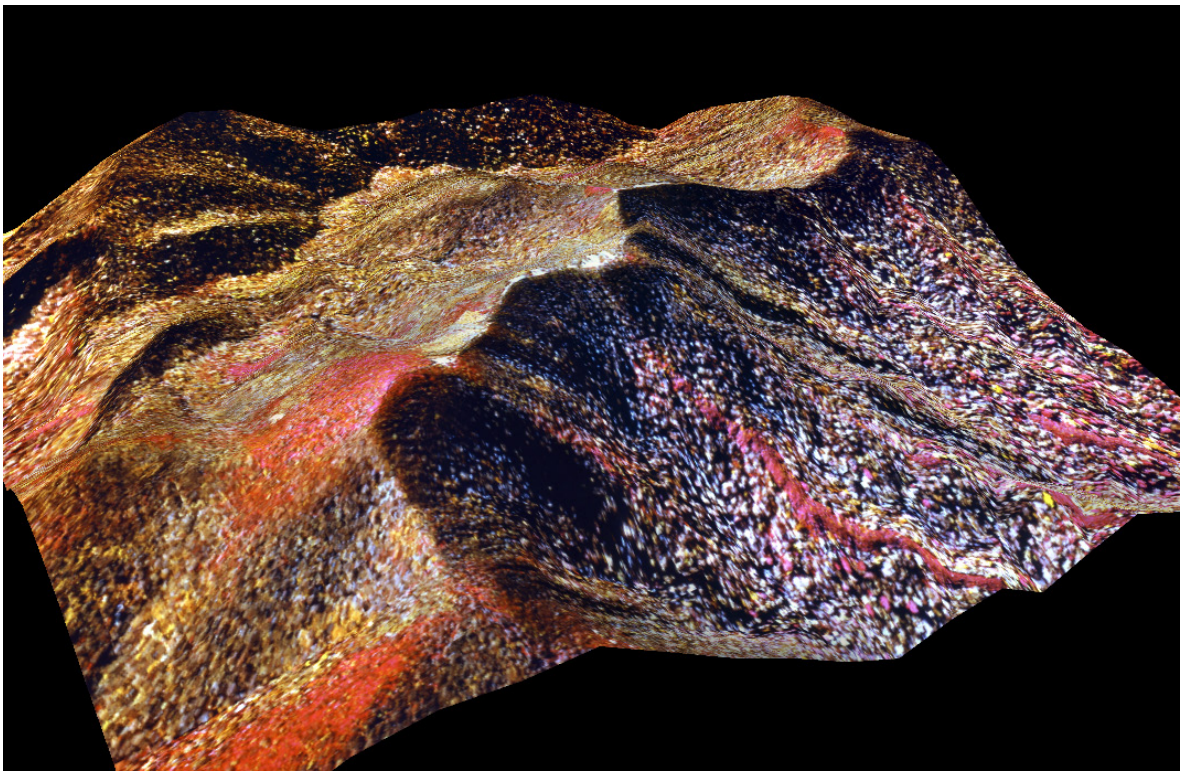
Thematic Accuracy Assessment: Great Smoky Mountains National Park Vegetation Map



Prepared by Michael Jenkins
Ecologist
National Park Service
February 2007

Suggested Citation: Jenkins, M.A. 2007. Thematic Accuracy Assessment: Great Smoky Mountains National Park Vegetation Map. National Park Service, Great Smoky Mountains National Park, Gatlinburg, Tennessee. 26 pp.

Acknowledgments

This report was prepared by the Inventory and Monitoring Program of Great Smoky Mountains National Park. I thank Eric Holzmueller, Leigh Tanner, Katie McDowell, David Turner, Dustin Wessel, Palmyra Romeo, Maggie Patrick, Gitte Venicx, and Jason Fridley for their assistance with fieldwork. Mike Story, Bridgette O'Donoghue, Rickie White, Robert Emmott, and Nora Murdock provided value input during the design of this assessment. Todd Jobe created the stratified design used to select polygons for sampling. Dumitru Salajanu of USDA FS-FIA generously donated his time to summarize FIA data for comparison to mapped vegetation classes. Becky Nichols, Keith Langdon, and Nancy Finley provided helpful comments on earlier drafts of this report. Funding was provided by the NPS Southeast Region Natural Resources Preservation Program and the USGS - NPS Vegetation Mapping Program.

Table of Contents

Acknowledgements…….i

Table of Contents……...ii

Introduction……1

Methods……. 2

Strategy for the selection of sample points……..2

FIA data……... 2

Field methods……...2

Data analysis…… 4

Results and Discussion…….. 5

NVCS associations…….. 5

USGS Quadrangles and contractor accuracy…… 10

CRMS interpreters' classes……10

Dominant vegetation……....10

Secondary vegetation and modifiers……10

FIA data……..11

Conclusions……..12

Future work……12

Literature Cited……13

Appendix A……..15

Appendix B……..18

Introduction

Over the past decade, management at the ecosystem or landscape scale has been emphasized on federal lands. This shift from the small-scale management of a few selected species to the large-scale management of biodiversity has highlighted the need for landscape-level spatial datasets that describe ecological communities. Digital maps of vegetation communities are one of the most critical of these spatial datasets. To provide these datasets to park managers, the NPS Inventory and Monitoring Program has worked cooperatively with the USGS Center for Biological Informatics to create digital vegetation maps for 280 national park units that contain significant natural resources.

