Large-Scale Ecosystem Mapping for the British Columbia Woodlot Program—

A Problem Analysis

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EXECUTIVE SUMMARY

Large-scale ecosystem mapping is a management tool that is widely developed in British Columbia at the level of the forest estate. Large-scale ecosystem mapping involves the portrayal of forest and range ecosystems at the biogeoclimatic ecosystem classification (BEC) level of site series. Although commonly developed by licencees with large tenures, large-scale ecosystem mapping is not commonly pursued by smaller tenure holders, such as woodlot licencees. However, the applications of large-scale ecosystem maps sought by larger licencees, such as refining productivity estimates, are also relevant to woodlot licencees. The intensive management that woodlots receive can be aided by acquiring detailed mapping of the woodlot's ecosystems. The Strategic Policy and Planning Branch, Ministry of Forests and Range, requested a problem analysis to help evaluate the potential for smaller licencees to develop large-scale ecosystem mapping.

This report documents the results of a provincial-level survey of woodlot specialists, woodlot licencees, and ecosystem specialists. The focus of the survey was to examine existing large-scale ecosystem mapping projects for woodlots, evaluate the relevant applications and methods, and to determine the considerations unique to woodlots for obtaining and applying this mapping.

The development of large-scale ecosystem mapping for woodlots has been sporadic, with the majority of these maps produced by two regional woodlot associations (Bulkley and Cariboo). Cost efficiencies in these projects were realized by treating all woodlots as a single study area, reducing GIS and ground sampling costs. However, other criteria in the standards had to be waived to achieve these efficiencies.

Cost estimates per hectare ranged from $4.62 to $17.19 to produce ecosystem maps using the ground inspection intensities suggested in the Terrestrial Ecosystem Mapping (TEM) standards, depending on ecosystem complexity and whether grouping of woodlots has occurred.

Improving estimates of forest productivity is the primary objective for developing these large-scale ecosystem maps. Other applications include harvest and retention planning and revising wildlife habitat mapping. Potential applications include supporting hydrological modeling and stand level harvesting and silvicultural treatments such as vegetation management.

There are a number of considerations that are particular to producing large-scale ecosystem mapping for woodlots. Primary among these is the issue of scale, which affects the accuracy of this mapping in three major ways. First, the scale at which large-scale ecosystem mapping for woodlots must be accurate is finer than the scale that is appropriate for mapping over larger tenures, and is related to the complexity of the ecosystems and the

applications to which the map will be put. Appropriate scales range from 1:5,000 to 1:10,000.

Second, this scale of map portrayal is also finer than the scale of key input layers, such as BEC mapping. Third, consequently, large-scale ecosystem mapping for woodlots requires more intensive ground checking than does mapping for larger tenures. These scale issues suggest that mapping methods that rely primarily on ground assessments (i.e., Terrestrial Ecosystem Mapping) are better suited to large-scale ecosystem mapping for woodlots than are modeling methods (i.e., Predictive Ecosystem Mapping).

While a collective approach that involves mapping multiple woodlots simultaneously creates cost efficiencies for GIS, creating a large study area as a rationale for reducing the intensity of ground sampling has potentially negative consequences for map accuracy. While the larger study area might achieve reasonable accuracy, this accuracy may not scale down to individual woodlots, which may be subject to inadequate ground sampling, relative to their ecological variability. Consequently, sampling protocols for accuracy assessment must address the accuracy of both the larger study area and individual woodlots.

Existing standards for TEM ground sampling intensity are reasonable for woodlots; because of their relatively small area, the requirement to sample a percentage (e.g., >50%) of the polygons is achievable. However, some consideration should be given to modifying TEM standards for digital data capture on these small tenures.

Utilizing large-scale ecosystem mapping to its full potential requires conversancy with the BEC system. This is a limitation for many woodlot licence holders. An expanded extension role through woodlot associations or the Ministry of Forests and Range would assist woodlot licencees to maximize the applications of this mapping.

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1. PROBLEM STATEMENT

Large-scale ecosystem mapping has been sporadically applied to woodlots. However, recent efforts have led to the development of large-scale ecosystem maps for groups of woodlots. These efforts have raised interest in the potential improvements to management that this mapping could provide to woodlot licencees. Conversely, there are also concerns about what are the appropriate methods to produce accurate maps for woodlots; to date, standards for producing ecosystem maps have not focused on issues that are relevant at the scale of woodlot operations.

Strategic Policy and Planning Branch of the Ministry of Forests and Range contracted Biome Ecological Consultants Ltd. to review the opportunities and obstacles relevant to large-scale ecosystem mapping for woodlots.

We framed this problem analysis around the following questions.

1. How can woodlot licencees use large scale ecological mapping?
2. What is the appropriate scale for ecosystem mapping for woodlots?
3. Can existing methods be applied to woodlots to produce accurate maps at the appropriate scale for woodlots?
4. What are the specifications for Predictive and Terrestrial Ecosystem Mapping (PEM and TEM) for woodlots?
5. What methods are most suitable to assess site productivity in conjunction with ecosystem mapping on woodlots?
6. What costs may be expected to produce accurate ecosystem maps for woodlots?

2. BACKGROUND

2.1 BC WOODLOT LICENCE PROGRAM

The Woodlot Licence Program within the British Columbia Ministry of Forests and Range (MoFR) provides licence holders the right to manage and harvest small areas of Crown land in conjunction with their private land. Improving the productivity of the land and promoting excellence in forest management are among the objectives of the program (BC Ministry of Forests and Range 1997).

The allowable size of the Crown portion of the woodlots is up to a maximum of 800 hectares on the coast and 1200 hectares in the interior (Federation of BC Woodlot Associations 2007) (this has recently increased from 400 and 600 hectares respectively). All existing woodlots are subject to the 400 and 600 hectare maximums.

There are 823 woodlots in the province covering 546,095 hectares with an annual allowable cut (AAC) of 2,437,383 m^3 [1](Federation of BC Woodlot Associations 2007).

