Evaluation of alternative remote sensing land cover products for modeling and monitoring forest bird habitat in the Western Boreal Plains

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ABSTRACT

Land cover products derived from remotely sensed data are now widely used in forest ecology and management as environmental layers for predictive modeling of wildlife distribution and abundance and as inputs to the design of bio-monitoring programmes. In the boreal forest, there is an urgent need to quantify the effects of industrial activity on wildlife habitat (e.g., songbirds and woodland caribou), in part to meet Environment Canada's mandates under the Species at Risk Act. Remote sensing data is the most likely spatially extensive data on habitat that can potentially meet such mandates. The purpose of this study was to evaluate the relative efficacy of three recently developed land cover products to describe forest habitat, by systematic comparison against a common vegetation data layer at resolutions of 250m and 1km. Specifically, we evaluated the: GLC 2000 North American Land Cover (NALC) 1km, 250m MODIS 2005 Land Cover Classification (LCC05) and the 25m Earth Observation for Sustainable Development of Forests (EOSD LC 2000) products. As ground truth data, we used an extensive suite of georeferenced vegetation relevé data, pre-classified according to a standardized taxonomy of plant communities (Canadian National Vegetation Classification). The study provisionally corrected ground truth data for temporal changes in land cover due to fire and forest harvesting over the sampling period. Relations between the classified relevé data and the land cover products are reported by means of user, producer and overall accuracy of a six common class legend. Overall the MODIS 2005 LC product showed the most consistency in agreement with independent reference data. The highest accuracy for all LC products was achieved with open to closed coniferous forest that had accuracies as high as 87.24 +/- 4.28%.

Keywords: Accuracy assessment, reference data, land cover, boreal forest, habitat

1 INTRODUCTION

Remotely sensed land cover data have long been used to develop explanatory or predictive models of the distribution and abundance of species, especially birds (Gottschalk et al. 2005). These models typically include many biophysical covariates such as climate and landform, with classified remote-sensed data as a surrogate for terrestrial vegetation (Venier et al. 2004). The vegetation attributes locally important to terrestrial fauna include the physiognomy of the dominant vegetation (e.g. tree, shrub, grass, lichen), the species composition, and forest structural attributes such as height and density as vertically distributed in the various layers (e.g. forest canopy, shrub and surface), all of which can be measured directly by intensive sampling at the plot level ($\approx$1ha). The vegetation data historically available to modelers fall along a continuum of thematic precision from plot level data to classified remote sensing data, with photo-interpreted Forest Resource Inventories (FRI) occupying some intermediate position. FRI data have been extensively and successfully used for avian habitat modeling in temperate (Fearer et al. 2007) and boreal ecosystems (Vernier et al 2008). Several studies have shown that FRI-based models perform as well as models based on detailed plot-level data, at least for some forest songbirds (Vernier, Schmiegelow and Cumming, unpublished data; Betts et al. 2006). One recent study compared models of grizzly bear

(*Ursus arctos horribilis*) habitat selection based on FRI and on classified remote sensing data (McDermid et al. 2009) and found that highly customized land cover data in fact improved upon the FRI models, provided that other remote sensing measures (e.g. of productivity) were also included. This is encouraging because of the growing need for habitat modeling over entire terrestrial biomes or continents (e.g. Buermann et al. 2008). At these synoptic scales, remotely sensed land cover products are the only available description of terrestrial vegetation; however, it is not clear is if any particular land cover product would be an adequate surrogate for vegetation structure over large areas and across taxa.

Currently the authors and their colleagues are involved in a number of national initiatives to model the distribution and abundance of songbirds (Bayne et al, *in review*), woodland caribou (Environment Canada 2008) and waterfowl across the Canadian boreal and taiga. In these various projects there are presently three remote sensing land cover products available as surrogates for terrestrial vegetation over these regions: EOSD LC 2000 (25m), MODIS-2005 (250m) and GLC 2000-NCA (1km). Ideally, one of these would prove the best or at least an adequate, surrogate for terrestrial vegetation for all the species in view. It follows that the purpose of this study is to evaluate these three land cover products from that perspective. In our opinion, the choice of best product cannot be determined simply by fitting competing models to the available taxonomic-specific observational data, because of the confounding effects of abiotic factors over these large extents and the highly unbalanced designs of the various contributing studies. Our approach instead is to compare the three products against a common set of standardized plot-level vegetation data. We used for this purpose vegetation relevé data collected by Provincial and Territorial governments for ecosystem classification. The data were assembled by the Canadian Forest Service as part of an ongoing project to develop the Canadian National Vegetation Classification (CNVC), itself part of an international initiative in circumpolar boreal vegetation mapping. The relevé data were classified by domain experts to standard and ecological meaningful units known as vegetation associations (Baldwin and Meades, 2008).