In August 2003, the vegetation map of Great Smoky Mountains National Park (GRSM) was delivered. This map was created by two separate projects. The USGS BRD/NPS Vegetation Mapping Program mapped the portions of GRSM contained within two 1:24,000 USGS Quadrangles (Cades Cove and Mount Le Conte) as a pilot project to determine the feasibility of mapping large, mountainous, and biologically diverse parks (The Nature Conservancy 1999). The Center for Remote Sensing and Mapping Science (CRMS) at the University of Georgia mapped the remainder of the Park, which is distributed across 25 additional Quadrangles. The overstory vegetation maps created by both projects were based upon 1:12,000 color infrared (IR) photography and required analog interpretation of over 1,000 individual photos (Welch et al. 2002). CRMS edge-mapped the outputs from both projects and finalized the classification system to create a single wall-to-wall map of GRSM. In addition, CRMS used 1:40,000-scale photos to create a wall-to-wall map of understory vegetation in GRSM. Due to the biological complexity and large size (>200,000 ha) of the Park, the final maps created by these efforts are very complex; the overstory vegetation map is comprised of nearly 50,000 individual polygons and the understory map is comprised of over 25,000 polygons (Madden et al. 2004).

Photointerpreters at CRMS identified 172 unique vegetation classes in the overstory map. A crosswalk was created to translate these classes into the community associations delineated by NatureServe as part of their National Vegetation Classification System (NVCS). This crosswalk allowed the new overstory map to be classified based upon the NVCS, which is the NPS standard, and resulted in 58 classes consisting of one-to-one, one-to-many, and many-to-one translations.

Before the new vegetation maps can be fully implemented into resource management, education, and research, an accuracy assessment must be completed. According to NPS/NBS Vegetation Mapping Program standards, all vegetation classes must be mapped to 80% accuracy (Stadelmann et al. 1994). In addition, these standards dictate that accuracy assessments should be independent of the mapping process, based upon an observational unit equivalent to or larger than the minimum mapping unit (MMU), and reflect the relative abundance of each class within the project area. To meet these requirements, an accuracy assessment based upon the recommendations of Stadelmann et al. (1994) was conducted.

Methods

Strategy for the selection of sample points

Because the NVCS system is the NPS national standard, this classification was used in the accuracy assessment. The draft vegetation map delivered by UGA-CRMS contained 58 unique classes. Some NVCS associations were combined since they were impossible to separate in 1:12000 color-IR photos. Other units, such as open water, roads, and developed areas, are not part of the NVCS classification. I also assessed the accuracy of the CRMS interpreters' classification and other associated class modifiers and secondary vegetation classes at each sample point visited. While the sample points did not include all the CRMS classes and modifiers, this assessment provides a quantification of the overall accuracy of the interpreters' classification and accuracy estimates of the most common classes. The accuracy of individual USGS quadrangles was assessed since multiple photo interpreters worked on the vegetation map on a quad-by-quad basis. In addition, the accuracy of polygons delineated by both cooperators (USGS BRD/NPS and UGA-CRMS) was determined.

Sampling for this assessment was designed to maximize the number of sample points while providing an adequate representation of the variability that exists within classes. To best meet these two requirements, I used a stratified random sample based upon an accessibility layer developed for GRSM (Jobe and McKnight 2003) to distribute selection points. At each selection point, 3 vegetation polygons that occur within 500 m of the point were selected. A sample point was then placed randomly in the central portion of each polygon.

Due to the large number of mapped associations and total polygons (49,971), the assignment of sample points within an association was not directly proportional to an association's total abundance or area. Instead, I assigned sample points to each association based upon broad polygon abundance classes. These classes are 1-5 polygons, 6-100 polygons, 101-500 polygons, 501-1000 polygons, 1001-2000 polygons, and >2000 polygons. The final stratification included 600 points. However, field crews were only able to sample 526 of these points (Figure 1). To insure that an adequate number of points were sampled in each class, we reduced the number of plots assigned to very common classes.

FIA data

To serve as an independent assessment of accuracy, USDA FIA (Forest Inventory and Analysis) plot data were used to assess the classification accuracy of polygons in which plots were located. FIA has sampled 83 plots within GRSM. These plots only occur in a limited number of associations and have limited replication within associations. In addition, this plot network was established using a hexagonal grid and subplots often occur in different polygons or on the boundary between polygons.

Field methods

For each selected polygon, a sample point was randomly located within the center region of the polygon to reduce spatial error and the effects of inter-class gradients. When possible, we maintained a 20 m buffer within the polygon edge when selecting sample points. In the field, all sample points were located with a Garmin hand-held GPS

unit. An area equal to the minimum mapping unit (MMU = 0.5 ha) was examined at each point. Where possible, this area was circular (radius = 40 m), but other shapes, including transects, were used if polygon shape did not allow placement of a circle.

