B.C. FOREST INVENTORY 2018

Environmental needs require sustainable management decisions.

ABSTRACT

Four questions were posed to an issue needing dozens, perhaps hundreds of inquiries pertinent to the issue of motivating abilities, technology and perceptions into the management of B.C.'s forestlands where wildlife, fisheries, aviary species, soils, geology, aboriginal heritage and current populations share this part of the world. Understanding and supporting shared resources is paramount to finding and maintaining a desired future condition.

William E. Schlosser, Ph.D.

Review of B.C.'s Forest Inventory Program

Expert Panel to Review B.C.'s Forest Inventory Program

At the Association of B.C. Forest Professionals (ABCFP) conference in February (2018), Doug Donaldson, Minister for Forests, Lands, Natural Resource Operations and Rural Development, announced the creation of a panel to review B.C.'s Forest Inventory Program.

The panel is made up of Clark Binkley, PhD, Honorary Member, Bill Bourgeois, PhD, RPF(Ret), Valerie LeMay, PhD, RPF, Ian Moss, PhD, RPF, and Nick Reynolds, M.SFM, RPF.

The panel is seeking answers to the following key questions:

1. Does the existing Forest Inventory Program, including growth and yield models, provide suitable and reliable information to support the decisions required for sustainable, well-managed forests?
2. What is working well? What is not working well?
3. How can the forest inventory be improved to provide more useful and reliable information?
4. What benefits would be achieved with the suggested improvements to the forest inventory?

Senior staff from the ABCFP will be interviewed by the panel in the coming weeks. The panel also welcomes individual submissions which can be emailed to the panel before June 30th, 2018. Aside from the general call for submissions, the panel will conduct follow-up interviews from May to July with some individuals and organizations who provided a submission to support the review.

Please email info@inventoryreview.ca if you would like to discuss your perspectives directly with the panel. Regional sessions may be held in July to provide an opportunity for input for primary inventory users.

The panel will submit its report with recommendations by September 30, 2018.

Response

I received this announcement with request to provide an outside perspective on the questions posed. I base on my thoughts and ideas of responses provided on the work I have contributed to in North American forests of B.C. and Alberta, Canada, in Alaska, Washington, Oregon, Idaho, Montana, Wyoming and Nevada, USA, and across the Pacific Ocean to the Russian Far East. I am William E. Schlosser, Ph.D., with doctorates in Environmental Science and Regional Planning, and Economic Sciences. I am a forester, a user and developer of technologies designed for forestry uses and for application initially intended for other purposes, but which provide insights to advancing ecosystem management in temperate and boreal forest ecosystems.

I am co-founder of D&D Larix, LLC, of Pullman, Washington.

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Resource Analysis web site

Analytic €¢onometri¢$ — Forest Resource Analysis System Software
YouTube videos of the FRASS concept

YouTube — Learning Economics with Dr. Bill

20 June 2018

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B.C. Forest Inventory Status

Timber Inventory Focus

In British Columbia and surrounding areas (Alaska, Alberta, Idaho, Montana, Washington) from about 1900 through 1960, analysts and practitioners synonymized forest inventory with tree measurements of species, diameter at breast height (DBH) and total Height. Although additional measurements were sometimes added to the inventory exercise, such as tree radial growth and age, the goal of measurement was to determine a volume estimate of each tree sampled, and by extension of forest mensuration mathematics, to determine the total volume on each block, summarized by species.

Throughout the region, creating jobs for people in new communities formed by forest management, infrastructure development, logging, trucking, milling and lumber distribution was the goal. As a forest industry, the region became known for the uniqueness of softwood lumber quality with unmatched land productivity on a sustainable basis. Entrepreneurial risk takers teamed with government agencies to create jobs with economic multipliers to sustain rural communities, towns, cities and metropolises.

The tax-base created growing governments from city to province, and up to the national level. Of course, other industries formed in B.C., some capturing attention from nature's aesthetics, such as tourism, hunting and sport fishing, some reaching out to natural resource associated industries such as commercial fisheries and mining. Additional industries developed in parallel to natural resource commodities and resources, such as medicine, education, aerospace, automotive manufacture, energy, and construction. Canada is a self-sustaining economy, but exports and imports with trading partners makes real economic growth possible and desirable.

Technology Made a Difference

Several manufacturers initiated the production of mainframe computers from the 1950s through the 1970s. Owned and managed by universities, governments, and some large corporations, the era launched a cultural paradigm shift to recognize the power of forming complex and extensive mathematical computations leading to the computer age. By 1985 the I.B.M. PC Jr. was introduced in North America; a market introduction of Personal Computers (PC) which ultimately was a financial failure for the IBM company. As the computer era transitioned from mainframes to PCs, the computational power of a PC evolved into a powerhouse enabling companies and individuals to solve complexity of mathematics, graphics, database management, and communications to levels never anticipated. Today, the "wireless telephone" unit introduced in 1990 and used by 'some' has been replaced by a "mobile device" seemingly used by 'all' to access the internet, record digital photos and videos, and also allowing people to talk to each other from most barely populated places.

Technological advancement has changed how we find data, manipulate it, analyze it, and share it with others. Keeping up to date with the status of technology is as challenging as keeping up to date with the science of forestry.