In this paper, we report the results of the first phase or our study, conducted on a restricted study region mainly within the boreal plains ecozone as contained in Alberta and British Columbia. We develop and critique a protocol for selecting validation points from an available pool of CNVC ground plots at the association level. We then develop a common legend of forested land cover classes for the three land cover products and assess their accuracy against the CNVC reference dataset. We conclude with an outline of the next steps of the project. It may be possible ultimately to help define a suitable land cover legend for habitat modeling and mapping based on physical or ecological characteristics as well as spectral characteristics of the underlying sensor data. We suggest that would establish and important and fruitful connection link between the ecological modeling, remote sensing and vegetation mapping communities.

2 METHODS

2.1 Land Cover Products

The three land cover products were developed by the Canadian Forest Service – EOSD LC 2000 (25m), the Canada Centre for Remote Sensing (CCRS) – MODIS 2005 (250m) and a co-operative effort between CCRS and the United States Geological Survey (USGS) – GLC 2000-NCA (1km). These regional to global scale land cover products were initiated in support of various land management, monitoring and reporting programs (Wulder et al., 2008; Latifovic et al., 2004) and represent a substantial leap forward in providing readily accessible land cover data for potential users in the sciences including use in wildlife modeling and monitoring. While each of these products has undergone internal quality assessment and in some cases classification accuracy assessment there have been no cross-comparison of all three products to a single ground referenced data set – one of the goals set out in this study.

Towards efforts to directly compare the three LC products to a common reference data set all three map legends in Table 1 were converted to a common six class common legend of forest classes using a lookup table presented in Table 2. This early initiative to compare land cover products focused mostly on mature forest with early seral stage forest or regenerating forest classes being gleaned from those LC classes that characterized recent disturbances events such as forest harvesting and fires e.g. classes 39 and 40 in MODIS, classes 21 and 25 in GLC 2000 and class 33 in EOSD LC 2000. Conversion of different scale and purposed land cover legends into a common legend may reduce the accuracy of product assessment as some classes are lost or cannot be split in transferal. In particular developing any sparse forest class was difficult with the GLC 2000-NCA product as this class usually only exists in pure form in high to medium resolution classifications and transfers poorly to coarse scale legends.

Value	Class Description: MODIS 2007 Metadata Legend
1	Temperate Needleleaved Evergreen: Closed Canopy homogenous
2	Temperate Needleleaved Evergreen: Closed Canopy hetrogenous
3	Deciduous Broadleaf Forest: Closed Canopy
4	Mixed Evergreen-Deciduous Forest: Mature to Old Closed Canopy
5	Mixed Evergreen-Deciduous Forest: Young Closed Canopy
6	Mixed Deciduous-Evergreen Forest: Closed Canopy
7	Evergreen Needleleaf Forest: Moss-Shrub Understory - Open Canopy - Medium Crown Density
8	Evergreen Needleleaf Forest: Lichen-Shrub Understory - Open Canopy - Medium Crown Density
9	Evergreen Needleleaf Forest: Shrub Moss Understory - Open Canopy - Low Crown Density
10	Evergreen Needleleaf Forest: Lichen (Rock) Understory - Open Canopy - Low Crown Density
50	Evergreen Needleleaf Forest: Poorly Drained - Open Canopy - Low Crown Density
11	Deciduous Broadleaf Forest: Open Canopy - Medium to Low Density
12	Deciduous Broadleaf Forest: Open Canopy - Low Regenerating to Young
13	Mixed Evergreen-Deciduous Forest: Open Canopy Medium to Low Density
14	Mixed Deciduous-Conifer Forest: Open Canopy Medium to Low Density
15	Mixed Deciduous-Evergreen Forest: Open Canopy Low Regerating to Young Mixed Cover
16	Shrubland: High Low Shrub - subalpine or sub polar
17	Herbaceous: Grassland in Prairie Region
18	Herbaceous: Herb-Shrub-Bare Cover
20	Herbaceous: Wetlands
21	Herbaceous: With sparse coniferous trees - shrub-herb lichen cover
23	Polar Grassland: Herb-Shrub
24	Polar Grassland: Shrub-Herb-Lichen-Bare
25	Polar Grassland: Herb-Shrub poorly drained
26	Polar Grassland: Lichen-Shrub-Herb-Bare Soil
27	Polar Grassland: Lichen-Herb Cover
28	Polar Grassland: Low vegetation cover
30	Herbaceous: Cropland-Woodland
32	Herbaceous: Cropland
33	Herbaceous: Cropland
34	Herbaceous: Cropland
35	Lichen: Barren
36	Lichen: Shrub-Herb-Bare
37	Lichen: Sedge-Moss-Low Shrub Wetland
38	Sparse Vegetation: Rock Outcrop
39	Sparse Vegetation: Recent Burn
40	Sparse Vegetation: Old Burn
42	Non-Vegetated: Urban and Built-Up
43	Non-Vegetated: Water Bodies
44	Non-Vegetated: Mixes of Water and Land
45	Non-Vegetated: Snow and Ice

