showing some important characteristics of the sampling designs by time period. This should facilitate comparison among the various inventories. Appendix II gives a more detailed point-form listing of the major items of the sampling designs that were summarized in the first section of the report and in Appendix I. Appendix III is a histogram showing the number of inventory plots established by year, inventory period, and type of sample plot.

SUMMARY OF INVENTORY PERIODS

Many events have occurred since the first inventory near the turn of the century and often the timing and sequence overlaps and is confusing. This section summarizes the major events in four subsections. These subsections are named by major events that occurred in the time period. The following list shows the specific events (given in Appendix II) that are covered in these subsections.

Compilation Inventories (1910-1950)

up to 1910	The First Compilation Inventory
1911-1918	The Second Compilation Inventory
1919-1937	The Last Compilation Inventory
1938-1950	Maintenance Surveys

The First Complete Inventory (1951-1960)

1951-1957	The First Complete Inventory
1958-1960	Maintenance Surveys

The Second Complete Inventory (1978-Present)

1978	Sub-Unit Surveys
1979-1981	Inventory Update Program
1982-1987	History Update Program
1988-1991	Re-Inventory Program

Compilation Inventories (1910-1950)

Prior to 1951, inventories were merely compilations of existing information. Of these three inventories in this period, and especially in the first (Fulton 1910), volume was estimated by guessing for many large areas. The next two inventories (Whitford and Craig1918, Mulholland 1937) used an increasing amount of information from surveys, but sampling was not done specifically of either. Where surveys were available, they were often done to different standards and thus were very difficult to summarize on a common basis. Sampling was really only done in the last inventory starting in 1927 and only for some areas of the Province. The sampling used in the 1927 inventory was strip cruising at various intervals, widths, and lengths. Estimates were given volume by drainage basin and Forest Districts (roughly equivalent to the present Forest Regions).

The objectives of these early inventories was to estimate how much wood was available for harvest. This was the level of information needed by the expanding industry at the time. Utilization standards changed dramatically in this time period in terms of the size and species that were considered merchantable. Estimates quickly became outdated because of rapid expansion of the industry, the ability to utilize new species and smaller trees, and increasingly intensive management. Two World Wars and the depression of the 1930's had a dramatic affect on field operations for these inventories (Sloan 1956).

The First Complete Inventory (1951-1960)

The second major period in the history of inventory sampling started in 1951 with the creation of the Forest Surveys and Inventory Division of the Forest Service and the signing of Federal-Provincial agreement for a new inventory of the Province. This first complete inventory of the Province from 1951 to 1957 took seven years from planning through to compilation. At the time, preliminary information from former inventories was not available for much of the area for designing the sampling plan. Also much of the area was not classifies prior to sampling and the two functions were done simultaneously. Only sparse sampling was done for much of the northern region of the Province. Aerial photographs were available for most of the Province the first time. Initially they were 40 chain photos taken by the military for reconnaissance of major topographic features, and did not give the desired resolution for a timber inventory. These were gradually replaced by higher resolution 20 and 40 chain photos taken specifically for the inventory.

The stated objective of the inventory was to provide estimates of total volume to a precision of +/- 10% (at 2 standard errors (se)) for major species in each Forest Inventory Zone (FIZ), and for all species at the subzone level. FIZ zones were similar but nut the same as the current zones. Estimates of average and total volumes were given by what were called Summary Types by FIZ and subzone. The Summary Types were groups of related forest types delineated from the aerial photos.

Access was very poor for many regions of the Province compared with today and this severely limited sampling operations. The emphasis of the inventory was on mature timber and older age classes. Attempts were not made to implement a statistically valid traditional stratified random design because budgetary and logistic constraints made this infeasible. The strata subjectively chosen for sampling were based largely on mature timber and available access. Random location of sample plots was used in the initial phases of the inventory, however, this was quickly replaced with subjective location of sample plots in "*representative*" areas of stands indentified from aerial photographs. The number of samples was not determined based on desired sampling precision because of the budgetary limitations. Practical and logistical restrictions were major factors affecting the sampling plan.

Activities in the last three years of this period (1958-1960) involved primarily maintenance surveys. Theses used the same methodology as the recent completed inventory and were designed primarily to enhance classification and to supplement the inventory. New 20 chain photos were used almost exclusively and sampling and classification were undertaken as separate functions.

The Second Complete Inventory (1961-1977)

The third major period in the history of inventory sampling brought the second complete inventory of the Province done between 1961-1977. The surveys done in this inventory are often referred to as *Unit Surveys* because the major sampling units were management units (Public Sustained Yield Units - PSYU's). Most of the volume data currently in the inventory data base (approx 77% of the sample plot clusters) were collected in this period. The emphasis was also on mature timber and used a similar approach as the 1951-1957 inventory. Major differences were: more samples taken; more refined strata definitions; new management units; more refined classification variables of age, height, site, and stoking; sampling and classification were combined; and higher resolution, larger scale (20 chain) aerial photos.

The objective of this inventory was to estimate total volume for each unit (PSYU) to +/- 10% (at 2 SE). The principles of stratified sampling were used, but logistic, budgetary, and administrative difficulties prevented the random selection of strata, stands, and samples (clusters of plots). The resulting design was termed "*modified stratified random sampling*". The strata were defined as age, height, and stoking classes within a given Inventory Type Group (ITG). ITG's were groups of forest types related by species composition.