21st Century Forest Management Technologies

Forest inventory data accumulation as of 2018 eclipses what was considered possible just 50 years ago. While the characteristics of a forest inventory still has its footing on tallying tree species, recording DBH and height, it also considers habitat types, riparian zones, soil types, geology, and measurements of understory vegetation species; density and diversity.

Today, data acquisition embraces more variables because technology facilitates processing those data into meaningful information to be used to manage natural resource ecosystems, not just trees. Tree characteristics are still recorded, but today we can discover how trees, wildlife, birds, fisheries, aquatic systems, soils, water, indigenous traditions and norms, and livelihoods of all people of the region are interrelated. Plot sample data now has a solid geospatial positioning component facilitated by Global Positioning Systems (GPS). Juxtaposition matters and accurately collected GPS site positions when taking plots, laying out P-line road-routes, or recording unique habitat locations, weave into a uniform structure for land management purposes.

This describes a critical component of the forest inventory collection mandate: forest inventory data is a management regime attribute. We originally collected forest inventory data to estimate the volume contained in trees, and through mathematics and statistics, we could estimate forest volume to use when selling timber products. Today, we can marginally increase the data collection process to embrace tree volume, plus growth significant attributes, wildlife habitat components, riparian zone characteristics, and so much more. Spatial data collected from aerial collection devices (airplane mounted), and satellite scanners (LANDSAT 8 ETM) provides ability to link known-ground data with remotely collected images (USGS 2018). These data provide manager the ability to make actionable decisions about forest ecosystems.

Of course, having these data is valuable, but utilizing them in concert with management objectives is priceless.

Forest Biometrics

Forest inventories are processed through computerized Growth & Yield programs, such as Table Interpolation Program for Stand Yields (TIPSY 2018), to capture estimates of periodic growth into the future by integrating an associated program to managed stand yield tables generated by Tree & Stand Simulator (TASS 2018) and Silviculture Impacts on Yield Lumber Value and Economic Return (SILVER 2018). The Province of British Columbia maintains forest tree yield tables for 10 commercial tree species supported by TASS, a biologically based, spatially explicit, individual tree model. Although this model has been updated with TASS II, it is still commonly referred to by the original name: TASS. A newer version, TASS III is the all-new public-release Windows™ version, which begins to extend TASS into more complex stand structures with multiple-species and -age cohorts.

The B.C. government website (referenced above) lists information: "Financial Analysis of $ilviculture Investment and Economic Return (FAN$IER) adds economic silvicultural investment analysis capability to both TIPSY and SYLVER. The Stand Development Modelling Group offers custom TASS runs to users needing more flexibility than TIPSY provides. Examples include spatial distributions and pruning."

The collection of biometric programs, made in B.C. for use by B.C. biometricians, is a significant accumulation of science and technology. However, inclusive distribution of these software programs is not widely available to all users, inclusive of yield tables, and both TIPSY and TASS provide managed stand yield tables only for single-species, even-aged stands. The anticipated release of TASS III promises expansion of TASS into more complex stand structures with multiple-species and -age cohorts. This anticipated update is an important forward movement of the B.C. biometric model. However, this important step is small, carrying only a couple species in a sea of other cohorts.

A few forest biometric Growth & Yield programs are available today on personal computers and most forest management offices have specialists who operate them. While 'endorsed' programs are listed here, other solutions are available from other governments, such as the U.S. Forest Service (USFS) "Prognosis" (Wykoff, Crookston and Stage 1982), and from private commercial companies such as Dr. Jim Arney's Forest Biometrics Research Institute (FBRI 2017, Arney 2016), called the Forest Projection System (FPS), headquartered in Portland, Oregon.

The former program by the USFS has Forest Vegetation Simulator (FVS) growth variants, individually created each for Alaska, coastal Washington, eastern Washington, west Cascades, east Cascades, Inland Empire (north Idaho), and Montana (FVS 2018). The Alaska variant was calibrated for Southeast Alaska and coastal British Columbia forestlands. Developed in a cooperative interface, the variant called PrognosisBC has been calibrated for species and site series that occur in B.C. This version is calibrated to B.C. environments and accepts input data in metric units (ESSA 2017). Although initial verification efforts have been conducted, it is not widely applied to forestlands in B.C., at least not yet.

The USFS Prognosis model runs on MS Windows PC operating systems and is provided free to all users as a completely operational system. A shell program to Prognosis was developed by the University of Washington, with cooperators, called the Landscape Management System (LMS 2013), to add processing integration with the Growth & Yield focus to describe wildlife habitat, Threatened, Endangered, and Sensitive (TES) species management, fisheries and riparian zone analysis, climate change effects, insects/pathogen integration, carbon sequestration, and a host of integrated management considerations.

The Prognosis/FVS models are multi-species, even- and uneven-age forest growth modeling programs. The LMS interface provides analysts the ability to scale analysis parameters in all modeled regions where the Prognosis/FVS program has been developed, currently in approximately 21 regions of North America (FVS 2018).

The FBRI solution, introduced above, is scalable to all forestland properties and has users in B.C. where the program has been used successfully to make Growth & Yield projections with timber volume merchandized for local market conditions. This model is designed to capture tree growth characteristics giving attention to density, species, soils, slope, aspect, and a range of additional variables to provide reliable predictions for even- and uneven-age management, with multiple specie scenarios. FBRI is a non-profit organization, but the services provided require an annual subscription fee based on the area of the subscriber's forestlands.