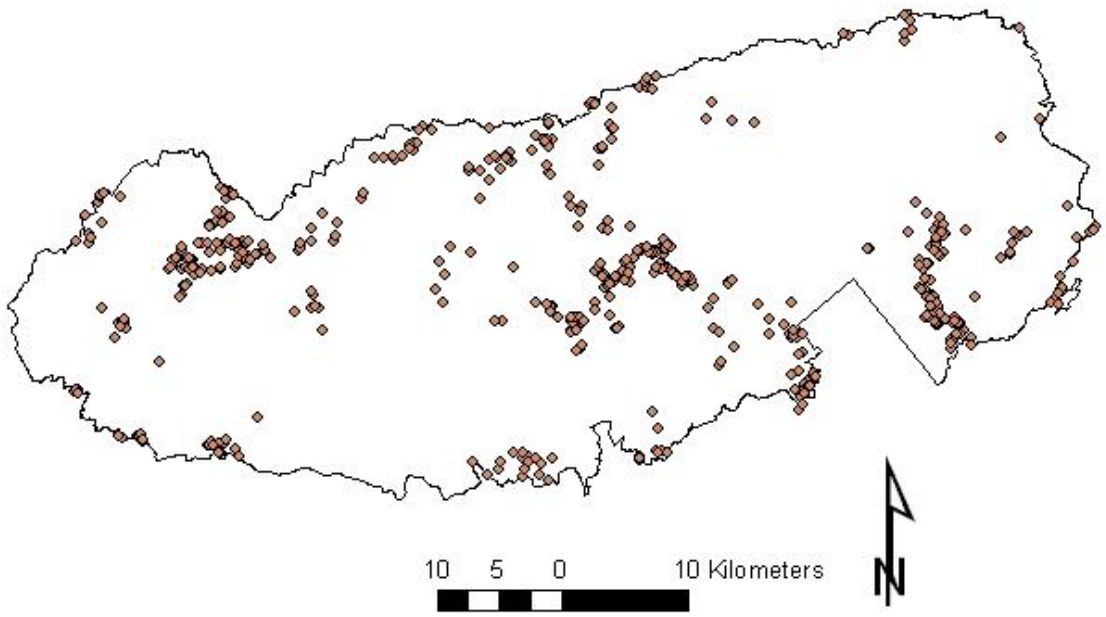


Figure 1. Locations of 526 accuracy assessment points selected with a stratified random sample based upon accessibility and map class.

At each point, field crews collected the following information: (1) point number and UTM coordinates, (2) names of crew members, (3) date and time of field visit, (4) shape and size of MMU and description of any alterations to size and shape, (4) description of any disturbance that may have occurred since 1998 (year of photography used to create map), (5) topographic variables (percent slope, slope position, aspect, slope shape, and elevation), and (6) the presence of streams, wetlands, rock outcrops or other inclusions. At each point, the field keys provided in White et al. (2003) were used to determine the vegetation association of the MMU. In addition, the following vegetation data were collected: (1) dominant overstory species and estimated percent canopy cover (2) dominant subcanopy species and estimated percent cover, (3) dominant woody shrub species and estimated percent cover, and (5) dominant and indicator herbaceous layer species and estimated percent cover. Cover was estimated using cover classes (Table 1) developed by Peet et al. (1998). Other vegetation characteristics, such as the presence of dead trees, rare or unusual species, and exotic insects and/or disease were noted. Examples of datasheets are provided in Appendix A.

Table 1. Cover-abundance scale classes used in permanent plot sampling (Peet et al. 1998).

Cover Range	Scale Value	Class Midpoint
Missing but nearby	--	--
Solitary or few individuals	1	0.3
0-1%	2	0.5
1-2%	3	1.5
2-5%	4	3.5
5-10%	5	7.5
10-25%	6	17.5
25-50%	7	37.5
50-75%	8	62.5
75-95%	9	85.0
95-100%	10	97.5

Data analysis

Data analysis followed the methods outlined by Stadelmann et al. (1994). Overall map accuracy was calculated by dividing the number of correctly identified polygons by the total number of polygons sampled. A Kappa Index, which adjusts accuracy for the polygons that were correctly classified by chance (Foody 1992) was also determined. A contingency matrix was produced to determine per class producers' and users' accuracy. Producers' accuracy represents the probability that a reference sample has been classified correctly. It is calculated by dividing the number of samples that have been classified correctly by the total number of samples in that class. Users' accuracy represents the probability that a sample from the classified data actually represents a given class on the ground. It is calculated by dividing the number of samples that have been correctly classified by the total number of samples that were classified as belonging to that class. These matrices were used to determine per class and overall accuracy with 90% confidence intervals (CIs). Confidence intervals for a binomial distribution were derived with the following equation (Snedecor and Cochran 1989):

$$\hat{p} \pm \left\{ z_{\alpha} \sqrt{\frac{\hat{p}(1 - \hat{p})}{n}} + \frac{1}{(2n)} \right\}$$

where z is derived from a table of the z-distribution at a given significance level. The term 1/(2n) is the correction for continuity and is used because the binomial distribution describes discrete populations. For large sample sizes, the correction will become very small because the normal distribution closely approximates the binomial distribution in large populations.

Accuracy (producers and users) and 90% CIs were calculated for NVCS associations and CRMS interpreter classes. Overall accuracy was also calculated for CRMS secondary vegetation, CRMS vegetation modifiers, and for each individual USGS 1:24,000 Quadrangle. The accuracy and CIs of each class were determined. Classes

based upon NVCS associations were combined to improve the accuracy of individual classes and achieve the required 80% overall map accuracy.

Results and Discussion

NVCS Associations

The vegetation map did not initially meet the 80% standard (initial accuracy = 71.5% ± 3.3% CIs; Figure 2). The Kappa Index was slightly lower (70.9%) than gross accuracy. Generally, producers' and users' accuracies were similar across classes (Figures 2 and 3). Average producers' accuracy across all classes was 70.6%, while average users' accuracy was 74.8%. The upper CIs of 9 classes were below 80% for producers' accuracy (Figure 2) and 8 were below 80% for users' accuracy (Figure 3). The producers' accuracy of 12 classes was below 50%, and the users' accuracy of 10 classes were below 50% (Figures 2 and 3). The initial accuracy of the GRSM map was comparable to or better than that of initial maps of other parks with less complex vegetation. For example, the initial accuracy of the vegetation map of Walnut Canyon National Monument was 50% and the initial accuracy of the map of Acadia National Park was 73% (Nora Murdock, APHN Ecologist, personal communication).

To achieve an overall accuracy of 80% and improve the accuracy of individual classes, the number of classes based upon NVCS associations was reduced from 58 to 40 by combining classes (Table 2). After the number of classes was reduced, the accuracy of the map improved to 80.4% with a Kappa Index of 80.0%. Average producers' accuracy across all classes improved to 82.8% and average users' accuracy improved to 84.3%. The upper CIs of all classes exceeded 80% for both producers' and users' accuracy. In addition, only one class had a producer's accuracy below 50% and one class had a users' accuracy below 50% (Table 3).