Strata were subjectively chosen such that sampling was concentrated in older age classes of the larger types. Often most of the area in a PSYU was contained in a small number of the strata, thus strata with proportionately small areas were usually not sampled. Stands within strata were chosen to avoid sampling areas where samples already existed, and with the objective of ensuring a geographic distribution of samples throughout the PSYU. Access was also a major consideration in stand selection and often was possible only by boat, float plane, helicopter, or on foot. Thus stands from several strata were often selected to be near each other to facilitate access.

Samples were sometimes randomly located in the target stands by using a grid overlay on aerial photos. However, many samples were subjectively located in areas considered to be representative of the stand. In mountainous areas, samples were often located on lower slope positions accessed by vehicle or boat, and on upper slope positions accessed by helicopter. The number of samples actually located was determined by the number that could be established by the crews in a field season. Rules of thumb were used for estimating the number of samples to be established, but budgetary constraints were usually an over-riding factor. The number of samples established by strata was monitored during the field season to check that strata were not over-sampled. However, this was not always achieved and some major types contained many samples while others contained very few. The achieved sampling precision was not monitored during the field season which resulted in varying sampling errors among strata.

Despite practical limitations, some attempts were made to implement a statistically valid sampling plan using randomly located samples. Sample size was computed from a rule of thumb indicating 150 samples per 500,000,000 cubic feet (approx 14,000,000 m3) and also considered impractical to implement under current limitations, primarily because accessing the randomly chosen samples was extremely difficult and was taking double and triple the time needed to establish the subjectively located samples.

The departure from the principles of traditional stratified sampling were necessary because of the limitations and conditions of the time. This has probably had two major results. First, the inventory was probably more efficient in that it gave more information for the limited financial resources. The subjective selection of strata with the highest per unit area volumes (the older age classes) and the highest total volumes (strata with the largest areas) ensured that theses important strata were included in the samples. However, the subjective selection of strata , stands within strata, and samples within stands has magnitude of the bias is not known and probably small, but samples were often subjectively located in stands to favour what was likely a higher than average conditions in terms of volume. Also the non-random sampling methods makes the interpretation of the calculated sampling errors difficult and inference based on traditional probability theory cannot be made in the usual sense.

History and Inventory Updates (1978-Present)

The most recent major period in the history of inventory sampling contains several significant changes. These were precipitated largely from a need for more detailed information about the forest resources. However, a major factor in the development of the inventory methods in this period was a change in philosophy in the Forest Service of what was needed from the inventory and how the information was to be used. There was a desire to provide estimate averages of groupings of similar forest types, thus could not provide estimates at the stand level. Consequently , a new sampling methodology was required to supply the information for the more stringent demands. This motivated significant changes in classification, sampling, data storage, compilation, and the method of estimating volumes for individual stands.

The Sub-Unit survey system developed and tested in 1977 was introduced in 1978. This sampling method was designed to provide more detailed estimates on much smaller areas. The sub-units were usually individual drainages as small as 5,000 ha. The sampling method was a multi-phase system using a linear cluster of 6 variable-radius plots and low-level aerial photographs. The sub-unit survey program was replaced with management unit surveys based on Timber Supply Areas (TSAs) in 1979 to reflect the new administrative boundaries.

The multi-phase sampling design used 70mm aerial photo plots as the first phase and ground based prism plots as the second phase. The intent was to define a relationship between estimated volumes of fixed-area plots from photo measurements and the actual volume measured from ground based variable-radius prism plots established in exactly the same place as the photo plots. This relationship could then be used to adjust a large number of other photo plots that could be taken less expensively. The multi-phase sampling methodology was the most statistically rigorous sampling design to date, but the system was difficult to implement and had many technical problems. There was also a lack of experience and expertise to operate the very sophisticated system at the Forest Region level where the cameras were based. Camera failures occurred frequently and were not detected until after the pictures were developed. Photo processing was done in Ontario which caused additional delays. Also it was very difficult to match the ground and photo plots. The multi-phase sampling system was unsuccessful because of a lack of funding and many practical problems. However, the opinion of those familiar with the process is that with modern technology and geographic conditions and the short-commings of previous attempts can be rectified.

A re-inventory program was initiated in 1998. However, this was really only a reclassification program because field sampling for volume was not undertaken. Other major changes in this period include converting the inventory data base to continuous variable instead of the formerly used classes. This was a significant change in the data base and allowed for the storage of actual values taken from samples and other measurements. Data previously collected and recorded as classes were either reinterpreted to a higher resolution or converted to class midpoints. The change to continuous variables was also accompanied by a change in the way in which volume were assigned to forest cover polygons. The formerly used Average Volume Line (AVL) approach where all stands in a given strata were assigned the average volume was replaced by predicting volumes for individual stands from a regression function using the polygon attributes expressed as continuous variables.