Implementation of improved forest biometric solutions beyond currently official B.C. resolutions is necessary because of shortcomings involving the TIPSY & TASS model family. At its foundation, these are single species, even-aged biometric models. While it can model all softwood species in the province, it cannot do them all in a single compilation – at least not yet, and not until TASS III is tested, approved and released. This currently means that a monoculture Douglas-fir run is made separate from a monoculture western hemlock run, separate from a monoculture western redcedar run, etc. A TIPSY analyst told me in 2007 (TIPSY 2018) that separate runs are made for each species, then adjusted for the percent each holds in the inventory on the block.

Furthermore, yield tables are closely held databases needed to make the program operate for forestland managers as they experiment with management scenario options. Without the yield tables, experimentation is not possible, and the utility of the software tool is lost to all but the "inside team". I believe that segregating yield tables and any other software framework away from users of the TIPSY and TASS programs confounds the true utility of the program's genesis.

The single-species, even-aged stand approach makes projections for young plantations especially problematic. Tree species, such as Douglas-fir, tolerate more shade as young seedlings than when they are mature trees competing for stand dominance. Conversely, western redcedar do not easily tolerate direct sunlight at any young stage of development, making the single-species approach inappropriate. Western redcedar growth needs to be modeled in mixed species biometric models to generate meaningful results into maturity (Brodie and Harrington 2010).

Fundamentally, TIPSY and TASS platforms, as historically implemented, are flawed methods of a government underwriting the design and deployment of forest growth estimates into the future. Each species responds uniquely to crowding, shade, wind stress and other competition characteristics, and en masse they respond based on their nearest neighbor. It is little wonder that few timber hectares are being successfully modeled and projected using these programs, and only a fraction of those modeled stand projections are being periodically checked against actual characteristics on the ground. A time series analysis approach is justified for everywhere the biometric programs are applied.

B.C.'s path forward should embrace a multiple-species, multiple-age biometric approach with broad deployment where users can experiment, test, and benefit from its use. TASS III can be the flagship application of this approach, with other programs such as PrognosisBC and FBRI's FPS used for interim modeling application and for result comparison purposes.

Input data needed to launch PrognosisBC FVS or FBRI FPS are not radically different from initiating a TASS/TIPSY projection for each block: all software platforms begin with tree plot data. The different approach is footed in deployment of a Site Index (SI) measure based on soils data. In the USA, the Soil Conservation Service (NRCS 2018) mapped soils data beginning with agricultural lands, then transitioned coverage to forestlands, and all other land types. This process has started in Canada and in B.C. currently agricultural lands are mostly completed (Virtual Soil Science 2018).

When I was faced with the challenge of missing SI data for properties in SE Alaska in 2008, I was able to work with foresters who worked the land and had a 'feeling' about SI values for various species they managed on specific sites. Within about 2 months, we were able to create a GIS mosaic showing SI values based on topography, soil characteristics, topographic position on the landscape, and other data to create the SI values needed to run the Prognosis Alaska FVS variant. As it turns out, the USFS offices in Ketchikan took exception to the approach we implemented and produced a closely-held SI polygon of Alaska showing the values they had developed for over 40 years. My client accepted their data and updated their records. A statistical comparison of these data revealed that while certain polygons were significantly different between data sets, some were identical, but the resulting values applied were not significantly different at the 70% Confidence Interval: not perfect, but not too bad.

One message to this association is not to dismiss other approaches applied: investigate different methods. When certain data are missing, make estimates and see if the results show valuable data. I am confident that something like SI values can be created for B.C. forestlands at marginal expense.

A FOREST ECOSYSTEM approach to Growth & Yield prognostications should make comparisons of tree height, diameter, taper, decadence, crown ratio, response to environmental factors, and tree volume, but also the delivery of reports from each biometric Growth & Yield model. This latter factor is a commonplace comparison where output robustness becomes the relative decision-making force. It also becomes a force of software re-development to generate the analysis results best suited to user needs.

Geospatial Analysis

Geographic Information Systems (GIS) are firmly footed in forest management arenas throughout North America. Although Environmental Systems Research Institute, Inc. (ESRI 2018) software dominates this market worldwide, other programs have become available, and are offered under a GNU licensing service (free ware), such as MapWindow (Ames, Meems and Faust 2018), QGIS (OSGeo 2018), Geographic Resources Analysis Support System (GRASS 2017), and others. ESRI current versions are best known as the ArcMap series and are served under various licensing levels from about $5,000/year per individual user license. Server licenses enable agencies and companies to serve their propriety data to authorized users through internet connected interfaces.

Mapping is the service best known from GIS software, but data creation serves a united amenity: database component creation. Geospatial data created through analyses of spatial components delivers new findings that can be combined with other data, spatial and tabular, to reveal interrelated associations.

All forest ecosystems have a temporal as well as a spatial dimension. Forest ecosystems, generating wood production, creating habitat and recreational values, continuing indigenous population traditions and norms and providing wildlife habitat, to a large degree depend on the underlying ecosystem structure, especially on its microstructure. Ecosystem managers collect specific data to help guide activities on the land. Much of these data are collected with timber production as the primary goal.