Value	Class Description: GLC 2000-NCA
1	N/A
2	N/A
3	Temperate Broadleaved Deciduous: Closed Canopy
4	Temperate Needleleaved Evergreen: Closed Canopy
5	Temperate Needleleaved Evergreen: Open Canopy
6	Temperate Needleleaved Mixed Forest: Closed Canopy
7	Temperate Mixed Broadleaf or Needleleaved: Closed Canopy
8	Temperate Mixed Broadleaf or Needleleaved: Open Canopy
9	Temperate Broadleaved Deciduous Shrubland: Closed Canopy
10	Temperate Broadleaved Deciduous Shrubland: Open Canopy
11	Temperate Needleleaved Evergreen Shrubland: Open Canopy
12	Temperate Mixed Broadleaved and Needleleaved Dwarf-Shrubland: Open Canopy
13	Temperate Grassland
14	Temperate Grassland: with Sparse Tree Layer
15	Temperate Grassland: with Sparse Shrub Layer
16	N/A
17	N/A
18	Cropland
19	Cropland and Shrubland/woodland
20	Subpolar Needleleaved Evergreen Forest: Open Canopy
21	Unconsolidated Material Sparse Vegetation (old burnt or other disturbance)
22	Urban and Built-up
23	Consolidated Rock Sparse Vegetation
24	Water
25	Burnt area (recent)
26	Snow and Ice
27	Wetlands
28	Herbaceous Wetlands
29	N/A
30	NA

Value	Class Description: EOSD 2000
11	Cloud
12	Shadow
20	Water
30	Non-Vegetated Land
31	Snow/Ice
32	Rock/Rubble
33	Exposed/Barren Land
34	Developed
40	Bryoids
50	Shrubland
51	Shrub: Tall
52	Shrub: Low
80	Wetland
81	Wetland: treed
82	Wetland: shrub
83	Wetland: herb
100	Herbs
110	Grassland
120	Agriculture
121	Agriculture: cropland
122	Agriculture: pasture/forage
200	Forest/Trees
211	Coniferous: Dense
212	Coniferous: Open
213	Coniferous: Sparse
221	Broadleaf: Dense
222	Broadleaf: Open
223	Broadleaf: Sparse
231	Mixedwood: Dense
232	Mixedwood: Open
233	Mixedwood: Sparse

Table 1. Class legends for MODIS, GLC 2000-NCA and EOSD land cover products.

Additionally, cut points for crown or canopy closure presented a challenge as different classification schemes had overlapping cut points e.g. open forest in the MODIS legend was categorized as 25-40% crown cover, but in the EOSD legend was categorized as 26-50%. Our end decision was to work with cut puts of less than 30% to define sparse forest and aggregate classes within the same life form in the open to closed range with closure >30%. In part, this decision was based on the desire to maintain and test the accuracy of some important ecologically meaningful classes in the common legend e.g. conifer forest: sparse treed wetlands.

	Matching Land Cover Class		
6 Common Class Legend	MODIS 2005	GLC 2000-NCA	EOSD 2000
Broadleaved Forest: Open to Closed	3, 11	3, 19	221, 222
Mixedwood Forest: Open to Closed	4, 5, 6, 13, 14	6, 7, 8, 12	231, 232
Coniferous Forest: Sparse	9, 10	11, 14	213
Coniferous Forest: Sparse/Treed Wetland	37, 50	27	81
Coniferous Forest: Open to Closed	1, 2, 7, 8	4, 5, 20	211, 212
Regenerating Forest: Harvest/Burn	12, 15, 39, 40	10, 12, 15, 21, 25	33, 51, 52

Table 2. Lookup table for converting MODIS, GLC and EOSD 250m and 1km land cover products into the 6 common class legend.

As a final step in the preparation of the land cover data for accuracy assessment the individual land cover products were converted and mapped to the six class common legend of forest classes and resampled using a majority rule to the appropriate pixel ground size e.g. resampling of the 25m EOSD LC 2000 to 250m and 1km and the 250m MODIS LC 2005 to 1km.

2.2 Reference Data Set

The basis for developing our land cover reference data was a subset of measured relevé plots currently being used to develop a classification of vegetation - the Canadian National Vegetation Classification (CNVC) across Canada. The CNVC is a nationally standardized classification of Canadian vegetation at various levels of taxonomic generalization. Classification units are preferentially developed from high quality measured relevé data (>70,000 relevés), provided by provincial and territorial ecological classification programs. The process attempts to engage partners with relevant expertise, data and jurisdictional authority in all regions of Canada in order to develop the classification units. The classification is based on floristic, ecological, and physiognomic criteria of measured data and is a hierarchical vegetation-ecological taxonomy. Specifically, the upper levels of the hierarchy reflect growth-form and physiognomic differences that are driven by broad climatic factors; the middle levels reflect biogeographic and broad ecological variation at the continental and regional scales; and the Alliance and Association levels reflect floristic and dominance variability in relation to local site-level ecology (Baldwin and Meades, 2008).