DISCUSSION OF HISTORICAL AND FUTURE TRENDS

Sampling designs used in forest inventories in British Columbia have changes from a mere compilation of available information or "*stock taking*" of timber to sophisticated multiphase sampling designs. Prior to 1951, the areas of interest were those under current exploitation or planned for development in the near future. Samples were not needed for inaccessible areas and those that did not have timber that was considered merchantable with technology of the day. Surveys reflected current utilization standards in species and size of trees. As a result, these inventories quickly became outdated as standards changed. Practitioners of the time realized that technology would change and allow utilization of currently non-merchantable timber, but priorities were on providing information for current management. Inventory sampling methodology has now changed to be more rigorous and covers the entire Province, involves much lower merchantability limits, and includes species that were formerly omitted. Despite differences of former inventories and advancements in sampling techniques that have paralleled advances in technology, there are several trends that emerge over the various periods of inventory that have profound affects on sampling designs. There are factors in large-scale inventories that are the same today as the turn of the century. Many of these factors will probably be the same in the next inventory. A review of historical trends and consideration of future possibilities may help to identify some areas that warrant special consideration.

Information Needs

Sampling systems are usually designed to provide only the type and resolution of information that is needed about the population being surveyed. Sampling systems used in former inventories were designed to provide the information needed at the current time under the current limitations. This was especially true of the first inventories. Forests are dynamic systems, and thus it is often said that inventories are outdated the minute the information is published. This is true and probably cannot be avoided. However, a major factor leading to the apparent lack of longevity of these inventories to provide information for management was that they often were designed to provide information to a standard that was very quickly as the forest grew and changed, but became outdated much faster because of changing requirements for information. This was certainly the case in the early years with merchantability standards of size and species of trees.

Some examples of changing standards are that in early years, surveys were done on the coast to 24 inch diameter limits and excluded hemlock and balsam. This information soon became inadequate when markets and technology changed to allow the utilization of other species and smaller trees. Also lodgepole pine was considered a non-merchantable species for most of the Province until the 1950's and 1960's, much of the central interior was classified as pine-scrub and led to thoughts that available mechantable timber volumes would soon be depleted. Deciduous species were considered non-merchantable until recently and were not intensively sampled in the last inventory between 1961 and 1977. In the previous inventories it was recognized that more of the resource would be merchantable as markets and technology changed, but sampling was usually designed to meet immediate needs only. It is likely that in many cases these anticipated changes occurred much faster than anticipated.

From a sampling perspective, these changes in utilization standards are simply changes in the type of information needed from the sample. Sampling systems were designed at the time to provide the needed information. Statistical reliability was not needed in the early part of the century because cut control and availability of timber was not a major consideration and survey methods were designed accordingly. Some changes in information needs are brought about by changes in technology to utilize different types and sizes of wood and the ability to sample and process data. However, others are brought about by changes in the public need for information about the forest. Future inventories must not only consider present and future utilization of timber, but also the need for information about the many other components of the forest. This type of information has not played a large role in the design of former inventories but will surely be a major component of future information needs. This will surely affect the sampling designs of future inventories.

Presently more detailed information is needed from the forest than ever before and from a myriad of forest resources other then timber. From the timber perspective, more detailed information is needed than has been collected in the past including information at the individual tree level. The current information needs are not only for an inventory in the traditional sense of what is out there, but also needed is information about the forest, trees, and ecosystems that will allow the detailed modeling of tree and stand growth and yield. Furthermore, the method in which growth and yield is modeled dictates the type of information that is needed. An example of the type of information that will probably be needed is spatial and temporal distributions of trees, information on crown characteristics, and information about the ecological characteristics of the forest. Information requirements will become more demanding as modeling techniques become more sophisticated.

Use of Information

Another trend that is apparent from previous inventories is that the information has been used, without exception, for purposes other than which the sampling plan was designed to provide. This has lead to dissatisfaction with previous inventories because the information was expected to provide answers that were not considered when the sampling system was designed or the questions had not been asked. For example, strata averages from the 1951-1957 inventory were sometimes used to estimate volumes of individual timer sales. It was not the objective of the inventory to estimate the volumes of individual stands, but the inventory information was used for this purpose and it created a perception that it did not adequately represent the forest. The likelihood of using information from the next inventory for purposes other than it is designed is almost assured. The challenge is to provide a sampling design that provides information for current as well as future information needs. Of course there is a trade-off between utilizing finite resources to obtain currently needed information against future information needs. It is impossible to know exactly what information will be required of the next inventory into the future. However, trends in timber utilization, public opinion and use of the forest, and forest management can be used to help identify the type of information that might be needed in the future.

Statistical Requirements

Despite attempts of former inventories to adhere to the statistical principles of sampling, it was not possible. Practical, logistical, administrative, and budgetary limitations were always over-riding factors. There were not enough resources to sample all strata and access was limited. Random location of samples in stands was achieved in some cases, but subjective location was favored because of

simplicity. The result is the inventories may have been more efficient in providing more information with finite financial resources than a strict random sampling procedure, but this deviation from statistical principles has probably introduced a bias (probably small but of unknown magnitude). Furthermore, interpretation of the sampling error and confidence intervals cannot be made from probability theory in the usual sense.

Implementation of forest inventory sampling based on strict random requirements is very difficult. The amount of additional confidence in the estimate in terms of unbiasedness may not be worth the large additional expense required to achieve the randomness. This was the finding of the practitioners who attempted to establish completely random samples in the 1961-77 inventory. However, it is highly desirable to have unbiased estimates unless the amount of bias is known to be small. Other sampling systems can be combined with random sampling to increase efficiency. Multi-phase and multi-stage designs combined with selecting units with probability proportional to size (PPS) and systematic sampling can greatly increase sampling efficiency. Multi-phase and multi-stage designs combined with selecting units with probability proportional to size (PPS) and systematic sampling can greatly increase sampling efficiency and reduce the amount of randomness needed at the ground level.