Although each segment of natural resource management generates, documents, and creates data, managers of GIS data are the most miserly cadre of professionals found worldwide. Data are hoarded, sequestered, and withheld from broad distribution, often with the reason that “users who do not understand the science of the findings will misuse these data". Generally, it is not openly shared with others who could use those data to manage the natural resource better.

In the USA, the Natural Resources Conservation Service (NRCS 2018) hosts a Geospatial Data Gateway where all federally created or vetted GIS data are shared without charging a fee to those who download the data. Their raster data includes digital elevation models (DEM) (at 1, 10 & 30 meter resolution), aerial photography (0.15, 1 & 10 meter resolution), and vector data for soils, land use, riparian ecology, streams, infrastructure, communities, and hundreds of other layers segmented by political boundaries of states and counties. This framework has facilitated data availability where internet connected users can experiment with the data and find information to be applied to analyses of the land.

Currently, geospatial data availability in B.C. (GeoBC Products 2018) is low in comparison to what has been created in B.C. The Base Map Data offered on the GeoBC site mostly comes to users at a fee ranging from free to $5,000 per dataset. Of course, the free downloads are not suitable for high resolution land management purposes, and it is unknown, to me, if the multiple-thousand-dollar layers serve the ultimate goal of the investment. Sharing these data at no charge can lead to increased awareness of opportunities available on the land, while also peaking interest amongst students who are seeking to learn how to integrate this into their life while in college. At this time, it seems those opportunities are being thwarted.

Data about soils is fundamental to land management for forestry, agriculture, and even commercial land development. Soils data explains productivity, erosiveness, and layer depth. It is the foundation of forestry's site index measurements and is most useful when reduced to GIS shapefiles loaded with attribute tables of soil type details. I have been unable to locate an inclusive soils layer of B.C. lands in a GIS layer as described here (AgriService BC 2018, Virtual Soil Science 2018). The B.C. Soil Information Finder conveys understanding of soils through a GoogleMaps online interface, but it is not available as a GIS shapefile for users to integrate with other geospatial data. The "Terrestrial Ecosystem Information" link on the AgriService (2018) page remains a broken link. Other links to soil-GIS data show inconsistent layer coverage across the Province, and attribute values such as site index are vague or non-existent. These data may be readily available to B.C. agency staff, and even to B.C. users, but for me, as a U.S. consultant working with B.C. clients, it remains unavailable. I have been told my some "B.C. specialists" that it is a dream to have these data developed.

We directly address forest inventory data in this critical review, but I urge you to consider GIS data as one component of forest inventory. It details the juxtaposition of block boundaries, roads, bridges, culverts, and multimodal connections to forestland resources. GIS displays site index boundaries on top of timber block boundaries, land ownership, streams and riparian zones. Geospatial analyses derive where TES species habitat is found and connected to secondary or tertiary habitats. Geospatial analysis gives the ability to "see" socioeconomic connections of aboriginal territory preference based on where observations are made: juxtaposition matters.

GIS data is a fundamental timber inventory component, and I recommend these data be served through an internet connected interface for all users to acquire at no cost and with no use-restrictions. When

B.C. charges users for access to geospatial data that was acquired using government funds, for use by government employees completing their official duties, it breaches the modus of operational justification. It is unreasonable to charge for these data which were remunerated as part of normal government operations.

Data Integration

Data integration across areas of study in B.C. environmental sciences is paramount to successful timberland management of this unique region. I have written about enabling management to serve timber production, wildlife, birds, fisheries, aquatic systems, soils, water, indigenous traditions and norms, and livelihoods of all people of the region. This can be achieved only when a broad blanket of information is collected, integrated, shared and understood in terms of all considerations – simultaneously.

Biometric Patchwork Data

Obviously, forest biometric data need to be considered across all forestlands, encompassing all timber blocks (productive and unproductive). While this task seems onerous to implement and maintain on 20 million hectares, it can be managed and maintained over an extended period of time: maybe within 25 to 50 years. If the process is not started, it will never be completed.

A widespread practice amongst biometricians, is to create a collection of representative timber associations, showing species, age, density, and soil characteristics, articulated using actual forest sample data. Begin by developing a GIS polygon layer identifying where precise data have been collected. The polygons will show block boundaries based on sample data. Next, aerial and satellite imagery can be integrated to make other block boundaries based on some of these same data categories. The mosaic created will show where actual data has been collected, and where sample data are missing.

I have used LANDSAT 8 ETM imagery slices from the infrared, near-infrared, and thermal bands to better identify species characteristics, one 15-meter cell at a time. While visible color bands can be used to create imagery viewable as if it were an aerial photograph (which it is not), the non-visible band reflectance rates can reveal what our eyes cannot identify. It rapidly makes the associations with other, similar regions possible. These virtual associations make conveyance of characteristics from ground-sampled areas to virtually-inspected blocks possible. It is not perfect, but it is better than having no data to build from.

In an operational application of this approach in southeast Alaska, I was able to create similar association relationships on 17 million hectares (43 million acres), using biometric inventory data recorded in 250,000 plots. The statistical framework required that approximately 15% of samples were removed from the database because of low significance of unique matches, but the remaining 210,000 inventory plots provided a meaningful starting point. Most of these inventory plots had been generated through Prognosis/FVS, Southeast Alaska and coastal British Columbia variant, from initial plot data which in some cases were 20 years old (all blocks were ‘grown’ forward to match the remote imagery recording date).