Excellence in forest management, one of the objectives of the program, can be achieved through an intimate knowledge of the ecology and productivity of these small holdings. Large-scale ecological mapping is one tool to capture and communicate this knowledge.

While the application of existing or enhanced resource inventories is a requirement for woodlot management, large-scale ecosystem mapping is not a required resource inventory. However, large-scale ecosystem mapping is a valuable tool for strategic and operational planning and for the assessment of site productivity for woodlots.

2.2 LARGE-SCALE ECOLOGICAL MAPPING

British Columbia has a well developed system of ecological classification (BC Ministry of Forests and Range 2007a). The Biogeoclimatic Ecosystem Classification (BEC) system integrates the effects that climate, soil and terrain features have on vegetation. At regional levels, broad patterns of climate are indicated by later successional vegetation and soil development and recognized as biogeoclimatic (BGC) units. At local scales segments of the landscape with similar vegetation, soil and topographic features are presented as site units. Practitioners utilize the classification for a wide variety of forest management applications, ranging from identifying patterns of forest disturbance, to selection of tree species for reforestation, to assessment of wildlife habitat.

The BGC and site levels within this classification system can be mapped at various scales. For example, the MoFR provides BGC mapping at the level of subzone / variant for the entire province. The BGC mapping has a very wide range of scales at which it is accurate (1:50,000 to 1:600,000). However, within the BEC hierarchy, it is the site level that has the widest application to forest management. Within the site level, the site series is the most widely used unit in the BEC system for operational forestry (BC Ministry of Forests and Range 2007a). Site series mapping is generally presented at scales from 1:5,000 to 1:20,000, with 1:20,000 scale mapping being the most widespread.

In this report the term “large-scale ecosystem mapping” is used to indicate site series level mapping. This type of mapping sometimes includes map units that are groupings of site series or map units not included in the BEC system, for example, some non-forested or non-vegetated map units.

There are established methods and standards for creating site series maps (BC Ministry of Environment 2006). Two approaches to creating these maps are Predictive Ecosystem Mapping (PEM) and Terrestrial Ecosystem Mapping (TEM).

[1] The current level of cut is largely due to short term increases to address mountain pine beetle mortality (2002 AAC was 1,262,714 m^3).

PEM uses a modeling approach where available input data is processed by a knowledge base. The knowledge base contains known relationships of map entities (site series) to the input data, such as digital elevation models, forest cover and terrain mapping. An initial PEM map is produced from the initial knowledge bases and then field checks are done to modify the knowledge base and assess the accuracy of prediction. The production of the final map is an iterative process until the mapper is satisfied with the agreement between the map and the field data.

TEM uses air photo interpretation and ground checks to create an ecosystem map. Map polygons are identified on aerial photographs on the basis of vegetation and terrain features. These polygons are then attributed with their site series composition based on air photo interpretation. Ground checks are then carried out in either a random or systematic approach and serve to revise the air photo classification.

PEM and TEM mapping is available for large portions of the province. These maps are generally presented at and accurate to a scale of 1:20,000. These maps are primarily applied to strategic planning processes at the Timber Supply Area (TSA) scale (up to over a million hectares).

Another method of gathering and displaying ecological data, specifically for woodlots, relies on the establishment of a systematic grid over the woodlot and the collection of ecological and forest productivity data at regular points on this grid. Sample points along the grid have been spaced at 50 or 100 meter intervals. Maps resulting from this approach can have polygons based either on forest cover or ecosystem attributes, but in either case site series data can be retrieved for map polygons.

3. METHODS

3.1 PROJECT TEAM AND RESPONSIBILITIES

The following organizations and individuals were involved in the project:

- Client:
    - Dave Bodak, Strategic Policy and Planning Branch / Project Initiation
    - Colleen McKendry, Strategic Policy and Planning Branch / Project Coordination
- Biome Ecological Consultants Ltd., Procter, BC, was the consultant. (see Appendix 1 for a summary of experience for the senior members of the Biome team):
    - Tom Braumandl, RPF, project leader and senior ecologist, was responsible for project research and summarizing the data and assisted with technical writing.
    - Pamela Dykstra, P.Ag., ecologist, was responsible for technical writing and assisted with data summaries.

3.2 INFORMATION SOURCES AND APPROACH TO THE PROBLEM ANALYSIS

T. Braumandl consulted with Ministry of Forests and Range staff including provincial, regional and district woodlot program personnel, and ecology specialists at Research Branch. Ministry of Environment Ecosystems Branch and Regional Operations Branch staff was also consulted, as were several woodlot licencees. T. Braumandl spoke with, and obtained information from, the project coordinators and the mappers for the two large-scale ecosystem mapping projects that are underway for regional woodlot associations.

T. Braumandl also reviewed the existing large-scale ecosystem mapping projects for woodlots, in particular, the Cariboo Woodlot Association PEM and the Bulkley Woodlot Association TEM projects.

Appendix 2 contains a list of the people contacted to gather information for this report.

3.3 PROJECT DELIVERABLES

This report comprises the project deliverable.

4. RESULTS AND DISCUSSION

4.1 EXISTING LARGE-SCALE ECOSYSTEM MAPPING FOR WOODLOTS

Relatively few woodlots have large-scale ecosystem mapping available. The vast majority of large-scale ecosystem maps for woodlots were generated by two large projects initiated by the Bulkley Woodlot Association (Mike Bandstra pers. comm. January 18, 2008) and the Cariboo Woodlot Association (John Gooding pers. comm. January 18, 2008). The Bulkley Woodlot Association TEM project is producing maps for 103 woodlots, while the Cariboo Woodlot Association PEM project produced maps for 26 woodlots. While no statistics were available for the number of woodlots that have large-scale ecosystem mapping, we estimate that fewer than 20 additional woodlots would have this type of mapping available, from the survey of Ministry woodlot program staff.