We were fortunate enough to gain access to ~1800 relevé plots for the western boreal plain, taiga plain and sections of the boreal shield and boreal cordillera. These data represent a wealth of potential information that can be used to derive an extensive ground referenced data set for assessing land cover products over large synoptic scales. Working towards that goal we developed a detailed protocol for both converting the ground measured relevé plot data into land cover classes and for vetting and time stamping disturbance events if and when e.g. fire or harvesting may have altered the forest conditions or completely changed the land cover e.g. to regenerating forest.

Using summary data on overstory and understory species % crown cover and overall plot mean % cover, along with site moisture conditions, and overstory species dominance we were able to develop equivalent land cover classes for each of the 53 different CNVC associations present in our study site which were then rolled up into the six classes in the common legend shown earlier in Table 2 with the exception of the regenerating forest: harvest and burn class. Reference points for this class were gleaned through a process of flagging disturbed CNVC plots according to the type and approximate year of disturbance and pooling these points into a regeneration class if time since disturbance was less than approximately 15 years.

A protocol was developed to determine which CNVC relevé points could be used as reference land cover points in our accuracy assessment of the three LC products including rules for flagging disturbances. We used a combination of visual interpretation of the nearly 1800 relevé plot locations via 30m Landsat Canada mosaics from 1990 and 2000, and 2.5m SPOT panchromatic mosaics from 2006. A simple vector overlay analysis of these plot locations was also used to flag reference plot locations for fire events in Alberta and British Columbia for the years between 2006 and 1970. Additionally, an anthropogenic disturbance layer available from Global Forest Watch Canada (GFWC, 2009) was also to vet out possible plots that experienced deforestation or land conversion e.g. to roads or settlement. Given this was an initial assessment phase; we were conservative in our flagging of disturbance events, only accepting points that made it through all the flagging procedures. In retrospect a secondary accuracy assessment of the GFWC disturbance layer revealed a tendency for that product to overestimate the extent of disturbances, particularly linear disturbances. For example, approximately 70% of the randomly selected points in the GFWC linear disturbance layer were >500m from an actual disturbance because linear features in this layer were buffered by 1km in each direction e.g. for all roads. This was evidently too broad of a definition of disturbance and it is hoped a refinement of this layer will increase the number of CNVC points that can be evaluated with out protocol and available for our reference data set. In sum total, 525 reference plots were vet out and used to develop error matrices with the three land cover products being assessed.

2.3 Accuracy Assessment

A series of classification error matrices were prepared for comparison of the land cover products to the CNVC common class reference data set using a neighborhood assessment approach. A discrete analysis was considered inappropriate given that many of the relevés point coordinates were recorded off topographic maps prior to the standard use of GPS in the late 1990s. To partially mitigate for spatial uncertainty associated with the coarse precision reference data, point locations were buffered by 125m effectively producing a 250m diameter circular neighborhood around each reference point. This reference neighborhood was then tagged with the reference land cover class for the associated CNVC point. A simple intersection between each of the common legend land cover products and the referenced neighborhood layer produced a series of possible matches to evaluate agreement between the two layers. It follows that agreement rules as shown in Figure 1. were set up to evaluate matching between the land cover products and reference land cover.

Using this method with both the 250m and 1km land cover data sets, a maximum of 4 potential pixels within the reference neighborhood were evaluated for matches to the referenced LC point. Alternative methods that make use of a mode or majority land cover class matching rule within a 3 x 3 window centered on the reference pixel are commonly used in similar situations (Trans et. al, 2004). While typically a neighborhood approach will result in an optimistic accuracy bias, especially in landscapes that are heterogeneous (Foody, 1996), the approach here was seen as a balanced alternative to a purely discrete assessment given out uncertainty about spatial positioning of the CNVC reference plots. Additionally, our use of a smaller reference neighborhood included fewer pixels (4) in the matching process versus a 3 x 3 window (9) typically used in applying a modal or majority matching rule in accuracy assessment.