Technological Advancement

Technology has also been a major factor in the design of forest inventory sampling systems. Initially the ability to sample the forest was very limited by ground and air access. The advancement of aerial photography has probably been the most significant technological development aiding forest inventory. The sampling system used in all the inventories after 1950 have been made possible by the ability to identify and map homogenous portions of the forest from aerial photos. Now high, medium, and low-level photography are all used to some extent in forest inventory sampling.

Another major technological advancement that has affected forest inventory sampling designs is the ability to store and manipulate virtually unlimited amounts of data with computers. The class-based inventories prior to 1977 were the result of the inability to annually deal with large amount of data expressed as continuous variables Now the difference in the amount of computer memory needed to store a class variable as opposed to a continuous variable is not important. The cost of mass storage of data is now so inexpensive that it is of little concern.

Technological advances of the future will undoubtedly have an equally or even more profound affect on the forest inventory sampling designs. The ability to manipulate and store data has far exceeded our ability to collect the data. The next major development in technology affecting forest inventory will probably be made in use of digital image analysis of aerially captured data. This will affect sampling designs in that large amounts of data will be captured quickly and easily at relatively low cost. These data can then be combined with relatively few very intensive sample points in a multi-phase sampling design similar in concept to that developed using 70mm photography. This type of data capture and analysis could also be used to sample for other types of attributes that have not traditionally been measured in forest inventories such as the spatial distribution of trees.

Also measurement techniques for ground sampling have changed little since the first inventory in the province. The enhanced ability to collect large amounts of precise data from ground measurements of trees will surely affect sampling designs. For example, upper stem diameters are almost never collected except under research conditions. The number of trees measured at a given plot is a function of the amount of time taken and the amount of information obtained. As with aerial technology, the next major advancement in ground sampling will probably be in digital image analysis of data captured at the plot level. Also the use in which information is collected at the plot and higher levels. These technological advancements will surely require changes in the sampling designs used to obtain the information.

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Appendix I - Some Important Characteristics of Major Inventory Periods in British Columbia.

Period	Objective	Sampling Design	Strata Definition
1910	Quantity forest resources in B.C.	No sampling. Compilation of existing information. Much guessing.	NA
1911-18	Estimate available merchantable timber supply in the Province	No Sampling. Compilation of available information. Took three years to compile information.	Province divided into 66 drainage basins
1919-37	New Inventory in 1927 to more accurately reflect the current state of the of forests and new merchantability standards	Some Area's surveyed, but there was a compilation of surveys, cruises, and other available information	Estimates given for the new 5 Forest Districts (somewhat similar to current Forest Regions) by drainage basin.
1938-50	Maintenance surveys only. Update function. No new inventory	Strip cruises.	NA
1951-57	The first complete inventory of the Province. Objective to estimate total volume for strata	Intent was modified stratified random sampling at the FIZ subzone level (not current FIZ)	Summary Types (groups of related forest types) by age, height, and stoking class.
1958-60	Maintenance surveys for the enhancement of classification	As above	As above
1961-77	Unit Survey's. Second complete inventory of B.C. Objective to estimate total volume by strata for aggregate forest types in each PSYU.	Intent was modified stratified random sampling at the PSYU level.	The 42 inventory type groups by age, height, and stoking class.
1978	Sub-Unit surveys. Objective to estimate detailed stand characteristics for smaller land units (usually for individual drainages)	Multi-phase stratified random sampling using 70mm low level photography and ground samples	Individual stands for sampling. Aggregated forest types for compilation and precision control.
1979-81	Re-inventory and update functions decentralized to Regions	As above.	As above
1982-87	History update program for major depletions from harvesting, fire, insects	NA	NA
1988-91	Re-inventory Program. Objective to re-classify TSAs on a 10 year cycle.	NA	NA

Precision Objectives	No. and Type of Plots	Location of Plots
NA	None	NA
NA	None	NA
NA	27 000 km of strips and 4 800 km of aerial photo strips. Reconnaissance surveys done were not available	Systematically located strips.
+/- 10 % of merchantable volume/acre	Strip cruises	Systematic strips at intervals of 1/2-one mile and 1/2-one chain in width.
+/- 10 % of total volume for: species by Province; major species by zone; and all species by subzones.	7 057 clusters of 4 fixed-radius sample plots	Subjective location in representative areas of stands. Random location of plots attempted but considered infeasible.
NA	2 824 clusters of 4 fixed-radius sample plots.	Subjective location in representative areas of stands
+/- 10 % of total volume for each PSYU	37 963 clusters of 2 fixed-radius sample plots.	Subjective location in representative areas of stands. Random location of plots attempted but considered infeasible
+/- 10 % of total volume for aggregated forest types	612 6-prism plot sample clusters. Phase 1:4-8 fixed area photo plots along a strip.	Phase 1: random strip in stand. Phase 2: plots selected randomly or in a restricted random manner to represent full range of variation
As above	1502 6-prism plots sample clusters	As Above
NA	278 6-prism plot sample clusters	None
NA	None	NA

Comments
First attempt at any inventory in B.C. (Fulton 1910)
Second attempt at an inventory (Whitford & Craig 1918) Much of the Province was unexplored. WW1 interrupted sampling
Third attempt at an inventory (Mulholland 1937). Depression of 1930's affected sampling. No new estimates for northern part of Province.
Sampling suspended in 1942 because of WWII
First complete inventory in Province took 7 years.
New aerial photos available at 1 : 15,840
Class-based inventory. About 77% of current data base from this period.
Concept developed and tested in 1977.
Program initiated but unsuccessful because of practical problems. Photo plots were used for classification
Field sampling ended in 1984. Monitoring from satellite imagery and silvicultural records
No file sampling (except for classification).