4.1.1 Bulkley Woodlot Association TEM project

This is the largest project in the province undertaken to obtain large-scale ecosystem mapping for woodlots. The Bulkley project has mapped more than twice the number of woodlots than all other large-scale ecosystem mapping projects combined. The Bulkley Woodlot Association project covers 103 woodlots in four Forest Districts (Skeena Stikine, Lakes and Morice, Nadina, Kalum), was initiated in 2005 and is scheduled for completion in March 2008. Timberline Forestry Consultants Ltd. is conducting the project. The study area totals 56,689 hectares. The Bulkley Woodlot Association is producing final maps for the woodlots at 1:10,000 scale.

A primary rationale for the approach in this project was that economies of scale could be realized by combining many woodlots into one project. One of the cost-saving features of the project was the application of low intensity field checking. The project used a survey intensity level of four. This survey intensity level requires many fewer ground inspections than the number required for survey intensities of 1 or 2, which are the prescribed survey intensity levels for maps of 1:10,000 scale (Resources Inventory Committee 1998) (survey intensity 4 requires sampling 15-25% of the polygons, compared to the >50% polygon visitation required for survey intensity 1 or 2). The rationale for selecting this survey intensity level was that the total area was over 50,000 hectares—the threshold study area size for using a survey intensity level of four (Table 6.3 in the TEM Standards) (Resources Inventory Committee 1998).

There were other relaxations of standards for this project to provide cost savings. The expanded legend will not include descriptions for seral stages not sampled. This modification should have a very minor impact on the utility of the maps. Bioterrain mapping was also not done on this project. The lack of bioterrain mapping is a relatively common relaxation of the standards and facilitates the integration with Vegetation Resource Inventory (VRI) mapping. The lack of bioterrain mapping will restrict interpretations of the map based on terrain features, such as erosion potential.

The basis for polygon delineation for the Bulkley project was the existing VRI mapping. The VRI polygons were subdivided in instances where considerable ecological variation was seen on the aerial photography. Using a common polygon base is a desirable feature as productivity estimates gathered on VRI polygons can complement SIBEC estimates that are generated on the basis of ecosystem polygons.

The approach to the TEM for the Bulkley woodlots creates three major limitations for application at the scale of individual woodlots. First, the survey intensity level that was applied is appropriate to maps portrayed at 1:20,000 to 1:50,000 scale, suggesting the TEM for the Bulkley woodlots should not be applied at scales larger than this. Each woodlot had 12 field inspections while the number of map polygons (an indicator of ecosystem complexity) ranged from 29 to 178. Therefore the individual woodlots experienced a wide range of field sampling intensities from 41 to 7% of polygons with ground inspections.

Second, it is debatable whether the entire project area should be considered one population. The study area ranges over four Forest Districts from the Terrace area to Burns Lake. The ecological conditions differ dramatically over the study area, ranging from the Coastal Western Hemlock zone near Terrace to the Sub-Boreal Spruce Zone of the Central Interior. Conditions can vary widely even within one Forest District, depending on climate and terrain features. The relatively low field inspection rate of this project, coupled with the ecological diversity, could impact the accuracy of the individual maps.

Third, lumping the 103 woodlots into a single sample population limits the effectiveness of the protocols for assessing the accuracy of TEM. At the time of writing, the TEM is undergoing an accuracy assessment, to address the primary objective for obtaining the large-scale ecosystem mapping—refinement of productivity estimates. The accuracy assessment is following the standards for a level four intensity level TEM to determine the AA sample size. The accuracy assessment, like the TEM project, considered the entire project area as one population. This resulted in a total of 108 accuracy assessment samples over the entire area; there is an average of slightly over one sample per woodlot to assess the accuracy of the maps.

The methods of accuracy assessment call for a process of random sample selection (i.e., the sample selection is not stratified), which suggests that many woodlots may not be sampled at all during the accuracy assessment. Similarly, because only eight of the 108 samples are ground samples, depending on the distribution of samples, it is likely that some biogeoclimatic units may not be ground-sampled at all.

Both Del Meidinger, the author of the protocol for accuracy assessments (Meidinger 2003) and Corey Erwin, Ministry of Environment provincial ecosystem mapping data custodian agree that this is an inadequate sample to properly assess the accuracy of the individual woodlot maps (Del Meidinger pers. comm. January 18, 2008, Corey Erwin pers. comm. January 18, 2008). The overall project may obtain a passing grade but some woodlots may be very poorly mapped and the licencees may have no sense of the accuracy of the TEM for individual woodlots.

The application of large-scale ecosystem mapping to woodlots is relatively novel. The current standards for large-scale ecological mapping and the protocols for assessing the accuracy of this mapping were derived primarily for mapping larger tracts of land. Rigorous digital data capture standards for these large project area maps allow for multiple parties to utilize this information for a wide variety of uses (Resources Inventory Committee 2000) and allow the data to be housed in the provincial Land and Resource Data Warehouse (LRDW). However, large-scale ecosystem mapping for woodlots will be utilized almost exclusively by the individual licence holder, reducing the necessity for the level of digital data capture required by the standard.

The mismatch between the protocols for accuracy assessment and the realities of ecosystem mapping at the scale appropriate to woodlots is an artifact of the historic applications of PEM and TEM. The TEM standards and the accuracy assessment protocol should be reassessed to better suit the needs of management of these small holdings (Del Meidinger pers. comm. January 15, 2008).

4.1.2 Cariboo Woodlot Association PEM project

A project was recently completed to obtain 1:10,000 scale PEM for 26 woodlots under the umbrella of the Cariboo Woodlot Association. The project attempted to refine the existing 1:20,000 scale East Williams Lake TSA-level PEM. The project attempted to obtain a digital elevation model accurate to 1:10,000 scale and rerun the PEM using this improved information. It was not possible to obtain the refined digital elevation model. The unaltered TSA-level PEM was then displayed at 1:10,000 scale for the 26 woodlots.