The revised vegetation map contains 40 classes comprised of 31 vegetation classes derived from NVCS associations (Table 3) and 9 classes that did not fit into the classification (roads, streams, etc.; Table 4). Prior to the combining of classes, 54 NVCS vegetation associations were included in the map. Therefore, 25 out of the total 79 associations included in the vegetation classification of GRSM were not included on the map. These associations were not included because: (1) they were two small to be delineated in 1:12,000 color-IR aerial photos, or (2) they were indistinguishable from other associations and should be combined into classes with other associations. Determining how these "missing" classes should be incorporated into classes shown by the vegetation map is yet to be determined.

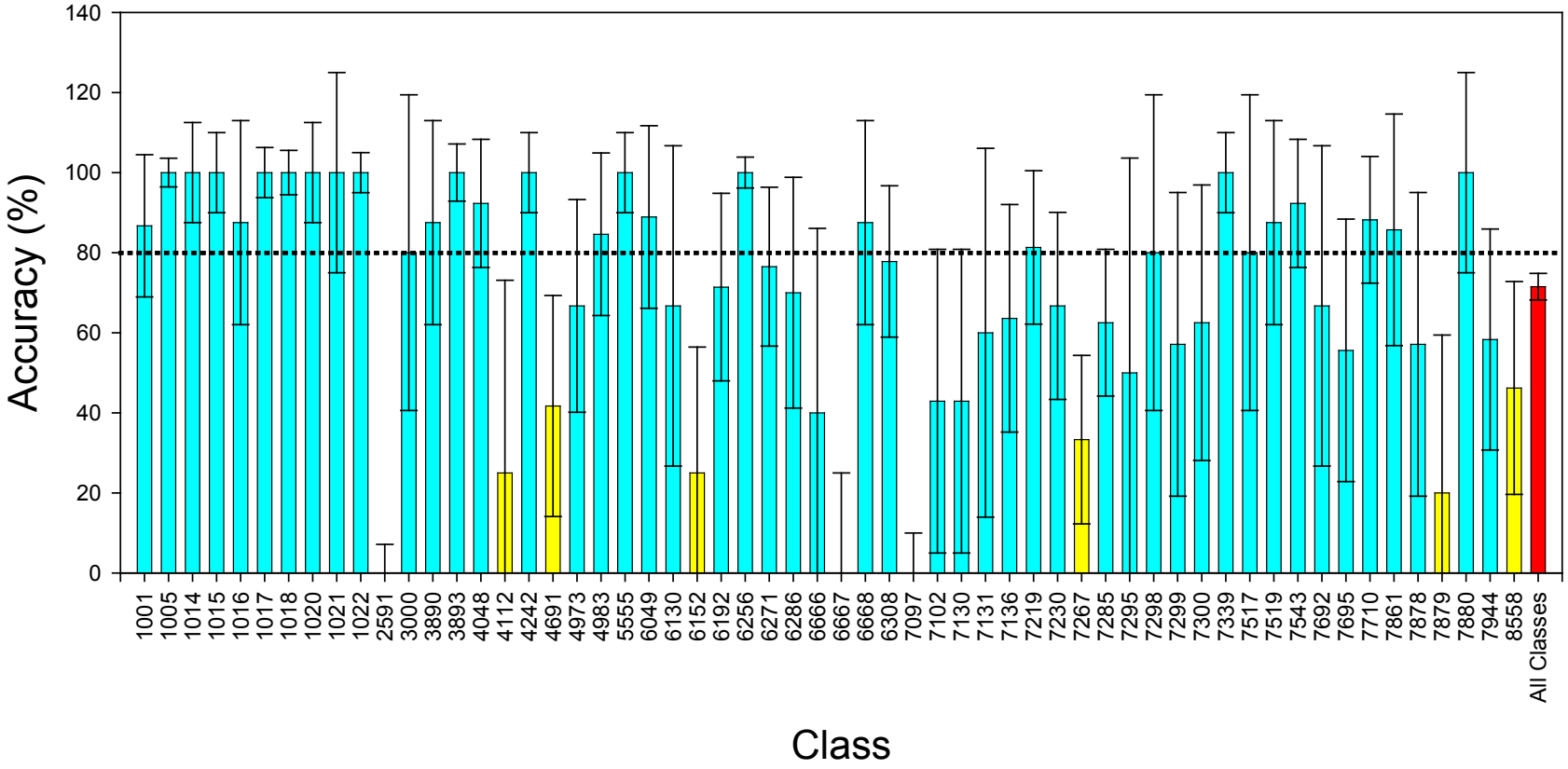


Figure 2. Producers' accuracy ± 90% confidence intervals for the original 58 map classes based upon the NVCS classification. The initial overall accuracy for the map is also shown (All Classes).