Appendix II - Point-Form of Summary of Significant Inventory Periods

1910: The First Compilation Inventory

- Fulton (1910) reported on his Royal Commission on Forestry on the general state of the forest industry
- This was the first attempt to quantify the forest resources in British Columbia.
- No sampling was done and very little information was available.
- Had information on some tenures but broad based estimates were from guessed averages per unit area multiplied by estimated total areas.
- A major difficulty in estimating timber volumes was in defining merchantability limits because "the standard of timber that can be profitably cut is being lowered every year" (Fulton 1910)
- No effort was made to estimate the volume of immature, non-commercial, not restocked forest land, or rate of growth.

1911-1918: The Second Compilation Inventory

- Increased awareness of natural resources resulting from activities in WWI.
- Recognized the need for an inventory of forest resources.
- Whitford and Craig (1918) reported on the Forest of British Columbia.
- This was the second attempt at an inventory in British Columbia but was only a compilation of other surveys.
- The objective was to secure an estimate of the available supply of merchantable timber in the Province.

- No sampling was done.
- No air photos were available
- Took three years to compile report.
- Estimates of merchantable timber by species given for the 66 drainage basins covering the Province.
- Estimates based on available information from reports provided by the newly created B.C. Forest Branch (in 1912), timber owners, surveyors and others.
- Compilations were for minimum stump diameter of 10 inches (which was considerably below utilization standards of the time (Sloan 1945. P. 199)).
- At the time much of the area of the Province remained unexplored.
- At best only reconnaissance surveys had been done in undeveloped areas.
- Had problems defining what was merchantable timber and land, e.g., older cruises were designed to estimate only amount of timber that was economical to cut, and Balsam and Hemlock were omitted from cruises as well as timber less than 24 inches in diameter.

1919-1937:The Last Compilation Inventory

- The previous inventory was still a good source of information for many resources, but became increasing inadequate for timber.
- Required a new inventory to meet current demands of industry and for administration of the forest resources
- Forest Service began a new inventory in 1927.

- Mulholland (1937) reported on the Forest Resources of British Columbia.
- This was the third attempt at an inventory in British Columbia, but as with the 1918 inventory, was only a compilation of many other smaller surveys

- The objective of new inventory was to provide more detailed estimates and to give as accurate a description of forest conditions as possible from available information.

- Province divided into 5 administrative Forest Districts (what now fairly well resemble our Forest Regions).

- Preliminary estimates were completed and published in Forest Service annual reports for individual Districts between 1928 and 1935

- The Mulholland report presented a complete inventory for the Province including updates for the Vancouver and Prince Rupert Forest Districts

- Emphasis of inventory was on volumes of mature timber and some description of the growing stock for future estimates of growth.

- No volume estimated for immature stands or trees that were considered to be wasted in the logging of mature stands.

- Intent was to continuously update the inventory as required to reflect change.

- The inventory was made mostly during the depression years of the 1930's and the poor market conditions and low profits were reflected in its assessment of merchantability (Sloan 1956, p.203)

- Surveys done for some areas and overall inventory was a compilation of all known cruises from private owners and the Forest Service.

- Field reconnaissance was done for areas not covered by surveys.

- Attempts were made to adjust different cruises to a common standard.

- Forest surveys covered 4,000,000 ha of productive forest, about 13% of the estimated total area in the Province capable of timber production.

- 27,000 km of surveys strips were done recording age, height, dbh, and volume.

- 4,800 km of aerial photos was stereoscopically plotted.

- Estimates of volume for the 27,000,000 ha "*unorganized northern territory*" were based on estimates from Whitford and Craig (1918) because at the time Mulholland (1937 p. 151) stated that " the forest resources of that bleak country are not of commercial importance and are entirely inaccessible at present".

- Maps showed volume per acre and percent species composition for mature stands, and composition, comparative density, and height of immature stands.

- Statistics were compiled from the summation of volume estimates from minor watersheds, blocks of timber, and individual surveyed lots and timber licenses.
- Published figures were by drainage basins and Forest District.

1938-1950: Maintenance Surveys

- Subsequent dissatisfaction of the maps created in the previous inventory for the unsurveyed areas were encountered because they were begin used for purposes other than for which they were designed (BCFS 1947).
- Maps were continually updated as new surveys of areas were completed.
- Sampling methods involved strip cruising at various widths and intervals, depending on the purpose of the specific survey.
- Strip intervals usually varied from one-half to one mile, and samples were from one-half to one chain wide and up to 20 chains in length.
- Precision of specific surveys continued until 1942 when operations were suspended because of WWII (Sloan 1956, p.203).
- The first Sloan (1945) report used the 1937 inventory with some amendments made from the surveys conducted in the intervening years.