A component of the project was a comparison of the results of the TSA-level PEM against a map produced through air photo interpretation and extensive ground checks (essentially a TEM process) for one woodlot (woodlot 588). Ray Coupé, MoFR research ecologist, Williams Lake, carried out the TEM-like mapping and the comparison of the two maps. One result of this exercise was the finding that approximately one third of the woodlot was mapped in the wrong biogeoclimatic variant by the PEM. Once this error was corrected, there was good agreement between the PEM and the Coupé map (76% of 120 random points had the same site series or site series group predicted) (Jack 2006). It should be noted that woodlot 588 is situated in an area of simple terrain and soil materials. Other portions of the same PEM did not have similar accuracy from this author's experience using the same PEM to locate specific ecosystems[2].

Given the final result, R. Coupé suggested that the PEM was a valuable first step to producing an accurate ecosystem map for woodlots. He suggests overlaying georegistered aerial photography over the PEM in order to adjust PEM polygon boundaries and refine the map through subsequent field work (Ray Coupé pers. comm. January 4, 2008). However, the large error in BGC mapping reveals the necessity of ground checks on PEM maps. In our opinion, the need to carry out detailed ground checks and refine the PEM results through the use of aerial photography reduces or eliminates the cost advantage of PEM.

The woodlot association had hoped that the TSA-level PEM accuracy assessment results could be applied to the 1:10,000 scale maps for the woodlots. The East Williams Lake TSA PEM had achieved the necessary accuracy to be used for

[2] T. Braumandl spent several weeks attempting to use the East Williams Lake PEM in 2006 to find drier or wetter than mesic ecosystems in order to carry out SIBEC sampling. He often found these areas to be incorrectly identified, sometimes over areas of hundreds of hectares. These observations are however, anecdotal as he did not carry out a formal accuracy assessment.

TSA-level timber supply review modeling (>65% map entity overlap) (Meidinger 2003). However both Del Meidinger and Corey Erwin agree that it is not appropriate to use the TSA-level accuracy assessment results for the woodlot maps (Del Meidinger pers. comm. January 15, 2008, Corey Erwin pers. comm. January 16, 2008). A separate accuracy assessment specific to the woodlot maps would have to be conducted if the mapping was to be used for AAC adjustments. The procedures for conducting accuracy assessments on woodlots should be reviewed and modified as appropriate by provincial experts to ensure they are practical and affordable (Del Meidinger pers. comm. February 29, 2008).

4.1.3 Large-Scale Ecosystem Mapping Projects on Individual Woodlots

Several large-scale ecosystem maps have been produced for individual woodlots at a variety of scales from 1:5,000 to 1:15,000 scale. Larger scale maps (1:5,000 scale) have been produced where ecosystem complexity is high. Large-scale ecosystem maps for individual woodlots have been produced for licencees that are conversant with the BEC system.

The large-scale ecosystem mapping produced for a group of woodlot licencees (Bulkley and Cariboo Woodlot Associations) had a primary objective to revise productivity estimates. The licencees, that have acquired large-scale ecosystem mapping for their individual woodlots now use the mapping for a wide variety of purposes. These purposes include:

- Strategic planning
    - Establishing management regimes for ecosystem types
    - Providing data to refine wildlife habitat mapping
    - Establishing areas where harvesting will be avoided
    - Establishing wildlife tree patches
    - Assessing agro-forestry potential
    - Providing rationale for rehabilitation treatments
    - Hydrological modeling to address community concerns
- Operational planning
    - Providing data for pre-harvest maps or site plans
    - Help establish harvest boundaries
- Assessing site productivity
    - Provide SIBEC estimates for polygons where local site index data can not be reliably gathered

The cost of gathering management information can be reduced by having large-scale ecosystem mapping available (Brent Petrick pers. comm. February 1, 2008). The ecosystem mapping can eliminate the need for additional inventories to assess information needs, e.g., agroforestry potential can be assessed on a few representative ecosystem polygons and then applied to the entire map area rather than having to have a field assessment done over the entire woodlot in the absence of ecosystem mapping.

The ecosystem maps for individual woodlots have been produced through TEM-like methods—air photo interpretation to delineate map polygons and field checking to establish the site series present within the polygons. Methods of field verification vary.

Some maps were produced by using a systematic grid with plots spaced at 100m (or some other length) intervals. This provides a huge number of ground inspections (526 plots on ~400 ha (WL#0086), 400 plots on ~600 ha (WL#495)). This level of ground checking would be equivalent to a TEM standards survey intensity level of one (>76% of polygons with ground inspections). The grid plots can also be used to gather timber type and tree productivity information.

Other maps have been produced using ground checks at various intensities, some of which vary from the TEM standards. Woodlot 1832 has a 1:5,000 scale map produced with a survey intensity level 3 field inspection rate. This scale was chosen due to the high ecosystem complexity of the area. Sixty seven (67) field inspections were carried out. The total number of map polygons was 250, hence the field inspection rate was 27%. The TEM standards state that for 1:5,000 scale maps the field inspection rate should be greater than 76%. This relatively low intensity of field checking was settled on due to funding constraints. A VRI project is planned for the future that will utilize the TEM polygons as much as possible. Additional ecosystem field assessments will be conducted during the VRI project to increase the survey intensity of the TEM (Tom Bradley pers. comm. February 2, 2008).

Woodlot 1458 has a 1:15,000 scale map produced through an integrated TEM/VRI process with a resulting survey intensity level of one (all polygons have been field checked). This woodlot is ecologically less complex with a total of 56 polygons.

4.2 EXISTING APPLICATIONS OF LARGE-SCALE ECOSYSTEM MAPPING ON WOODLOTS

There are two major applications for large-scale ecosystem mapping of woodlots:

1. revising productivity estimates through the application of SIBEC data, and
2. guiding strategic and operational planning.

4.2.1 Productivity estimation and ecosystem mapping for woodlots

A powerful interpretation of large-scale ecosystem mapping is the estimation of tree productivity. Large-scale ecosystem mapping allows licencees to apply SIBEC estimates to their land base. This is very often an improvement over the available forest cover site index estimates and often (in the case of TSA-level mapping) results in increases to the AAC.