User's and producer's accuracies were calculated and reported for each of the six common classes and reported along with overall forest class accuracy. To provide some level of confidence in making inferences based on our accuracy analysis confidence limits at the 95% level were derived for each of the error assessments from the following formula:

$$t\sqrt{\frac{p(1\text{-}p)}{n\text{-}1}} \qquad \text{(Foody, 2008)} \qquad (1)$$

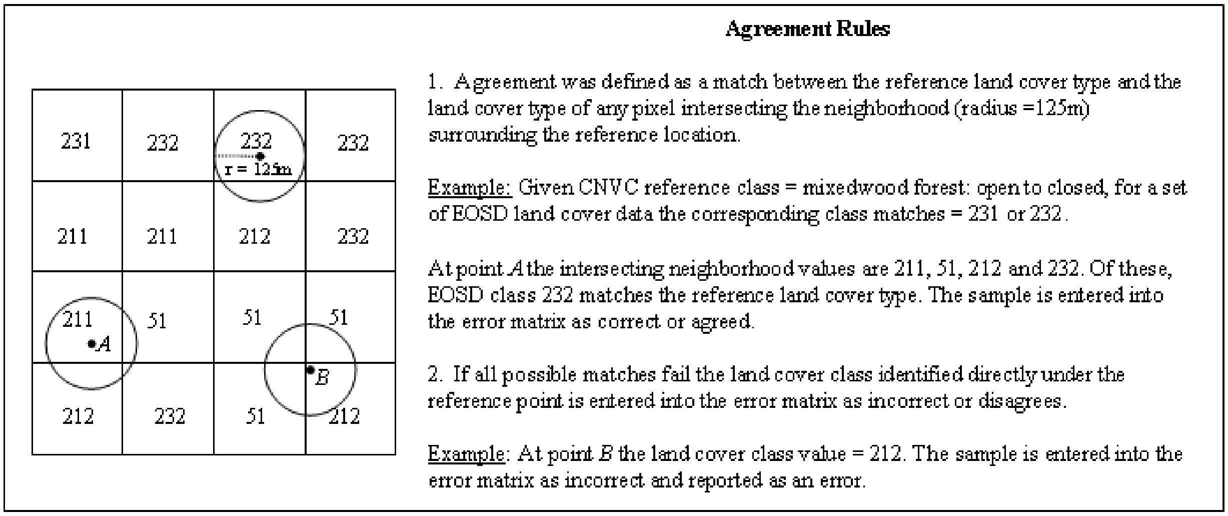

Figure 1. Neighborhood agreement rules for matching the reference land cover type and classified land cover products at 250m and 1km. A neighborhood assessment of accuracy allowed use of reference data with lower spatial precision e.g. referenced to 1:50,000 scale topographic maps.

3. RESULTS AND DISCUSSION

3.1 Comparison of EOSD LC 2000 and MODIS 2005 at 250m

The accuracy analysis for the 250m EOSD and MODIS land cover products are presented in Table 3. and Table 4. Each table states the producer and user accuracy for the product along with the 95% confidence level for each class and total overall accuracy of all forest classes. It is immediately evident the highest class accuracy was produced in the open to closed coniferous forest class in both land cover products, with EOSD LC 2000 having a somewhat higher reported accuracy of 87 +/- 4.68%. Regardless, in both products the high accuracy and level of confidence indicate a very good agreement of these products with the reference data set for open to closed coniferous forest. In fact, both products show similar trends in the classes that produced the best and worst accuracies for all conifer classes.

There were marked differences between the accuracies reported for broadleaf and mixedwood forest. In EOSD LC 2000 broadleaved open to closed forest had a 68 +/14.98% agreement with the reference data, although the user's accuracy was very low suggesting a low probability that a pixel classified as broadleaf forest actually represents this class on the ground. MODIS 2005 had the second lowest accuracy reported for the broadleaf open to closed class. In contrast, MODIS showed a better agreement with the reference data than EOSD LC 2000 for mixedwood forest at 50 +/- 7.84% for the producer's and 73 +/- 8.33% user's accuracy and indicates it may be relatively reliable in representing mixedwood forest in the boreal plains. In summary, overall accuracies for the forested classes for both land cover products were similar at 51 +/- 4.28% for EOSD LC 2000 and 56 +/- 4.25% for MODIS 2005. Neither product showed any clear advantage outside of the differences in being able to accurately and reliably represent mixedwood forest – which MODIS was superior at doing.

	Producer's Accuracy			User's Accuracy		
Class Label	%	Standard Error %	95% Level of Confidence (+/-) %	%	Standard Error %	95% Level of Confidence (+/-) %
Broadleaved: Open to Closed	68.42	7.64	14.98	28.57	4.76	9.33
Mixedwood: Open to Closed	17.96	2.98	5.84	100.00	0.00	0.00
Coniferous: Sparse	9.30	4.48	8.78	57.14	20.20	39.60
Coniferous: Sparse -Treed Wetland	34.78	10.15	19.90	20.00	6.41	12.55
Coniferous: Open to Closed	87.24	2.39	4.68	81.04	2.70	5.30
Regenerating: Harvest/Burn	50.88	6.68	13.09	58.00	7.05	13.82
Overall Forest Class Accuracy N = 525	**51.15**	**2.19**	**4.28**			

Table 3. Neighborhood assessment of user's and producer's accuracy for EOSD LC 2000 (250m) land cover product circa year 2000. Reference data sample size: broadleaved open to closed, n=38; mixedwood open to closed, n=167; coniferous sparse, n=43; coniferous sparse treed wetland, n=23; coniferous: open to closed, n=196; regenerating: harvest/burn, n=58.