1951-1957: The First Complete Provincial Inventory

- The first complete inventory began in 1951 after the creation of a new Forest Surveys and Inventory Division of the Forest Service.
- The inventory was funded through a Federal-Provincial agreement to collect information to a standard for inclusion in national statistics.
- Planning began in 1951 and sampling started in 1952.
- The inventory took seven years and was complete in 1957 (B.C. Dept. Lds. For. 1957).

- The second Sloan (1956) Commission report used the inventory published in the 1954 Annual Report. This was an interim report as field sampling was not yet complete.
- Malcolm (1957) described the sampling procedures for this inventory.

Classification

- Province divided into 7 inventory zones ranging from 1.6 to 16 million ha (not the current Forest Inventory Zones) and subzones of about 400,000 to 800,000 ha.
- Initially only old air force photos available, but new 20 and 40 chain photos were flown for the entire Province.
- Forest types delineated on photos from stereoscopic interpretation aided by ground and air observations.
- Forest types delineated by:

1) Stand structure (e.g., mature, immature, etc)
2) Species composition
3) Age class (3 to 5 classes depending on structure)
4) Height class (4 for mature timber)
5) Stoking class (3 classes based on no./acre)

- Minimum forest type size was 16 ha and at the outset of the inventory was much larger.
- Classification and sampling procedures occurred simultaneously because did not have previously delineated photos.

Sampling Overview

- Intent was to use stratified random sampling at the FIZ subzone level, but was not achieved because of practical and logistical limitations.
- The resulting sampling design was termed "*modified stratified random sampling*".
- Strata were called Summary Types and were groups of one or more of the 11 related forest types (groupings of related species) recognized in classification falling within a wide range of species composition, age, height, and stocking.

- 264 possible Summary Type combination.
- Stated precision objectives were to estimate total volume to within +/0 10% (at 2 SE):

1) By species in the Province as a whole.
2) For major species in FIZ zones.
3) Collectively for all species in FIZ subzones

- Number of samples required to meet stated precision requirements not calculated or controlled until late in the inventory.

- Sample plots were fixed-radius circular plots, with size ranging from 0.0004 to 0.2 ha depending on species composition, stoking, and age class.
- Samples were clusters of 4 plots for mature stands and 2 plots for immature stands.
- Attempts in the initial phases of the inventory to randomly locate samples (plot clusters) within stands using grid overlays on photos, however, this was soon replaced with subjective location of samples in "*representative*" areas of stands

- Average volume per acre was computed by species and forest type from the various sampling strata.
- Total volume was computed as the product of these averages multiplied by the areas computed for each areas from the forest cover maps.

1958-1960: Maintenance Surveys

- Maintenance surveys conducted for the enhancement of classification.
- Had some crews supplementing the sampling from the 1951-1957 inventory.
- Larger scale 1:15,840 photos allowed more refined classification.
- Sampling and classification were separate field functions.

1961-1977: The Second Complete Provincial Inventory (Unit Surveys)

- Initiated the second complete inventory (Unit Survey) of the Province.
- Objective was to estimate average volume by strata for groupings of related forest types for each sampling Unit (Public Sustained Yield Units -PSYUs).
- Volumes for individual stands were assigned the average of the stratum, known as the Average Volume Line (AVL) approach (as with the previous inventory).
- Most of the current volume data base (approx 77% of sample plot clusters) was collected in this period.
- Sampling and classification functions were combined.

Classification

- Air photos delineated by species, age, height, stocking, and site for productive forest land.
- Forest types (stands) classified into 42 Inventory Types Groups (ITG) by species for mature and the 17 Growth Types Groups for immature, and by 9 age classes, 8 height class, 4 stocking class, and 4 site classes.
- Samples were summarized during the field season to ensure that target types were actually sampled.

Sampling Overview

- Survey projects were undertaken separately for each Unit (PSYU) which ranged in size from 140,000 to 5,500,000 ha.
- Each PSYU was sampled in a single season and was not revisited until a re-inventory was scheduled, thus additional samples were not located in strata determined to be sparsely sampled after compilation of the data.
- Sampling design based on principles of stratified random sampling but were not achieved because of practical and logistical limitations.
- Resulting sampling design was termed "*modified stratified random sampling*".
- Strata were ITGs by age, height, stoking, and sometimes site class or disturbance class.

- Precision requirements were to estimate total volume of the PSYU to +/- 10% (at 2 SE).
- Ground sample information was collected as continuous variables but was recorded in the data base only as classes.
- The resulting inventory was class-based.
- Data base only included: species to the nearest 10%; age in 20 year classes up to 140, then 141-250, and 250 and older; height in 30 foot (9 m) classes; and stocking into 5 broad classes.
- Original data for the exact measurements were kept only on the field sheets.