The revision of productivity estimates and hence the revision of AAC's is the most widespread objective for gathering this mapping. The projects for large-scale ecological mapping for areas covered by the Cariboo and Bulkley Woodlot Associations were undertaken with the primary objective of revising productivity estimates.

Given the intensive management found on woodlots, productivity estimation should rely as heavily as possible on local data. Local productivity data can be gathered using either using site index curves and local height and age data or growth intercept data if available for the tree species in question and depending on stand age. However, there are many situations where the use of site index curves and growth intercept tables may not be possible; for example, old growth stands or polygons with no suitable sample trees. Where this is the case and an accurate large-scale ecosystem map is available, the best data available are the SIBEC estimates (Shirley Mah, pers. comm. January 21, 2008).

The calculation of AAC on woodlots is facilitated through the use of the Woodlot for Windows software (Ministry of Forests 2002b). The site index data for use in the software should ideally be generated from one set of polygons, whether it is based on local height/age data or SIBEC. Where ecosystem and forest cover (VRI) polygons are not similar it becomes less straightforward to use SIBEC estimates from the ecosystem map, if the input polygons for Woodlot for Windows are based on forest cover. For example, if a Woodlot for Windows analysis polygon (the forest cover polygon) has more than one ecosystem polygon according to the large-scale ecosystem mapping, SIBEC estimates could vary between the ecosystem polygons, and two or more productivity estimates could be attributed to the forest cover polygon. In this case, some area weighting for the ecosystems represented within the analysis polygon should occur. This difficulty in computation reinforces the desirability of integrating the VRI and ecosystem mapping.

4.2.2 Applying ecosystem mapping to strategic and operational planning for woodlots

Large-scale ecosystem mapping can aid in strategic level planning in a wide number of ways, for example:

- the identification of areas where harvesting should be avoided,
- the identification of areas where machine traffic may be problematic,
- the indication of patterns of natural disturbance at a more refined scale than the biogeoclimatic variant level,
- helping locate wildlife tree patches,
- assessing agro-forestry potential,
- providing rationale for rehabilitation treatments, and
- to refine wildlife habitat mapping generated from TSA-level assessments.

Large-scale ecosystem mapping can have significant impacts on the level of harvest through the refinement of broader (TSA or landscape) level assessments. For example, a re-assessment of ungulate winter range that utilized the woodlot ecosystem map resulted in an approximately 75% increase in the AAC for Woodlot 1458 (Neil Bow pers. comm. December 18, 2007). Another example is the quantification of patterns of natural disturbance. This type of assessment is an important application in order to obtain certification from the Forest Stewardship Council, as FSC appraisal of woodlot management plans centers on how well forest management emulates natural disturbance patterns (John Cathro pers. comm. January 4, 2008, Forest Stewardship Council Canada 2005).

Operational planning is also aided by large-scale ecosystem mapping. Large-scale ecosystem mapping supports management decisions such as the appropriate season of harvest, suitable species for reforestation, and stocking standards. Site plans under the Forest Practices Code (FPC) (BC Ministry of Forests and Range 2001) and pre-harvest maps under the Forest and Range Practices Act (FRPA) (BC Ministry of Forests and Range 2004) require that site series be identified prior to harvest. Large-scale ecosystem mapping provides this information and can speed up field assessments for operational planning.

4.3 POTENTIAL APPLICATIONS[3]

There is a broad array of additional interpretations that managers can make from large-scale ecosystem mapping. Some of these include:

- hydrological modeling (Tom Bradley of woodlot 1832 is hoping to use his mapping to allay community concerns about impacts of harvesting on water supply [Tom Bradley pers. comm. February 2, 2008]);
- indicating the need for stand tending treatments; and
- assessing growth-limiting factors and indicating appropriate harvest, species selection and stand tending treatments to address these growth-limiting factors.

4.4 CONSIDERATIONS FOR OBTAINING AND APPLYING ACCURATE LARGE-SCALE ECOSYSTEM MAPPING FOR WOODLOTS

4.4.1 Determining the appropriate scale for map portrayal

Most large-scale ecosystem mapping in the province has been produced for use on very large tracts of land; for example, TSAs and Tree Farm Licences (TFLs). This mapping has been used for broad level strategic planning and timber supply review (TSR) purposes. Maps are typically displayed at a scale of 1:20,000.

However, 1:20,000 scale mapping is not appropriate for small tracts of land such as woodlots. Woodlot management is practiced at a fine scale. Harvest blocks are often less than 5 hectares in size and treatments can be applied to

[3] We can not be certain that any of the applications in this section that we consider to be ‘potential’ applications have not been made on some woodlots that have large-scale ecosystem mapping available, as T. Braumandl didn’t speak to all licencees that have this mapping.

areas that range down to individual trees—treatment areas 0.5 ha in size are not uncommon. Appropriate scales for woodlot mapping are 1:5,000 and 1:10,000 scale (Courtin et al. 1998, Del Meidinger pers. comm. January 15, 2008, Corey Erwin pers. comm. January 16, 2008). Determining the appropriate scale for an individual woodlot depends on the terrain and ecosystem complexity that characterizes the woodlot and the applications to which the map will be put. For environmentally complex areas where the map will be used for operational planning, a scale of 1:5,000 is most appropriate. In areas of less environmental complexity where the map application is primarily to refine productivity estimates, a scale of 1:10,000 is adequate.

4.4.2 Scale and input data—BEC

A map can be portrayed at a variety of scales. However, this plasticity does not mean that a map is equally accurate at all scales. Just as a photograph can not be enlarged indefinitely, there is a level of resolution attached to a map that limits the scale at which it ought to be portrayed. The accuracy of the map relates in large part to the accuracy of the input data used to generate the map, whether that input data is a digital elevation model, aerial photography or ground samples.

Two major BEC issues exist at the woodlot scale which require thorough field checks:

- biogeoclimatic unit boundaries and
- transitional areas between biogeoclimatic units.