	Producer's Accuracy			User's Accuracy		
Class Label	%	Standard Error %	95% Level of Confidence (+/-) %	%	Standard Error %	95% Level of Confidence (+/-) %
Broadleaved: Open to Closed	14.29	6.00	11.76	17.24	7.14	13.99
Mixedwood: Open to Closed	50.96	4.00	7.84	73.39	4.25	8.33
Coniferous: Sparse	22.50	6.69	13.11	33.33	9.25	18.12
Coniferous: Sparse Treed Wetland	13.64	7.49	14.68	7.50	4.22	8.27
Coniferous: Open to Closed	79.58	2.92	5.73	72.38	3.09	6.06
Regenerating: Harvest/Burn	56.25	5.58	10.94	65.22	5.78	11.32
Overall Forest Class Accuracy N = 525	**56.00**	**2.17**	**4.25**			

Table 4. Neighborhood assessment of user's and producer's accuracy for MODIS 2005 (250m) land cover product circa year 2005. Reference data sample size: broadleaved open to closed, n=35; mixedwood open to closed, n=157; coniferous sparse, n=40; coniferous sparse treed wetland, n=22; coniferous: open to closed, n=191; regenerating: harvest/burn, n=80.

3.2 Comparison of EOSD LC 2000, MODIS 2005 and GLC 2000-NCA at 1km

The accuracy analysis for the 1km land cover products are presented in Table 4 through Table 6. As above, each table states the producer and user accuracy for the product along with the 95% confidence level for each class and total overall accuracy of all forest classes. Similar to the 250m land cover assessment the class with the highest producer and user accuracies for all three LC products was open to closed coniferous forest. All three LC products showed producer accuracies ranging from 69 to 73 +/ ~6% with MODIS 2005 having the most balanced user and producer accuracies indicating that it is likely the most reliable product for mapping open to closed conifer forest.

In the open to closed broadleaved class EOSD LC 2000 showed a stark decrease in accuracy as compared to the 250m product; while MODIS 2005 showed an increase. These flipping of results between the 1km and 250m products is likely a specious result due to the relatively small sample size of this class (n=38). Indeed, efforts will be made in the next phase of this project to try and include more CNVC reference data in this category. This class was a relatively straight forward cross match between classes so it is not likely there is much error caused by legend transfer. However, broadleaved forest can often be confused with shrub classes as well. Further investigation into

Class Label	Producer's Accuracy %	Standard Error %	95% Level of Confidence (+/-) %	User's Accuracy %	Standard Error %	95% Level of Confidence (+/-) %
Broadleaved: Open to Closed	36.84	7.93	15.54	15.22	3.77	7.38
Mixedwood: Open to Closed	1.20	0.84	1.65	12.50	8.54	16.74
Coniferous: Sparse	0.00	0.00	0.00	0.00	0.00	0.00
Coniferous: Sparse -Treed Wetland	17.39	8.08	15.84	10.00	4.80	9.42
Coniferous: Open to Closed	72.96	3.18	6.23	54.58	3.08	6.04
Regenerating: Harvest/Burn	50.88	6.68	13.09	76.32	6.99	13.70
Overall Forest Class Accuracy N = 525	**36.64**	**2.11**	**4.13**			

Table 5. Neighborhood assessment of user's and producer's accuracy for EOSD LC 2000 (1km) land cover product circa year 2000. Reference data sample size: broadleaved open to closed, n=38; mixedwood open to closed, n=167; coniferous sparse, n=43; coniferous sparse treed wetland, n=23; coniferous: open to closed, n=196; regenerating: harvest/burn, n=58.

Class Label	Producer's Accuracy %	Standard Error %	95% Level of Confidence (+/-) %	User's Accuracy %	Standard Error %	95% Level of Confidence (+/-) %
Broadleaved: Open to Closed	25.71	7.50	14.69	23.68	6.99	13.70
Mixedwood: Open to Closed	37.58	3.88	7.60	59.00	4.94	9.69
Coniferous: Sparse	20.00	6.41	12.55	57.14	13.73	26.90
Coniferous: Sparse -Treed Wetland	4.55	4.55	8.91	3.85	3.85	7.54
Coniferous: Open to Closed	69.11	3.35	6.57	61.40	3.33	6.52
Regenerating: Harvest/Burn	62.50	5.45	10.68	68.49	5.47	10.73
All Other Non-Forest						
Overall Forest Class Accuracy N = 525	**49.33**	**2.18**	**4.28**			

Table 6. Neighborhood assessment of user's and producer's accuracy for MODIS 2005 (1km) land cover product circa year 2005. Reference data sample size: broadleaved open to closed, n=35; mixedwood open to closed, n=157; coniferous sparse, n=40; coniferous sparse treed wetland, n=22; coniferous: open to closed, n=191; regenerating: harvest/burn, n=80.