Sample Size Calculation and Allocation

- All stands in PSYUs were summarized by strata (ITG by age, height, and stoking class) from the previous inventory noting area, number of existing samples, and an estimate of the desired number of additional required samples.
- Strata were subjectively selected from each ITG to favour older age classes with proportionately large areas.
- Strata were selected such that their area would comprise about 80% for the ITG.
- Initial sampling plan developed from estimated total number of samples needed in the Unit (PSYU)
- Initially estimated as a rule of thumb that about 16 samples per major stratum were needed to achieve the desired precision of +/- 10% at 2 SE
- After 1963, the estimated number of samples needed for a given grouping of types of a major species was determined from experiences in similar PSYUs.
- The actual number of samples was limited by the annual budget.
- Sample compilation occurred at the end of season, thus desired control over sampling size and precision was not closely controlled.
- A tally of the number of samples established in each stratum was made during the field season to help guard against over-sampling. However, some projects contained from 2 up to 100 samples in the major types (Hegyi 1990).

Sample Location

- Stands were chosen for sampling to ensure geographic distribution throughout the PSYU, and to avoid areas where previous sampling had occurred.
- Access and terrain were also major considerations and most stands were selected to facilitate access.
- Samples were changed to a cluster of 2 fixed-area plots of varying size that roughly equalled the total area of the 4-plot clusters used in the previous inventory.
- Some samples were randomly located in the subjectively chosen strata and stands by selection of random coordinates from a transparent grid overlay on photos.
- However, many other samples were subjectively located directly from aerial photos to be representative of the stand
- Subjectively located plots were often established close to roads, rivers, lakes, and on lower slope positions.
- Attempts were made at using truly randomly located plots and a rigorous stratified random sampling design adhering to statistical principles, however, this doubled and tripled the time required to establish samples and was abandoned for the subjective location of samples.

Theoretical Comments on the Sampling Design

- Sampling design based on statistical principles, but deviations from theoretical statistical assumptions were necessary because of administrative, practical, logistical, and budgetary limitations.
- The intended stratified random sampling design deviated from theoretical statistical principles in that:

1) Not all strata were sampled and those chosen were not always chosen at random.
2) Selection of stands within strata was not always random.
3) Selection of sample plot locations within stands was not always random.
4) Plot sizes were changed depending on stand conditions.
5) Samples were not allocated proportionately among strata and estimates were not weighted appropriately for the unequal sample size and unequal area.

- Deviations from the theoretical statistical sampling assumptions probably had several affects:

1) Generally, this may have resulted in a more efficient survey for estimating total volume of the PSYUs in that sampling was concentrated in the large and higher volume types.

2) Estimates of average volumes were probably biased based because:

- Some strata were not considered for sampling in the subjective selection.
- Some stands were not considered for sampling in the subjective selection.
- Samples (plot clusters) were not always randomly located in stands and in some cases may have been located in such a manner as to favour higher productivity areas such as lower slopes and areas of better than average stocking.
- Samples were not weighted by the area from which they were taken.
- Plots of varying sizes were weighted equally in the estimates.

- Sampling concentrated on the older stands thus only poor representation from younger age classes (some units had very little immature, especially on the coast), however, more emphasis was put on immature after 1973.
- Deciduous forest types and much lodgepole pine was considered to be non-commercial at the beginning of the survey and was poorly sampled (Forest Resources Commission 1990)

1978: Sub-Unit Surveys

- Sub-unit Survey methodology replaced the class-based Unit surveys and was used only in 1978.
- This was in response to the need for more detailed estimates including stand level parameters at the sub-unit level (individual drainages as small as 5,000 ha).
- This change to Sub-unit Surveys was also accompanied by major changes in classification, sampling, volume calculation, and the way that inventory data were collected and stored in the data base.
- The class-based system was replaced with a system that recorded the classification attributes as continuous variables in the data base.

- Volume calculation was changed from the AVL method to a regression approach where the predictor variables were the classification parameters expressed in continuous units.

- Sampling methodology changed to a multi-phase design.
- The first phase was low-level 70 mm air photo fixed-area plots and the second phase was variable-radius ground plots for double sampling (Hegyi 1985, 1990).
- The intent was to define relationships between photo plots and ground plots to adjust other photo measurements where ground plots were not established.
- Sample plots were changed from the previously used cluster of 2 fixed-area plots to a linear cluster of 6 variable-radius (prism) plots to facilitate the new sampling methodology.
- Only cursory testing of the new sampling method.
- The multi-phase sampling design was not successful because of poor funding and many practical problems.

1979-1981: Inventory Update

- In 1979 the Forest Service reorganized, decentralized many function to the regions, and created the new management units called Timber Supply Areas (TSAs).
- Sub-unit Survey system replaced by a Management Unit (TSA) type of inventory implemented using the sub-unit classification and survey methodology.
- 70 mm photo booms developed earlier were sent to each Region.
- Intent was to provide capability for re-inventory and updating in each Region.
- Program was not successful because the practical aspects of the sampling methodology were not perfected, and operation of the camera booms required a high level expertise and training that was not available in the Regions.
- First and second phase samples were established using the multi-phase sampling system but relationships between photo volume and plot volumes were never successfully established for assigning stand volumes on an operational basis.
- The 70 mm photographs were used mainly for classification purposes.

1982-1987: History Update

- Funding constraints reduced the inventory program to a maintenance mode but facilitated conversion and placement of data base to digital format and re-compililation of existing data to new Timber Supply Area (TSA) management units.
- No major operational field sampling was undertaken.
- A program was introduced to monitor depletions such as harvesting, insects damage, and fires. This was done through silvicultural records and high level satellite imagery.