Biogeoclimatic variant mapping is available for most of the province to a maximum of 1:50,000 scale accuracy (available at 1:20,000 scale but accurate at approximately 1:50,000) (BC Ministry of Forests and Range 2007a, Del Meidinger pers. comm. February 29, 2008). Consequently, BGC boundaries can be significantly in error when applying this mapping to the woodlot scale. Field checking of BGC unit boundaries should occur if existing mapping shows a boundary within 150 meters vertical elevation or within a kilometer of the woodlot, as this is the approximate limit of accuracy of the available mapping.

Ecosystems may be transitional between two BGC units in the vicinity of BGC boundaries. Ecosystems may exhibit features transitional between the BGC units including such things as vegetation composition, soil development and tree productivity over an area that could comprise a significant portion of a woodlot. Failing to note the extent of these types of transitions may reduce the usefulness of the map for management interpretation, e.g. productivity estimates may be inaccurate.

4.4.3 Scale and input data—general

For PEM maps dependant on digital data for their production, existing input data is not available that is accurate at scales larger than 1:20,000. Input data, for example, enhanced digital elevation models or detailed terrain materials mapping, accurate to 1:5,000 or 1:10,000 scale for PEM maps, could be generated. However, these processes would add considerable extra cost to producing a PEM; the primary advantage of PEM over TEM methods has historically been cost savings due to the ready availability of existing data suitable to produce 1:20,000 scale maps.

4.4.4 Intensity of field inspections

TEM is acknowledged as a more appropriate means than PEM for producing larger scale ecosystem maps (BC Ministry of Environment 2006). Standards exist for producing TEM maps at 1:5,000 and 1:10,000 scale (Resources Inventory Committee 1998). The critical factor for producing accurate maps at these large scales is frequent ground checks. The TEM standards include survey intensity levels appropriate to the size, scale and use to which the maps will be put. These survey intensity levels indicate the number of ground checks that are required to produce maps accurate for the various scales and uses to which the maps will be put.

The standards prescribe a survey intensity level of 1 or 2 for 1:10,000 or greater scale mapping for areas of less than 5,000 hectares. These survey intensity levels require that over 50% of polygons should undergo some field inspection (Table 6.3 in the TEM Standards; Resources Inventory Committee 1998).

While this may appear onerous and costly, there are two factors—the small size of woodlots and the relatively small number of map polygons—that mitigate costs. There are a relatively small number of map polygons on a woodlot (a range of 29 for extremely simple terrain (Woodlot 143 Kalum District; Mike Bandstra pers. comm. January 18, 2008) to 250 for extremely complex terrain (woodlot 1832 Winlaw Creek; Tom Bradley pers. comm. January 9, 2008). The small number of polygons and small areas means that the completion of field evaluations of greater than 50% of the polygons can be completed in a relatively short time (I estimate between 1 and 5 crew days). This level of field verification is in accordance with suggested sampling requirements for updating Forest Inventory data for woodlots in order to adjust AAC levels (Ministry of Forests 2002a)[4].

4.4.5 Accuracy assessment protocol

If large-scale ecosystem mapping is to be used for adjustment of the woodlot AAC, the map must be subject to an accuracy assessment to determine that it is sufficiently accurate for this purpose (Meidinger 2003, Del Meidinger pers. comm. January 15, 2008). The intensity and consequently the cost of the accuracy assessment should be related to the amount of field checking done to

[4] These guidelines suggest that all forest inventory polygons within a woodlot area must be sampled.

produce the map. A map having a high proportion of polygons field checked during mapping should require a less intensive accuracy assessment. The protocol for accuracy assessments (Meidinger 2003) was written with maps produced for large areas (TSAs and TFLs) in mind. Guidance for appropriate accuracy assessment procedures for woodlots is necessary, particularly if mapping standards (e.g., sampling intensity) are relaxed.

4.4.6 Forest cover and ecosystem polygon compatibility—TEM/VRI integration

One of the resource inventories required for woodlot management is forest cover information. There is an opportunity to meld the forest cover inventory and the large-scale ecosystem mapping information onto a common polygon basis. Using a common polygon basis simplifies the analysis of site productivity and AAC calculations, and simplifies management decisions such as specifying harvest and retention areas. Integrated projects should lead to higher levels of ground inspections than stand-alone TEM projects and so should lead to more accurate maps.

This process "Integration of Terrestrial Ecosystem Mapping (TEM) and Vegetation Resources Inventory (VRI)" has an approved provincial government standard and procedures (BC Ministry of Sustainable Resource Management 2002). Acquiring large-scale ecosystem mapping through the Terrestrial Ecosystem Mapping process (BC Ministry of Environment 2007) or a TEM/VRI integrated inventory are eligible expenses under the Land-Base Investment Program of the Forest Investment Account (FIA) (BC Ministry of Forests and Range 2007b). However eligible funding is restricted to the photo-interpretation phase (phase I) of VRI. There are also cost caps placed on funding for VRI on woodlots.

4.4.7 Knowledge limitations

A good working knowledge of the BEC system is needed in order to use the maps to guide operations and refine strategic planning on woodlots. The level of knowledge of the BEC system among woodlot licencees is variable, with a majority of licence holders having only a cursory understanding of the classification system. However, using this mapping to adjust AAC's through the application of SIBEC estimates does not require the woodlot licence holders to be conversant with the BEC system.

Large scale ecosystem mapping is a powerful tool for managing forest land as there are numerous interpretative purposes to which the maps can be put. Given the woodlot licence program objective of promoting excellence in forest management, it would be ideal if ecosystem mapping could be applied to its full potential. This would require that it be implemented on woodlots where licencees are conversant with the BEC program. The use of this type of mapping and familiarization with the BEC system could be extended to other woodlot licencees by these early adopters and through an expanded extension function within the MoFR.