After beginning the landscape patchwork approach, block data should be periodically updated, checked, and maintained to provide continuous landscape data. These biometric data, blended with GIS polygons, needs to be created by FLNRO&RD, and made available to land management efforts.

Satellite Imagery

The application of the patchwork approach can integrate geospatial analyses utilizing satellite images to identify species, sub-surface hydrologic flow, photosynthetic activity, and associated broad-scale site productivity features. The US Geological Service (USGS 2018) has maintained satellites capturing multispectral images of the earth since about 1975. While the original images recorded data at 90-meter resolution, the current satellite, Landsat 8 OLS, records multispectral data showing 30- and 15-meter resolution images. The USGS provides these data at no charge to people and organizations around the world. These data can be acquired by the forest management cadre of B.C. on a four-day repeating cycle for each scene captured. These images should be integrated into the B.C. Province's forest management strategies as the biometric patchwork is realized. This option represents an incredible increase in the value of decision making for B.C. environmental management.

These data should be acquired, analyzed, and reduced to databases available to, and understood by users. FLNRO&RD can increase the value of ecosystem management by creating these shared records, while paying little more than analysts' salaries, but the benefits can be immense.

The measure of 'immense value' to forestland management is a relative measure. I do not give values to "double" something, or to reduce a cost by some amount. Relatively speaking, a well-developed Growth & Yield system deployed on the Province, can provide insights to anticipating insect or disease outbreaks, continuously linked wildfire risks, or expatriation of critical wildlife habitat based on planned forest management activities. Finally, it also gives linkage to continuity for forest product cycle management: employment, revenue, road network management, and all phases of forest development.

Timber Markets

Market data details the financial realities of managing forestlands. The B.C. Province owns 94% of the 20 million hectares of land and forest resources, giving foundation to land management that employs people and businesses working in the timber and the wood processing industries. Stumpage rates are processed by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRO&RD) (British Columbia Ministries 2018) and provided through the Provincial internet web site, listing stumpage prices associated with timber sales in monthly records (B.C. Ministry FLNRO&RD 2018).

These market data are actionable for timber harvest decisions made across the Province as a means of scheduling harvest timing on timber blocks considering market cycles and forest biometric findings of Growth & Yield. Combination of these two factors in decision making events is fundamental to capturing the highest financial returns from forests when harvest decisions are made. Currently, it is not evident that biometric and econometric considerations are being consecutively applied to harvest decisions on Provincial forestlands.

While stumpage prices serve the standard of the Province, delivered log market prices serve a level of detail important to sellers of the final timber products bought by wood processing facilities: lumber mills, wood fiber and pulp processors. Ultimately, all trees are cut into logs and those logs are sold as a commodity based on species, small-end diameter and length, less any reductions for defect (Schlosser 2018). This is the product purchased by final raw material buyers. These data need to be recorded monthly, made available to everyone, and used when deciding financially optimal timber block harvest timing.

Investigation of these data can reveal market cycles which form the foundation to make price predictions through time. When revealed, harvest timing can be placed in recognition of market cycles for individual species, and individual log characteristics. Forest econometricians place the combined attention of biometrics and econometrics in land resource management to find financially optimal timber harvest timing, taken one timber block at a time. Through my company, D&D Larix, I developed the Forest Resource Analysis System Software (FRASS 2018) in 2010 to realize this approach on forestlands located near Eatonville, Washington. This approach can be applied to all forestlands in B.C. with biometric data detailing tree characteristics annually for about 10 years, then at each quinquennium, matched with timber market cycle evolution at matching time-stamp dates. Utilization of this approach will increase financial profitability of timber harvests from B.C. forestlands while streamlining wood processing operations around the province.

The essential foundation of this econometric approach is two-sided: 1) forest biometric data with log merchandising articulation, and 2) delivered log market prices recorded monthly through time.

Ecosystem Management Decision Making Tools

Discussions within the forestland management community, and within other interest groups, has concentrated attention on single factor issues: timber supply continuity, aviary species management, salmon habitat preservation, aesthetics, water quality, or indigenous people's traditional land issues. Sustainable forest management needs to consider all of these with the inclusion of timber production profitability. If all timber management and production is removed from the socioeconomic landscape of British Columbia, employment levels will drop precipitously, protection against wildfires, insects and disease will cease. Forest landscapes of B.C. will become dramatically different as people are removed from the landscape, communities, cities and the province. That drastic change can be avoided by managing for true multiple use objectives, and at all time-scale measurements.

Forest inventory data collection and processing serves as the foundation of B.C. forest management efforts. Developing a world-class system to apply to the first-class landscape is justified and it needs to be implemented now.

This critical review of B.C. forest inventory activities has scratched the surface of an intricate infrastructure. I have identified details to give example of several features that in my opinion, need repaired or replaced. Addressing these factors will improve the efficiency of everyone who collects the data, processes it, designs management scenario based on these data results, and then those who implement management activities based on these information.

The Panel's Questions

Considering the B.C. inventory status described above, I attempt to put the panel's questions to discussion.

Question 1: Biometric Extensibility

Does the existing Forest Inventory Program, including growth and yield models, provide suitable and reliable information to support the decisions required for sustainable, well-managed forests?