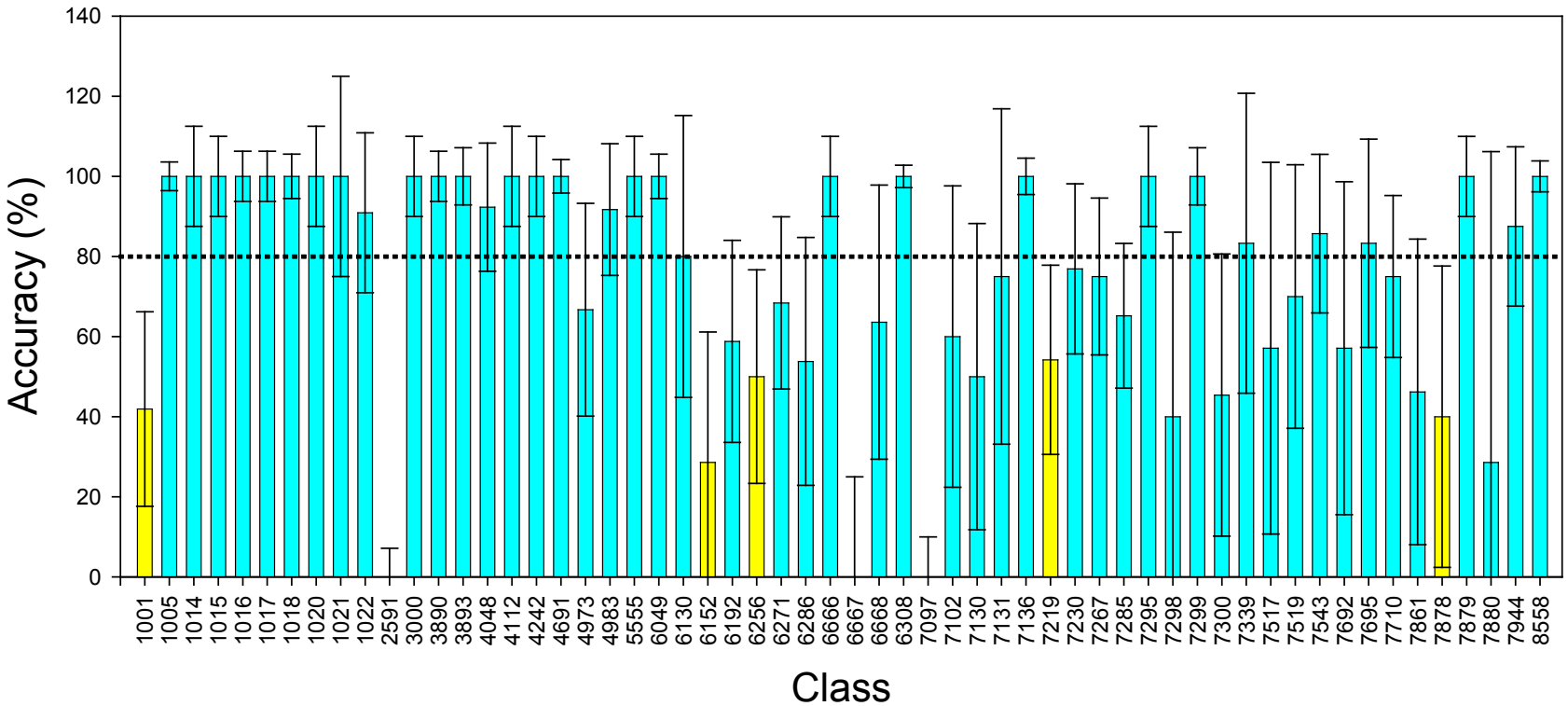


Figure 3. Users' accuracy ± 90% confidence intervals for the original 58 map classes based upon the NVCS classification.

Table 2. NVCS associations combined to increase overall map accuracy to 80%. Corresponding CRMS interpreters' classes are also provided.

NVCS Association	New Class	CRMS Classes
2591, 3560, 7078, 7097, 7119, 7493	1001 (generic yellow pines)	PI, PIv, Pie, PIr, PIp, PIp/OzH, PIp-OzH, PI/OzH, PI-OzH, OzH/PIr, PIv/OzH, PIv-OzH, OzH/PIv
3000, 3836, and 4113	1002 (generic wetlands)	Wt, Wt:Je, Wt:4112, Wt:8433, Wt:Fb, Wt:G, Wt:4290, Wt:*Ls*, Hx:*Ls*, Wt:7388, AL:*Ag*, AL:*Sn*, AL:Sb
4691 and 7880	1003 (floodplain forests)	MAL, MAL/T, MAL-T, MALt, MALc, MALc:Ls, MALj, T/MAL
6666, 6667, 6668	1004 (generic ericaceous shrubs, non heath bald)	K, K/R, R/K, K-R, R
3814 and 7876	1005 (heath)	Hth, Hth:R, Hth:K
7219 and 7879	1006 (successional hardwoods)	Hx, HxL, HxL/T, HxL-T, T/HxL, HxJ
6271 and 7267	1007 (chestnut oak forest)	OzH, OzH/PI, OzH/PIs, OzHf, OzHf/PIs
6130, 6246, and 7300	1008 (high elevation beech and red oak with deciduous shrubs)	NHxBe, NHxBe/Hb, NHxBe/G, MOr/Sb
7295, 7298 and 7299	1009 (high elevation red oak/white oak forest)	MOa, MOa/K, MOr/G, MOr/R-K, MOr/R, MOr/K
4983, 6256, 7861 and 8558	1010 (northern hardwoods and acid hardwoods)	S/NHxB, S-NHxB, NHxB/S, S/NHx, S-NHx, NHx/S, S/NHxB, NHxB-S, S-NHx, NHx, T/NHx, NHx/T, NHx-T, NHxB/T, T/NHxB
4973, 4982, 7285	1011 (northern hardwoods and boulderfields)	NHxR, NHxR/T, NHxR-T, T/NHxR, NHx:Fg, NHx:Bol
6152, 6272	1012 (spruce and hemlock)	S/T, S-T, T/S, S-T/R
7130, 7131, 6049, 6308	1013 (spruce-fir)	F, (F), (F)S, F/Sb, F/R, S(F), S/F, S-F, S-F/Sb, S-F/R, S, S/Sb, S/R

Table 3. Producers' and users' accuracy for the 40 NVCS association-based classes included in the final version of the vegetation map.