4.5 COSTS TO ACQUIRE LARGE-SCALE ECOSYSTEM MAPPING FOR WOODLOTS

The cost data available were limited to partial data from three projects: the Bulkley Woodlot Association TEM, Woodlot 1458 and Woodlot 1832. The two individual woodlots experienced considerably higher costs per hectare, as would be expected. Woodlot 1832 is more complex, with more than twice the number of polygons per woodlot than the average in the Bulkley Woodlot Association project. Both the individual woodlot projects had higher proportions of polygons field inspected than the Bulkley project (67 and 30 plots/woodlot compared to 12 plots/woodlot for the Bulkley project). The individual woodlots had costs per hectare of $9.82 and $11.85 for Woodlots 1832 and 1458, respectively. Total project costs for the individual woodlots were $7,550 and $7,100 for Woodlots 1832 and 1458, respectively. The Bulkley Woodlot Project costs (based on first year costs to complete 54 woodlots) were approximately $2.11 per hectare.

The Woodlot 1832 project used a field sampling intensity that was approximately half that suggested in the TEM standard (note that the intent was for subsequent VRI sampling to bring the field check intensity in line with the standard). In order for the Woodlot 1832 TEM to meet existing TEM standards for field checking, costs might be expected to increase by 75% to $17.19/ha or $13,213 for the entire project cost. This could be considered a worst case cost due to the very high number of polygons on this woodlot.

The Bulkley Woodlot Association project is the only large-scale ecosystem mapping project that has been subjected to an accuracy assessment to my knowledge. The cost for the accuracy assessment on a per hectare basis was $0.77 (total cost $43,500).

When evaluating these costs it should be noted that both Del Meidinger and Corey Erwin felt that the field assessments of the TEM and the accuracy assessment sample size are inadequate to properly assess the accuracy of individual woodlots within the Bulkley project. Costs for both the TEM and the accuracy assessment would likely increase to provide accurate mapping for operational and strategic planning on individual woodlots. If the Bulkley TEM had increased its field validation checks to the greater than 50% level suggested in the TEM standard, this would mean a four and half fold increase in field sampling. Assuming some efficiencies of scale for the additional work, field sampling and data entry costs might increase 3 fold. This would translate to an approximate total cost per hectare of $4.62. It is difficult to predict the added costs of an improved accuracy assessment approach (subdividing the study area into ecologically homogenous populations)—a conservative estimate might be to double the cost to $1.54 hectare.

Although based on a limited sample, large-scale ecosystem mapping has been produced for woodlots of 600 hectares in size for between $7,000 and $13,000.

The cost savings of grouping woodlots together into larger, more efficient projects, while attractive, are to some degree offset by the fact that these large projects will have a number of licencees that have only a cursory understanding of BEC. Those licencees that are not conversant with BEC will likely only use the large-scale ecosystem mapping for site productivity assessment rather than its full range of interpretation. Extension, either from other woodlot licencees who are conversant with the BEC system or MoFR staff, may encourage the application of the large-scale ecosystem mapping for a wider range of uses. An increased level of extension in the future is desirable but certainly not assured.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 APPROPRIATE SCALE FOR LARGE-SCALE ECOSYSTEM MAPPING

There are two scales that are appropriate to large-scale ecosystem mapping for woodlots: 1:5,000 and 1:10,000.

The 1:5,000 scale is appropriate where ecosystem complexity is high and maps are to be used for operational and strategic planning.

The 1:10,000 scale is appropriate where ecosystem complexity is moderate to low and/or maps are to be used primarily for assessment of site productivity. This scale may also be more appropriate for the new maximum size of woodlots (1,200 hectares).

5.2 SUITABILITY OF PEM AND TEM METHODS FOR OBTAINING LARGE-SCALE ECOSYSTEM MAPPING FOR WOODLOTS

PEM appears unsuitable for obtaining large-scale ecosystem mapping for woodlots unless:

- digital input data are available that are accurate to the portrayed map scale (1:5,000 or 1:10,000),
- BGC lines are verified in the field, or
- an existing TSA-level PEM with a high degree of accuracy, having accuracy assessments done in ecosystems and terrain similar to that of the woodlot, is used as an initial step to stratify the woodlot, with subsequent revisions based on air photo interpretation and ground checks.

At present these limitations would almost certainly lead to a PEM approach having no cost advantage to a direct TEM approach.

TEM methods should be employed, using a survey intensity level of 1 for 1:5,000 and survey intensity levels of 1 or 2 for 1:10,000 scale maps.

5.3 GROUPING WOODLOTS INTO LARGER LARGE-SCALE ECOSYSTEM MAPPING PROJECTS

Cost savings are realized by grouping woodlots into larger large-scale ecosystem mapping projects. These cost savings are to some extent reduced by the fact that the majority of licencees may not utilize the mapping to its full potential.

Grouping of woodlots into projects should ensure that participating woodlots have a reasonable amount of ecological similarity or projects should be subdivided on the basis of ecological similarity.

5.4 COST OF MAPPING INDIVIDUAL WOODLOTS

Although per hectare costs for mapping individual woodlots are considerably higher than for groups of woodlot, the intensive use of this information may justify the added expense. The total project cost for this information seems very reasonable.

5.5 REVISION OF TEM STANDARDS AND ACCURACY ASSESSMENT PROTOCOL

TEM standards have been frequently relaxed for large-scale ecosystem mapping projects for woodlots in various and apparently inconsistent ways. It would be desirable if the TEM standards were revised for application to woodlots to provide consistency and cost-savings where appropriate.

Guidance for appropriate accuracy assessment (AA) procedures for woodlots mapping is also necessary. Revisions of both TEM and AA procedures should be done in an integrated manner to ensure compatibility and maximize value.

5.6 INTEGRATION OF TEM AND VRI PROJECTS FOR WOODLOTS

Where possible, TEM projects should be integrated with VRI mapping and data collection. This integration would create cost savings, as well as facilitating AAC determinations. It should, however, be kept in mind that using VRI polygons as the basis for the ecosystem (TEM) polygons may complicate making terrain-based interpretations.