Class Label	Producer's Accuracy %	Standard Error %	95% Level of Confidence (+/-) %	User's Accuracy %	Standard Error %	95% Level of Confidence (+/-) %
Broadleaved: Open to Closed	18.42	6.37	12.49	36.84	11.37	22.28
Mixedwood: Open to Closed	38.32	3.77	7.40	56.14	4.67	9.15
Coniferous: Sparse	46.51	7.70	15.08	25.00	4.87	9.55
Coniferous: Sparse -Treed Wetland	0.00	0.00	0.00	0.00	0.00	0.00
Coniferous: Open to Closed	70.92	3.25	6.37	54.09	3.11	6.10
Regenerating: Harvest/Burn	15.79	4.87	9.55	64.29	13.29	26.05
Overall Forest Class Accuracy N = 525	**45.61**	**2.18**	**4.27**			

Table 7. Neighborhood assessment of user's and producer's accuracy for GLC 2000-NCA (1km) land cover product circa year 2000. Reference data sample size: broadleaved open to closed, n=38; mixedwood open to closed, n=167; coniferous sparse, n=43; coniferous sparse treed wetland, n=23; coniferous: open to closed, n=196; regenerating: harvest/burn, n=58.

the other land cover categories that were confused with broadleaved forest might provide additional insight into the low reported accuracies. Furthermore, at the 1km scale we start to see the effects of averaging taking place on some of the more spatially isolated classes of which broadleaved forest particularly in areas surrounding long narrow riparian zones may be averaged out at these coarser scales. The same could be said for sparse coniferous treed wetlands that reported extremely low accuracies for all products. Assessment of the 25m EOSD LC 2000 product may prove useful for these land cover types that are smaller in extent and spatially isolated in the landscape.

In looking at the early seral stage class of regenerating forest both EOSD LC 2000 and MODIS 2005 showed considerably better agreement with the CNVC reference data set than did the GLC 2000-NCA. In fact, the MODIS LC accuracy was marginally higher at 62.5 +/- 10.68% in comparison to the equivalent 250m assessment. A closer look at both the 1km EOSD LC 2000 and MODIS 2005 product, reveals regenerating forest had the highest user accuracies of any of the six common classes indicating there is good probability that a given pixel on the ground will actually represent this class. User accuracy was also higher for both EOSD and MODIS LC products in comparison to the 250m data. Many of the sampled points in the regenerating forest class were located in cut block areas that at a scale of 1km would be a mosaic of regenerating forest mixed with remaining mature forest. It is interesting to note how the 1km pixel size appears to be able to integrate and possibly improve mapping of this structurally complex pattern on the landscape. A larger sample size would improve our confidence in making such inferences in future.

Overall, the MODIS 2005 land cover product again had the highest overall forest class accuracy in this instance 49.33 +/- 4.28% although the GLC 2000-NCA product had similar levels of agreement with the reference data set. EOSD LC 2000 showed a markedly lower accuracy as compared to the other two LC products and even in comparison to the 250m assessment of EOSD LC 2000.

In such extensive regional assessments of land cover, products derived from larger foot print sensors and those with high temporal resolution such as MODIS may have an advantage over higher spatial resolution sensors such as Landsat. Because the production of large regional scale land cover maps requires stitching together numerous Landsat scenes there are additional inconsistencies in classification caused by radiometric inconsistency between neighboring tiles with different acquisition dates and acquisition conditions that can be minimized with MODIS. In the next stage of this project we intent to evaluate EOSD LC 2000 at its native resolution of 25m which may in fact be where the true advantage of this product becomes evident.

4 CONCLUSIONS

At these synoptic scales, remotely sensed land cover products are the only available description of terrestrial vegetation. In this paper we successfully develop a protocol for selecting an independent set of reference data from vegetation relevé data originally collected for the CNVC in Alberta and British Columbia. These data are then used for evaluating the accuracy and ability of three land cover products: EOSD LC 2000, MODIS 2005 and GLC 2000-NCA to represent six common forest land cover classes in the boreal plain. While it is not clear is if any particular land cover product would be an adequate surrogate for vegetation structure over large areas and across taxa this initial phase of our study provides some insights into the which products and forest classes might best suite that role. After summary accuracy assessments of the three LC products were conducted at 250m and 1km the LC product showing the best overall consistent agreement with the independent reference data was MODIS 2005. In terms of individual classes, the highest accuracy for all LC products was achieved with open to closed coniferous forest at 250m that had accuracies as high as 87.24 +/- 4.28%. Regenerating forest was also consistently mapped well in comparison to other forest classes.