Class	Producer ± CI	User ± CI	No. of Plots
1001	81.5 ± 14.1	64.7 ± 16.7	27
1002	66.7 ± 31.4	100.0 ± 5.6	9
1003	71.4 ± 23.4	83.3 ± 20.0	14
1004	86.7 ± 17.8	100.0 ± 3.3	15
1005	100.0 ± 3.6	100.0 ± 3.6	14
1006	81.0 ± 16.5	68.0 ± 19.1	21
1007	65.7 ± 14.6	85.2 ± 11.3	35
1008	78.9 ± 18.0	88.2 ± 14.8	19
1009	75.0 ± 20.9	70.6 ± 21.9	16
1010	87.0 ± 9.3	72.7 ± 11.9	46
1011	77.1 ± 13.1	77.1 ± 13.1	35
1012	62.5 ± 34.4	62.5 ± 34.4	8
1013	76.7 ± 11.7	100.0 ± 1.3	38
1014	100.0 ± 12.5	100.0 ± 12.5	4
1015	100.0 ± 10.0	100.0 ± 10.0	5
1016	87.5 ± 25.5	100.0 ± 6.3	8
1017	100.0 ± 6.3	100.0 ± 6.3	8
1018	100.0 ± 5.6	100.0 ± 5.6	9
1019	100.0 ± 10.0	100.0 ± 10.0	5
1020	100.0 ± 12.5	100.0 ± 12.5	4
1021	100.0 ± 25.0	100.0 ± 25.0	2
1022	100.0 ± 5.0	90.9 ± 20.0	10
3890	87.5 ± 25.5	100.0 ± 6.3	8
3893	100.0 ± 7.1	100.0 ± 7.1	7
4048	100.0 ± 3.8	100.0 ± 3.8	13
4242	100.0 ± 10.0	100.0 ± 10.0	5
6192	71.4 ± 23.4	58.8 ± 25.2	14
6286	70.0 ± 28.8	53.8 ± 30.9	10
7102	42.9 ± 37.9	75.0 ± 34.1	7
7136	63.6 ± 28.4	100.0 ± 4.5	11
7230	66.7 ± 23.4	76.9 ± 21.2	15
7339	100.0 ± 10.0	83.3 ± 37.4	5
7517	100.0 ± 10.0	62.5 ± 45.6	5
7519	87.5 ± 25.5	70.0 ± 32.9	8
7543	92.3 ± 16.0	85.7 ± 19.8	13
7692	66.7 ± 40.0	57.1 ± 41.6	6
7695	55.6 ± 32.8	83.3 ± 26.0	9
7710	88.2 ± 15.8	75.0 ± 20.2	17
7878	57.1 ± 37.9	40.0 ± 37.6	7
7944	58.3 ± 27.6	87.5 ± 19.9	12

Table 4. Other classes included on the vegetation map that are not part of the NCVS classification system.

New Class	Description	CRMS Class
1014	Roads	RD
1015	Successional vegetation	SU
1016	Sparse vegetation	SV
1017	Rock	RK
1018	Mud, gravel	Mud
1019	Water	W
1020	Dead vegetation	Dd
1021	Exotic vegetation	E
1022	Human influence	HI

USGS Quadrangles and contractor accuracy

Accuracy varied from 40% to 100% among individual quad maps (Table 5). Accuracy improved with the number of polygons sampled, suggesting that some of the low accuracies may be a result of variability resulting from low replication. Generally, the quads located within the interior of the Park were among the most accurate (ranging from 57.1% for Silers Bald to 81.3% for Thunderhead Mountain). The accuracy of many quads was likely improved by the combining of classes performed to reach 80% accuracy. Polygons across the two quads mapped by the USGS BRD/NPS Vegetation Mapping Program (Cades Cove and Mount Le Conte) were 76.2% accurate. Polygons classified across the quads mapped by CRMS were 69.7% accurate.

CRMS interpreters' classes

Dominant vegetation

Overall, the interpreter classes used by CRMS in photo interpretation were more accurate than the NVCS-based classes derived by CRMS as described in the crosswalk developed by Madden et al. (2004). The overall accuracy of the map based upon CRMS classes was 74.0 ± 3.2% with a Kappa Index of 72.5%. While this assessment has focused on the NVCS associations, which are the standard classification units for NPS vegetation maps, the CRMS classes may be useful for locating polygons dominated by a single species or a group of species. Producers' and users' accuracies for sampled CRSM classes are provided in Appendix B.

Secondary vegetation and modifiers

The CRSM interpreters' classification system also identified secondary, but discernable, cover classes within polygons. This secondary vegetation classification is most likely to be used in ecotonal areas where transitions between vegetation types occur (Madden et al. 2004). Data from sampled polygons were reassessed to determine if a second vegetation type was identified and correctly classified. Overall, the secondary vegetation classifications were quite accurate with an overall accuracy of 78% (Appendix B).

The CRMS classification system also identifies modifiers within polygons. Modifiers describe additional influences on vegetation, such as recent disturbance, land use, dominant tree species, dead trees, roads, homesites, etc. The accuracy of modifiers was very high; overall accuracy was 82.8%. However, interpreters only assigned modifiers when they were identifiable within a photo. Therefore, modifiers do not represent the occurrence of a given condition across

the entire Park. Rather, they represent polygons where the given condition was readily identified.

Table 5. Accuracy (percent of polygons correctly classified from all polygons within a Quadrangle) for 23 USGS Quadrangles that contain Great Smoky Mountains National Park. No polygons were sampled on the Fontana Dam Quad.

Quad	No. Correct	No. Sampled	Percent Correct
Blockhouse	5	5	100.0
Bryson City	6	10	60.0
Bunches Bald	48	72	66.7
Cades Cove	53	74	71.6
Calderwood	9	13	69.2
Clingmans Dome	75	98	76.5
Cove Creek	11	12	91.7
Dellwood	14	14	100.0
Fontana Dam	9	13	69.2
Gatlinburg	24	36	66.7
Mt. Guyot	2	3	66.7
Hartford	2	5	40.0
Jones Cove	4	4	100.0
Kinzel Springs	5	12	41.7
Mt. Le Conte	24	27	88.9
Luftee Knob	4	8	50.0
Noland Creek	13	17	76.5
Silers Bald	12	21	57.1
Smokemont	25	39	64.1
Tapoco	5	11	45.5
Thunderhead	13	16	81.3
Waterville	1	1	100.0
Wear Cove	10	15	66.7