The suite of forest Growth & Yield solutions created and deployed for B.C. forestlands is, in my opinion, not suitable to provide information to make the array of forest management decisions needed by users of this system. The TIPSY program was initially designed in 1975, then updated as computing moved from mainframe computer stacks, to personal computers. TIPSY, SILVER, and TASS, accompanied by variable retention yield adjustment protocols (Di Lucca, Goudie and Stearns-Smith 2004), has achieved meaningful technological advancement of Growth & Yield prognostications on B.C. ecosystems. However, the system fails to capture multiple species and variable retention management scenario commonly applied to forestland management situations. The current systems neither integrate insect and disease, wildfire risk profiles, nor global climate change to the management scenario.

Processing capabilities need to serve the system with better attuned growth interactions between trees and in response to site disturbances such as timber thinning, insects, disease and wildfire effects. B.C. forest ecosystems are situated uniquely to the potential effects of global climate change. Modeling the effects will be challenging, but at not impossible. These potential incidents are witnessed across the province and users need a biometrics model capable of modeling these in the virtual reality of today's management regime.

Effects of insect and disease can be predicted by other growth modeling programs, such as PrognosisBC developed by the USFS, and the FBRI forest biometric growth modelling system. Other Growth & Yield programs are able to process and report growth disruption events based on age and species of cohorts in each timber block, while currently TIPSY and TASS cannot.

The litany of forest ecosystem insights that can be delivered by forest Growth & Yield programs include insights for soils, hydrology, biotic and abiotic species diversity, dependent species habitat continuity, economics of commodity growth placed in terms of size through years, and much more. The insights captured through the cadre of programs officially used by B.C. foresters are limited. Where adaptations have been applied, such as the aforementioned "variable retention yield adjustment protocols", the complications involved in the integration with the overall system has proven to be inefficient and delivered to a small cadre of professionals located at the inner circle of official B.C. forest biometrics.

At this time, B.C. forest inventory efforts can focus attention to redesign the status quo, implement process-oriented changes to how data are collected, processed, and shared with others. This change of direction will cost less than continuing along the current track and generating questionable data, which is distributed to a limited number of outlets.

Now, is an opportune time to change orientation and increase forest management effectiveness, starting with forest biometrics.

Question 2: Working well?

What is working well? What is not working well?

While software utility and scientific solutions provided by the B.C. government are progressive and based on strong foundations, the inconsistent updates of the entire approach are outdated and inefficient. Ecosystem management within B.C. can be achieved by the professionals of the region, but the analytic tools need to be updated while the administration of these technologies needs to be drastically changed. I recommend that Growth & Yield data are used as an ecosystem management time-based tool.

I suggest setting the goal to attain measured Growth & Yield data based on forest block polygons, ultimately for about 30% of forest polygons in the Province. This may be achieved by starting with an actual block data sample rate of only 1% or 2%, with the remaining 98% linked through block-similarity using remote sensing data. This feeble sampling rate is low, but through time it can be increased to the point where site data are replicated to other blocks with more statistical reliability. Polygon data collection and replication through the network of remote sensing and data sampling efforts can integrate all forestland parcels in the Province.

The discussion of the technology used (TIPSY, TASS) has been addressed. It is doubtful that the software system will be repaired, modernized and made available to all potential users of the service in a timely manner. When deployed to the world, it needs all augmentations made part of the system and available to all users on personal computer systems. This specifically addresses multiple species modeling, volume tables, and site index array modeling.

It appears these augmentations are necessary to run the system on properties of B.C., but they have been withheld from a wide distribution. While it may serve the question of Allowable Annual Cut (AAC) for timber blocks, it does not address the larger question of sustainability at the current rotation, the next rotation or timber rotations into perpetuity from each unique block and on every block in the Province. This perpetual flow of timber obviously tracks to employment levels, mill manufacture and export revenues, it also associates with all other multiple-use considerations.

A complete rewrite of the biometrics system in B.C. needs to address forest inventory's purpose. From the beginning, forest inventory was designed to estimate timber volume at the time inventory was taken, and then in increments of time into the future. These increments may be annually for a few years, transitioning into reports at each quinquennium, or at each decade for a span of years reaching out 250 years, more or less.

The obvious question to ask is "why estimate conditions so far into the future?".

We derive so much more data today from a forest inventory than just the volume of timber on a block. Today we can derive wildlife and bird habitat of the forest resource along that same span of time. We can estimate effects to river aqua-systems and the anadromous habitat created. Forest biometrics provides the linkage between the physical site characteristics across the landscape to the people who depend on the same resource for financial benefits. Logging, infrastructure development, wildfire protection, and forest health overall leads to the wood processing industries making lumber to build houses, heat our homes, and create energy, all while employing people across the Province through gainful endeavors that establish sustainable and real economic value.

Forest biometric data generate insights to Carbon sequestration in the bole of the tree, in roots, branches and needles/leaves. Forests are Carbon sinks as they grow, with an increasing annual sequestration rate peaking, then declining as trees mature then senesce. When timber is harvested for lumber products the half-life of sequestered Carbon extends for approximately 100 years, making the lumber recovery feature of mills paramount to reducing Carbon emissions (Schlosser, Bassman, et al. 2002). Forest regeneration increases Carbon sequestration rates as young and rapidly growing trees capture more Carbon than their mature predecessors.