Steps forward in the next phase of this project will include revisiting some of the rejected CNVC reference points based on our improved knowledge of the GFWC disturbance layer inaccuracies. Once an exhaustive set of reference data are developed new accuracy assessments will be performed. Additionally, these data will be used as direct input into bird modeling and possible integration of FRI data. We will also consider how these land cover products could be directly linked to the observational wildlife data and discuss some implications for the appropriate use and possible improvement of land cover products for species habitat modeling.

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REFERENCES

[1] Baldwin, K.A. and W.J. Meades. 2008. The Canadian National Vegetation Classification. In: Talbot, S.S., ed. (2008): Proceedings of the Fourth International Conservation of Arctic Flora and Fauna (CAFF) Flora Group Workshop, 15-18 May 2007, Tórshavn, Faroe Islands. CAFF Technical Report No. 15. [http://caff.arcticportal.org/document-library/technical-report: June 9, 2009].

[2] Bayne, E.M., S.G. Cumming, S. Fang, K. Lefevre, D. Mazerolle, F.K.A. Schmiegelow and S.J. Song, submitted. Toward continental conservation of Canada's boreal forest avifauna: The method and madness of large-scale ecological models. Avian Conservation and Ecology. [http://www.borealbirds.ca: June 9, 2009]

[3] Betts, M.G., A.W. Diamond, G.J. Forbes, M-A. Villard and J.S. Gunn, 2006. The importance of spatial autocorrelation, extent and resolution in predicting forest bird occurrence. Ecological Modelling. 191: 197-224.

[4] Buermann, W., S. Saatchi, T.B. Smith, B.R. Zutta, J.A. Chaves, B. Milá, and C.H. Graham, 2008. Predicting species distributions across the Amazonian and Andean regions using remote sensing data. Journal of Biogeography. 35: 1160–1176.

[5] Environment Canada. 2008. Appendix 6.4: Environmental niche analysis – predicting potential occurrence of threatened boreal woodland caribou to support species recovery in Canada. Pages 120-143 In: Scientific review for the identification of critical habitat for woodland caribou (Rangifer tarandus caribou), boreal population, in Canada. August 2008. Ottawa: Environment Canada. 72 pp. plus 180 pp Appendices.

[6] Fearer, T.M., S.P. Prisley, D.F. Stauffer and P.D. Keyser, 2007. A method for integrating the Breeding Bird Survey and Forest Inventory and Analysis databases to evaluate forest bird-habitat relationships at multiple spatial scales. Forest Ecology and Management. 243: 128-143.

[7] Foody, G.M., 2008. Harshness in image classification accuracy assessment. International Journal of Remote Sensing. 29(11): 3137-3158.

[8] Global Forest Watch Canada, 2009. Canada Access – Combined. [http://www.globalforestwatch.ca/datawarehouse.html]

[9] Gottschalk, T.K., F. Huettmann and M. Ehlers, 2005. Thirty years of analysing and modelling avian habitat relationships using satellite imagery data: a review. International Journal of Remote Sensing. 26:2631-2656.

[10] Hammond, T.O., D.L. Verbyla, 1996. Optimistic bias in classification accuracy assessment. International Journal of Remote Sensing. 7(6): 1261-1266.

[11] Latifovic, R., Z-L, Zhu, J. Cihlar, C. Giri, I. Olthof, 2004. Land cover mapping of North and Central America – Global Land Cover 2000. Remote Sensing of Environment. 89:116-127.

[12] McDermid, G.J., R.J. Hall,. G.A. Sanchez-Azofeifa, S.E. Franklin, G.B. Stenhouse, T. Kobliuk and E.F. LeDrew, 2009. Remote sensing and forest inventory for wildlife habitat assessment. Forest Ecology and Management. 257: 2262-2269.

[13] Tran, L.T., T. Jarnagin, C.G. Knight, L. Baskaran, 2004. Mapping spatial accuracy and estimating landscape

[14] indicators from thematic land-cover maps using fuzzy set theory. In: R.S. Lunetta and J.G. Lyon ed. Remote sensing and GIS accuracy assessment. CRC Press, New York. 304p.

[15] Venier, L.A., J. Pearce, J.E. McKee, D.W. McKenney and G.J. Niemi, 2004. Climate and satellite-based land cover for predicting breeding bird distribution in the Great Lakes Basin. J. Biogeography. 31:315-331

[16] Vernier, P. R., F.K A. Schmiegelow, S. Hannon and S.G. Cumming, 2008. Generalizability of songbird habitat models in boreal mixedwood forests of Alberta. Ecological Modelling. 211: 191-201.

[17] Wulder, M.A., J.C. White, M. Cranny, R.J. Hall, J.E. Luther, A. Beaudoin, D.G. Goodenough, J. A Dechka. 2008, Monitoring Canada's forests. Part 1: Completion of the EOSD land cover project. Canadian Journal of Remote Sensing. 34(6): 549-562.