FIA data

Analysis of the FIA plot data revealed an overall accuracy of 65.1% for the NVCS associations. This value is roughly equal to the 71.5% accuracy determined in this assessment. Because the FIA plots were located in a cluster of four 0.016 ha subplots spaced 36 m apart, they are more likely to fall within multiple polygons or occur within the transitional area along the edges of polygons. While FIA staff identified plots where subplots were obviously in different polygons, these data generally captured more of the transitional, non-interior portions of polygons. This may have reduced the overall accuracy in comparison to that calculated in this report. However, the FIA data may provide a better assessment of overall accuracy and homogeneity throughout polygons. Comparisons of individual associations between the FIA plots and this assessment suggest that both analyses produced similar per class accuracies for associations where 5 or more

plots were sampled in both datasets (Table 6). With the exception of two associations (7230 and 7543), per-class accuracies derived by the two studies were very similar. One class that was combined with another class because of low accuracy in this assessment (8558) also exhibited low accuracy in the analysis of FIA data.

Table 6. Comparison of producers' accuracy calculated from FIA data and from the polygons sampled for this assessment. Only associations for which both datasets contained 5 or more plots/polygons are shown.

Association	FIA accuracy	No. of FIA samples	Assessment Accuracy	No. of Assessment Samples
4983	100.0	5	100.0	10
6192	66.7	9	100.0	14
6256	100.0	5	76.5	13
6271	70.0	10	70.0	17
7230	100.0	6	33.0	15
7543	25.0	8	66.7	13
7710	80.0	5	85.5	17
8558	44.4	9	46.2	13

Conclusions

By combining some classes, 80% accuracy was achieved for the vegetation map of GRSM. Overall, the initial accuracy of the map was comparable to or better than the initial accuracy of maps from other parks. The interpreters' classes used by CRMS were comparable in accuracy and may be of use to researchers who wish to focus on individual or groups of overstory species. The secondary vegetation and modifier classes were quite accurate (78.0% and 82.8%, respectively), but were only applied when visible within a polygon and do not provide a comprehensive assessment of secondary vegetation communities or conditions across the Park. Analysis of data from FIA plots revealed overall and per class accuracies similar to that of this assessment. Once a final version is produced, this vegetation map will provide a valuable tool to resource managers and researchers in Great Smoky Mountains National Park.

Future work

The next step in the mapping project will be to combine classes to produce a final version of the vegetation map. This will require combining classes identified in this assessment, but will also require the assigning of unmapped classes to existing mapped classes. For example, *Tsuga canadensis – Halesia tetraptera* – (*Fagus grandifolia*, *Magnolia fraseri*) / *Rhododendron maximum* / *Dryopteris intermedia* (a G2 association) could not be separated from other *Tsuga canadensis*-dominated associations in the aerial photos. The position of this and other unmapped classes within the final classification must be determined. Metadata for the final version of the vegetation map must also be developed.

Another association, Montane Alluvial Forest, was mapped with relatively low accuracy (producers' accuracy = 41.7 ± 27.5%) and was combined with another class. This association has been of great interest to compliance and resource management efforts in the Park and a more accurate assessment of its distribution is needed. However, since most forests of this association were heavily disturbed prior to the creation of GRSM, most examples of this association are in a state of successional transition. Consequently, they are difficult to separate from *Liriodendron – Acer rubrum – Robinia pseudoacacia* Forest and other successional associations. In-field mapping of forests along major streams in the Park may be necessary.

The aerial photography used to create the vegetation map was flown in 1997. After 1997, pine stands throughout GRSM experienced heavy overstory mortality from the southern pine beetle (*Dendroctonus frontalis*). Because of this mortality, pine classes delineated in the vegetation map are already inaccurate. Consequently, further analysis is needed to assess the contemporary condition of these classes and update the vegetation map. Because pine can easily be separated from hardwood forests with remote sensing, this assessment could be accomplished through the interpretation of satellite data.

In addition to the overstory map, CRMS also created an understory map that derives classes based upon the relative cover of *Kalmia latifolia*, *Rhododenron* spp., deciduous shrubs, and herbaceous vegetation. This spatial dataset was not created as part of the NPS/USGS BRD Vegetation Mapping Program and has no requirements for overall or per class accuracy. However, an assessment of the accuracy of this map must be performed and metadata must be developed.

Literature Cited

Foody, G.M. 1992. On the compensation for chance agreement in image classification accuracy assessment. Photogrammetric Engineering and Remote Sensing 58: 1459-1460.

Jobe, R. T., and M. McKnight. 2003. Selection of permanent vegetation samples within Great Smoky Mountains National Park. Report to Great Smoky Mountains National Park, Gatlinburg, Tennessee. 4 pp.

Madden, M., R. Welch, T. Jordan, P. Jackson, R. Seavey, and J. Seavey. 2004. Digital vegetation maps for the Great Smoky Mountains National Park, Final Report to the U.S. Department of Interior National Park Service, CA 1443-CA-5460-98-019, Center for Remote Sensing and Mapping Science, University of Georgia, Athens, Georgia. 112 pp.

The Nature Conservancy. 1999. BRD-NPS Vegetation Mapping Program: Vegetation Classification of Great Smoky Mountains National Park (Cades Cove and Mount Le Conte Quadrangles). The Nature Conservancy, Arlington, Virginia. 195 pp.

Peet, R. K., T.R. Wentworth, and P. S. White. 1998. A flexible multipurpose method for recording vegetation composition and structure. Castanea 63: 262-274.

Snedecor, G.W., and W.G. Cochran. 1989. Statistical Methods, Eighth Edition. The University of Iowa Press, Ames, Iowa. 503 pp.