1988-1991: Re-inventory Program (Re-classification only)

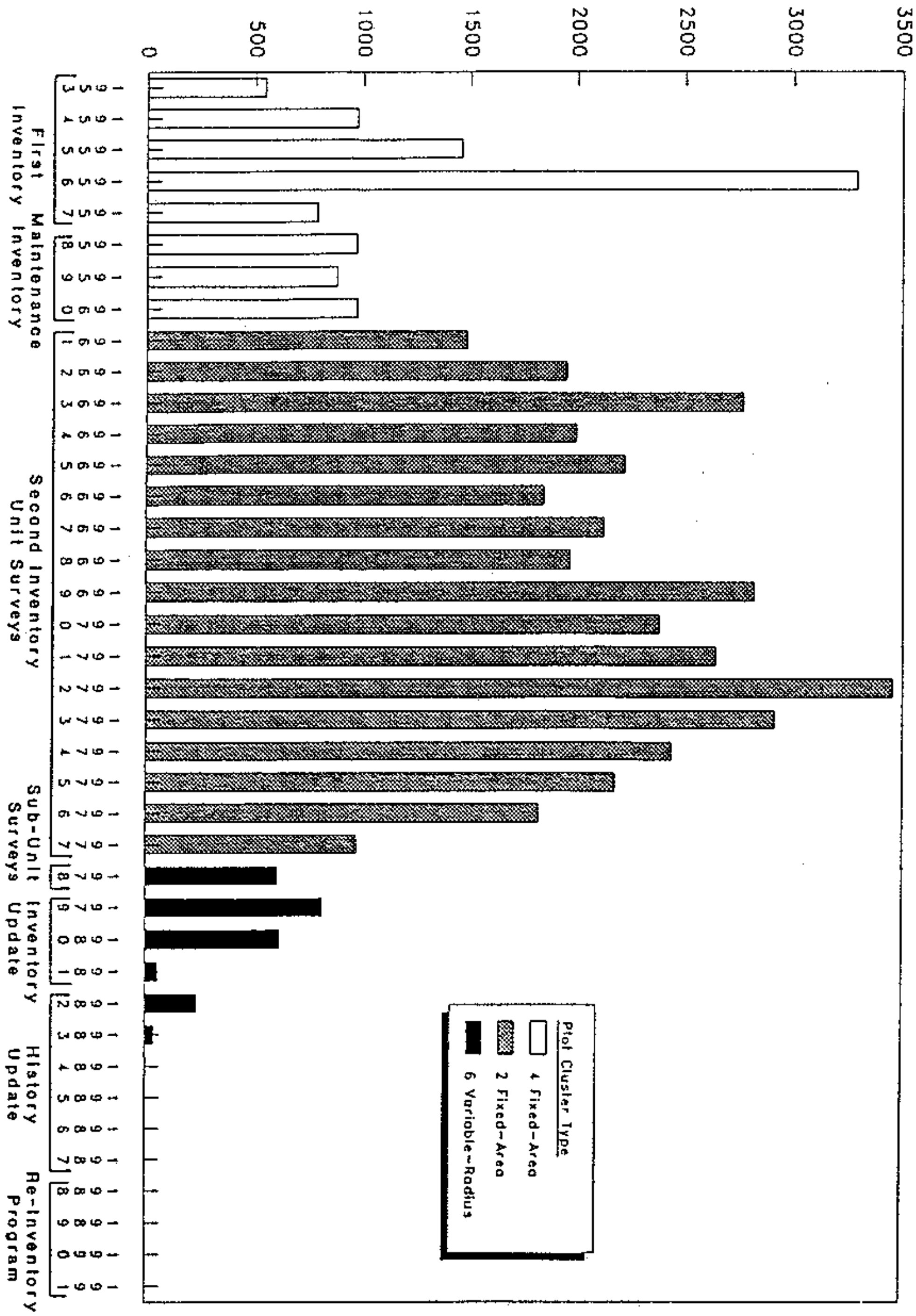
- In 1988, a program introduced to re-inventory TSAs on a 10 year cycle.
- Funding increased to complete conversion of forest cover maps to digital format, to begin inventory of management units (TSAs), and to improve the image analysis system used in the inventory update program (Ministry of Forests 1991).
- This initiative was not a re-inventory in the usual sense in that only re-classification of new photos was undertaken with supporting air and ground calls.
- No field sampling undertaken.
- Volumes assigned to polygons from prediction equations (VDYP) developed primarily from samples collected between 1961 and 1977.

1991-Present (from Ministry of Forests 1991)

- A major increase in funding through the Forest Renewal Program (FRP) covering a five year period provided for Timber resource inventory, inventory update, forest resource geographic information systems, statistical analysis and summaries, growth and yield, and remote sensing.
- FRP funding is tied to specific inventory program goals, with little being allocated to improving current inventory systems.

- FRP funding enabling hiring of additional staff, completion of the second growth inventory; improvement of accuracy of the inventory through the installation of additional ground samples of growth and yield; possibly of integrating cruising data into the inventory; and update of all active forest cover maps on a 2 year cycle, and inactive maps on a 5 year cycle.

APPENDIX III - Number of Sample Plots by Year of Establishment



Source: Personal communication from Jack McLellan, January 1992.