5.7 EXPANDED EXTENSION ROLE TO PROMOTE THE USE OF LARGE-SCALE ECOSYSTEM MAPPING ON WOODLOTS

Extension to increase the familiarity of woodlot licencees with the BEC system and the potential uses of large-scale ecosystem mapping could potentially improve the level of forest management on woodlots—a stated goal of the woodlot program. This enhanced level of extension could be provided through woodlot associations by those licencees conversant with BEC. Dedicated extension staff in the MoFR woodlot program well versed in BEC principles or extension by MoFR or external, expert ecologists would also assist in the goal of increasing the level of forest management on woodlots.

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APPENDIX 1. BIOME ECOLOGICAL CONSULTANTS LTD. PROJECT TEAM

COMPANY BACKGROUND

We established Biome Ecological Consultants Ltd. (BEC Ltd.) in April 2002 to provide services in ecological mapping and classification, forest ecosystem research and monitoring, project auditing, and ecosystem management consulting.

BEC Ltd. provides extensive experience in all phases of ecosystem research, from problem analysis to project conception and planning, field work, analysis, and reporting. We apply our experience to projects in vegetation management, forest disturbance, and ecosystem classification development and refinement.

Our other experience includes development of standards, expert reviews of proposed approaches to ecosystem management at the provincial and regional levels, development of ecosystem restoration and monitoring programs, development of structural attribute definitions of old-growth forests, and old growth management planning.

BEC Ltd. employs two full time, professional ecologists. Our complementary training and experience provides our clients with cross-disciplinary expertise in forest and range ecosystems. From a network of professional contacts established during more than 40 years of combined experience in forestry in BC, BEC Ltd. also regularly assembles project teams to suit the needs of our clients. Assembling project teams that are dictated by the needs of our clients enables us to employ senior professionals in their relevant areas of expertise in a cost effective way. At BEC Ltd. we strive for professional excellence. We provide data and information that are highly relevant and readily applicable to the needs of our clients.

PROJECT PERSONNEL

Tom Braumandl, B.S.F. Forest Biology (1979), RPF is a principal of BEC Ltd., and the senior forest ecologist for Biome. Tom has 28 years of experience in ecological classification and mapping, primarily gained through planning, implementing and extending the B.C. Ministry of Forests' ecological research program for 22 years in the Nelson Forest Region. Tom has worked on various aspects of PEM and TEM since their inception, including several accuracy assessment and quality assurance projects in southeast British Columbia during the past six years with BEC Ltd.

Pamela Dykstra, P.Ag., is a principal of BEC Ltd., and is currently completing her Masters of Resource Management at the School of Resource Management, Simon Fraser University (thesis defense approved, degree completion by April, 2008). Pamela has 13 years of experience in all phases of forest ecosystem research. Before establishing Biome, Pamela spent seven years as a research assistant with the British Columbia Ministry of Forests Forest Sciences Section. Pamela has been involved in literature reviews, expert reviews of provincial and regional strategic-level ecosystem-based plans, and all phases of PEM and TEM accuracy assessment projects in southeast British Columbia during the past six years with BEC Ltd.

APPENDIX 2. INDIVIDUALS AND ORGANIZATIONS CONSULTED

Name	Affiliation/position
Mike Bandstra	Forsite Consultants / Bulkley Woodlot Association TEM Project coordinator
Abbey Bates	BC Ministry of Forests and Range, Headwaters Forest District / Tenures Forester - Woodlots
Neil Bow	BC Ministry of Forests and Range, Kootenay Lake Forest District / Tenures Forester - Woodlots
Tom Bradley	Woodlot licencee, Winlaw
David Brown	BC Ministry of Forests and Range, Arrow Boundary Forest District / Tenures Forester - Woodlots
John Cathro	Consultant / Chair of the Forest Stewardship Council of British Columbia Regional Initiative
Alvin Cober	BC Ministry of Environment, Ecosystems Section, Queen Charlotte City / Ecosystem Biologist
Ray Coupé	BC Ministry of Forests and Range, Southern Interior Region, Williams Lake / Research Ecologist
Ron Donelly	BC Ministry of Forests and Range, Skeena Stikine Forest District / Tenures Forester – Woodlots (former)
Corey Erwin	BC Ministry of Environment, Ecosystems Branch / Vegetation Ecologist
Chris Finke	BC Ministry of Forests and Range, Northern Interior Forest Region / Timber Tenures Specialist,
Alan Gilchrist	BC Ministry of Forests and Range, Vanderhoof Forest District / Tenures Forester - Woodlots
John Gooding	J.D. Gooding & Associates Ltd. / Cariboo Woodlot Association PEM project coordinator
Trudy Goold	BC Ministry of Forests and Range, Southern Interior Region / Tenures Forester
David Haley	BC Ministry of Forests and Range, Resource Tenures and Engineering Branch / Tenures Forester - Woodlots
Steve Henderson	BC Ministry of Forests and Range, Prince George Forest District / Tenures Forester - Woodlots
Al Hopwood	Woodlot licencee, Courtenay
Ksenia Konwicki	Timberline Forest Inventory Consultants Ltd. / Ecologist
Rod Krimmer	Woodlot licencee, Williams Lake
Brian Kukulies	BC Ministry of Forests and Range, Sunshine Coast Forest District / Tenures Forester - Woodlots
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Shirley Mah	BC Ministry of Forests and Range, Research Branch / Interpretations Forester
Shaun McAmmond	BC Ministry of Forests and Range, Peace Forest District / Tenures Forester - Woodlots

Name	Affiliation/position
Del Meidinger	BC Ministry of Forests and Range, Research Branch / Research Scientist Forest Ecology
Alison Patch	BC Ministry of Forests and Range, Nadina Forest District / Tenures Forester - Woodlots
John Perras	BC Ministry of Forests and Range, Kalum Forest District / Tenures Forester - Woodlots
Brent Petrick	Woodlot licencee, Nelson
Peter van Allen	Woodlot licencee, Kaslo
Bill Wells	Former woodlot licencee, Kaslo