The nature of value is no longer limited to just timber products. Forest biometrics can be the source of these data if we task the software for these details.

Real economic value is a critical condition everyone needs to consider. If wood products from the forest are discontinued, the economic benefits from forestlands will stop. While TIPSY and TASS systems are acceptable, their current sequestration from all interested and capable people as fully functional multi-species and management-reflective programs is unacceptable. This situation needs to change.

Question 3: What can be done differently?

How can the forest inventory be improved to provide more useful and reliable information?

In the preceding litany of topics discussed, the question of "what to do now?" becomes paramount. I recommend the forest Growth & Yield analysis systems of B.C. are changed drastically. This needs to be repaired beginning with justification, sample design, and data collection. At its genesis, B.C. forest inventory data are unreliable at the polygon scale. Forest biometric software solutions in B.C. are not providing the forest management profession with the tools needed in the reality of the 21st century. B.C. can do better than this. This drastic change takes three distinct steps forward:

1. Develop TASS III and all associated programs into a unified platform.
    a. I recommend the TASS III protocols be completely developed and released, then all associated programs be integrated into a single forest biometrics platform.
2. In parallel with the current system's interim period of software redesign and rewrite, transition forest inventory and biometric operations to the USFS PrognosisBC model.
    a. Apply post processing algorithms to merchandise logs from inventory assessments.
3. It is recommended that FLNRO Facilitate the use of fully-functional software dissemination to anyone who will use it as a fully-functional software dissemination.
    a. Include biometric analysis programs, GIS data, and training of the use of these systems to all interested users (not just employees).

Treat Biometric Modeling as a Process, not a Destination

Step 1. Today, biometricians can provide detailed information about timber products growing on forest sites, merchandising logs from each tree stem to indicate sort and grade by volume. This is a mathematical exercise that can be integrated into computer software and enabled for every user of the system. I suggest the programmers and analytic specialists conduct a review of what others have accomplished in other systems, then integrate the outcomes that attract the most notable results. The TIPSY/TASS III approach can adopt these revisions and make the platform efficient. Expand this approach to include all species found in the Province.

Step 2. I recommend the B.C. FLNRO&RD integrate use of the findings made with the USFS/FVS PrognosisBC software system.

The critical investigator will recognize the PrognosisBC variant is designed for this region and can serve as a launching point moving ahead, at no cost of software development. It can be accomplished with fundamental training taken in combination of online sessions and live-training events. I have been a part of teaching FVS system training activities lasting three days to one week, and foresters with basic computer skills became operational in the software in that amount of training time.

I developed a timber volume measurement algorithm to generate FVS volume in Smalian cubic meters for each log merchandised – not just a total tree volume measurement. Instead of converting board foot measurements into cubic meters, I merchandize logs using taper formulae based on species, age, DBH, and total height estimates for each tree at each FVS reporting period. This generates tree diameter estimates at points along the tree bole to match log lengths bought by wood processors (lumber mills), plus trim. It is where forest biometrics meets log merchandising. I would make these algorithms available to B.C.'s ultimate software solution at no cost.

With these tree bole measurements effected on each tree reported by FVS on each timber block, volume and value can be derived at each reporting date made. This is a critical step for forest management decision making, but more steps still remain to be taken.

Delivered Log Markets

Step 1. In parallel with these biometric considerations, B.C. needs to address log market data. Market data articulates market cycle changes to delivered log markets in a region. Disruptions to market forces cause prices to spike up or down in real terms, but through time, these prices return to base price level, in real terms (Schlosser 2018). Price cycle estimates are developed for each sort and grade traded in competitive markets. This enables forest managers to estimate financial returns on forestland investments through time.

Log merchandising is described in each timber block grown in forest biometric analyses. This creates the valuation link between biometrics and commodity value, placed through time for the current rotation, the next rotation, then each rotation into perpetuity.

The next valuation step is to link these attributes with the macroeconomy of Canada using the Producer Price Index, goods - Industrial Product Price Indexes (IPPI - monthly). Maintained by Statistics Canada

(Government of Canada 2018), these macroeconomic data guide the time value of money giving the analyst the ability to convert nominal price data recorded monthly through exchanges in the marketplace, into real values – absent the effects of inflation. It enables analysts to make economic comparisons through time: a characteristic sought when managing forestlands where investments in the land resource may take several decades to reveal profitability.

FRASS

Step 2. I developed the Forest Resource Analysis System Software (FRASS) in 2010 to apply to forestlands in Washington State, with the goal to develop a forestland financial analysis system by combining biometrics, geospatial analyses, riparian zone management, TES species habitat, macroeconomic and microeconomic conditions into a blended network to discover financially optimal harvest timing on each block of an ownership starting with the current rotation, transitioning to the next rotation, then each rotation into perpetuity. The FRASS system generates economic findings concerning forestland ownership to reveal interconnected attributes pulling all factors into unison.

Written as a Software-as-a-Service program, FRASS hosts client data in secure databases and processes them on specially designed computer server systems to provide analyses on the server-side of operations. Authorized users can access the site, modify options, and receive digital reports through the secure internet connected system. Authorized users can access the platform from any internet connected device without increasing storage, processor speed, or purchasing additional software.

Properties within the FRASS platform reveal how owner characteristics influence microeconomic decisions leading to harvest timing alternatives. The system generates reports for authorized users to determine harvest dates on each timber block of an ownership. On the land ownership side of the report, it provides information to arrange logging operator availability, infrastructure sustainability, and to plan for reforestation events (slash burning, seedlings, tree planters). To the marketing side of operations, it allows wood processing organizations to plan years in advance for anticipated timber volume by sort and grade to enter the local markets. En masse, FRASS reports provide estimation of employment levels anticipated for all primary and secondary activities, in the short-term and into the long-term future.

I would give demonstrations of this system to decision makers and analysts to witness what is available from forest biometric analyses. This approach can aid B.C.'s intensive management migration.

Step 3. Expanding the awareness, use, and support of the forest biometrics system of B.C. is fundamental to adoption of articulate forest management activities. The biometric approach defines its usefulness and adoption. From this turning point, it can launch the path into an efficient future.

Question 4: What would be better if we changed the process?

What benefits would be achieved with the suggested improvements to the forest inventory?

Finding problems with an existing system seems not too challenging. Determining how to fix it can be drastically more complicated. Improvements I have detailed in this critical review could lead to faster data processing with higher accuracy for managers of the resource. Initially, this targets the timber inventory personnel who are involved in scheduling and marketing timber sales, planning multimodal transportation networks, reforestation coordination, and the series of interrelated activities. Beyond the timber management cadre, this approach opens cooperation with other natural resource cohorts managing wildlife, aquatic resources, socioeconomic outreach concerning employment, indigenous norms and traditions.

When the resource is vast and seems impenetrable, people often fall into the mode of considering forestlands as an endless endowment. When managed appropriately, the endowment will sustain the benefactors into perpetuity. However, when the endowment is tapped at the foundation level, returns from it will drop, and eventually expire.

The critical time for British Columbia to optimize forestland management activities is now. Trade with the USA has been dealt a blow in the form of duties placed on Canadian lumber as it enters the USA market. This free trade fiasco has hurt B.C. lumber and timber industries, as well as the secondary industries associated with these primary employment sectors. Internationally, this type of event has been dealt with, by some, to increase production to make up for the drop in per unit compensation. In natural resource management, that response can lead to ecologic tragedy.

Astute ecosystem management is the stated goal of FLNRO&RD. Resource managers need the best tools made available when designing management strategies for B.C. forestlands. The political disruption has destabilized B.C. forest management activities. This time of destabilization makes this an opportune time to restructure operational and managerial systems.

Ultimately, this revised approach links forest management activities with the Provincial economy of direct forest management and logging jobs. These activities all have a multiplier effect of the revenue created by these activities.

Actionable Strategies to Advance B.C. Forest Inventory

While forested ecosystems of British Columbia are unique, distinct, and exquisite endowments, it is the people who live in them, manage them, and protect them from negative events, that allows us to realize the greatness of this region. Forestland managers strive to collect and process information to achieve their goals. This becomes challenging for everyone as the science of forestry evolves in parallel with technological development, geospatial analysis techniques, database administration interconnectedness, and political guidance features.

I believe there is a need to update processes and procedures at FLNRO&RD to realize purpose and outcome. I restate the recommendations made earlier in this critical review:

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1. Develop TASS III and all associated programs into a unified platform.
    a. I recommend the TASS III protocols be completely developed and released, then all associated programs be integrated into a single forest biometrics platform.
2. In parallel with the current system's interim period of software redesign and rewrite, transition forest inventory and biometric operations to the USFS PrognosisBC model.

    b. Apply post processing algorithms to merchandise logs from inventory assessments.

3. It is recommended that FLNRO Facilitate the use of fully-functional software dissemination to anyone who will use it as a fully-functional software dissemination.
    a. Include biometric analysis programs, GIS data, and training of the use of these systems to all interested users (not just employees).

Several operational decisions need to be made and implemented within FLNRO&RD infrastructure. Some procedures need to be implemented internally, some through insistence of oversight administrators, and some with assistance from outside the organization.

Creation of pilot project areas within B.C. may facilitate understanding and acceptance of the protocols I have identified here. Many pilot site options are available. I suggest the areas selected be representative of forest management opportunities around the province and have viable lumber processing markets. The pilot project area might be portions of Vancouver Island, plus a north coast area, and Interior BC sites. In these coastal areas, the PrognosisBC/FVS variant would facilitate biometric projections. Geospatial data could be developed and made available for all sites and integrated into block records as they are processed.

Migration of existing data into PrognosisBC input files is expected to facilitate a reasonable beginning to this process. Input data are in some cases identical (species), and in others a matter of recoding (PPS sampling rate), and in some an issue of new data development or estimation (SI). It is an attainable and reasonable expectation to achieve an operational Growth & Yield system for the Province.

Through my company, D&D Larix, LLC, I would coordinate with B.C. decision makers to actualize these changes through consultation, training, technology development, and hosting a B.C. FRASS Platform for forestland managers. The FRASS Platform can be transitioned to FLNRO&RD computer servers to provide all authorized users local access to the financial optimization of B.C. ecosystem management. The system can be fully managed by B.C. specialists: consider this as one option.

I would coordinate with the Association of B.C. Forest Professionals about the recommendations I have made, and opportunities I have suggested.

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