Stadelmann, M., A. Curtis., R. Vaughan, and M. Goodchild, contributing authors. 1994. Accuracy assessment procedures—final draft. NPS/NBS Vegetation Mapping Program. http://biology.usgs.gov/npsveg/

Welch, R., M. Madden, and T. Jordan. 2002. Photogrammetric and GIS techniques for the development of vegetation databases of mountainous areas: Great Smoky Mountains National Park. ISPRS Journal of Photogrammetry and Remote Sensing 57: 53-68.

White, R. D., K.D. Patterson, A. Weakley, C.J. Ulrey, and J. Drake. 2003. Vegetation classification of Great Smoky Mountains National Park. Report submitted to BRD-NPS Vegetation Mapping Program. NatureServe, Durham, North Carolina. 376 pp.

Appendix A.

Examples of field datasheets used in accuracy assessment.

ACCURACY ASSESSMENT

Polygon #_____ Date/Time_____ Crew_____

MMU size _____ Description of alterations to MMU_____

Location Description

UTM Coordinates

_____ E _____ N ± _____ meters

Quad_____

Trailhead, directions from trail, other identifying site features:

Site Description

Slope (%) _____ Aspect _____ Slope shape _____ Topographic position _____
Elevation _____

Disturbance

Fire_____
Pine beetle_____
Windstorm_____
Hogs_____
Other insects_____
Disease_____
Other disturbance_____

Additional Disturbance Notes:

Inclusions

Streams _____
Wetlands _____
Rock Outcrops _____
Other _____

Additional Inclusion Notes

Vegetation Association Identified with Field Keys _____
Mapped NVCS Association
_____

Other Vegetation Notes and General Comments:

Polygon # _____

Vegetation Data

Strata: **C=Canopy; Su = Subcanopy; Sh = Shrub; H = Herb.** **Cover classes:** **Missing but nearby --; Solitary or few = 1; 0-1% = 2; 1-2% = 3; 2-5% = 4; 5-10% = 5; 10-25% = 6; 25-50% = 7; 50-75% = 8; 75-90% = 9; 95-100% = 10**

Strata	Species	Cover Class	Notes

Appendix B.

Producers' and users' accuracy of dominant vegetation classes and producers' accuracy of secondary vegetation and vegetation modifier classes employed by photo interpreters at CRMS.

Appendix B1. Producers' and users' accuracy of vegetation classes used by photo interpreters at the University of Georgia (CRSM classes).

UGA Class	Producers' Accuracy	Users' Accuracy	No. Sampled
(F)	100.0	100.0	4
AL	80.0	100.0	5
CHx	76.9	100.0	13
CHx/T	100.0	100.0	1
CHxA	85.7	100.0	7
CHxA-T	100.0	100.0	1
CHxL	100.0	100.0	3
CHxO	85.7	100.0	7
CHxR	66.7	100.0	9
Dd	100.0	100.0	4
F	100.0	75.0	3
F/S	50.0	100.0	2
Fb	100.0	83.3	5
G	100.0	100.0	3
Gb	100.0	100.0	5
Grv	100.0	100.0	9
HI	100.0	90.9	10
Hth	100.0	100.0	14
HxA	100.0	25.0	1
HxA/T	100.0	100.0	2
HxBl	100.0	66.7	4
HxJ	20.0	100.0	5
HxL	80.0	57.1	15
K	40.0	100.0	5
K/R	0.0	0.0	1
MAL	25.0	0.0	4
MALc	40.0	66.7	5
MALc:Ls	100.0	28.6	2
MALj	100.0	0.0	5
MALt	100.0	100.0	2
MOa	25.0	100.0	4
MOr	75.0	60.0	4
MOr/G	100.0	45.5	5
MOr/R	100.0	100.0	1
MOr/R-K	50.0	100.0	2
MOr/Sb	75.0	54.5	8
NHx	77.8	82.4	18
NHxA	80.0	80.0	5
NHxA/T	80.0	100.0	5
NHxB	85.7	60.0	7
NHxB/S	100.0	66.7	6
NHxB/T	100.0	100.0	2
NHxBe	40.0	20.0	5

NHxBe/G	80.0	100.0	5
NHxBe/Hb	100.0	100.0	1
NHxE	100.0	100.0	1
NHxR	72.7	80.0	11
NHxY	50.0	100.0	8
OmH	83.3	38.5	6
OmH/T	100.0	50.0	1
OmHA	73.3	91.7	15
OmHL	33.3	100.0	3
OmHp/R	60.0	60.0	10
OmHr	75.0	100.0	4
OmHR	83.3	62.5	6
OzH	71.4	62.5	7
OzH/PI	66.7	0.0	9
OzH/PIv	0.0	0.0	1
OzHf	61.1	84.6	18
P	80.0	100.0	5
PI	85.7	27.3	7
PI/OzH	100.0	57.1	4
PI-OzH	0.0	0.0	2
PIp	0.0	0.0	1
PIp/OzH	0.0	0.0	3
PIp-OzH	0.0	0.0	1
PIs	54.5	100.0	11
PIs/OmH	100.0	50.0	4
PIs/OmHA	100.0	100.0	1
PIs/OzH	87.5	77.8	8
PIs/T	0.0	0.0	2
PIs-T	60.0	100.0	5
PIv	0.0	0.0	4
PIv/OzH	0.0	0.0	1
PIv-OzH	0.0	0.0	2
R	87.5	63.6	8
R/K	0.0	0.0	1
RD	100.0	100.0	4
RK	100.0	100.0	8
S	55.6	100.0	9
S(F)	100.0	57.1	8
S/NHx	100.0	100.0	6
S/NHxA	100.0	100.0	1
S/NHxB	25.0	16.7	4
S/R	33.3	100.0	9
S/Sb	66.7	100.0	3
S/T	0.0	0.0	3
Sb	100.0	100.0	8
Seep	100.0	100.0	1

S-F/Sb	100.0	100.0	2
S-NHx	100.0	100.0	2
S-NHxB	0.0	0.0	1
S-T	25.0	100.0	4
S-T/R	0.0	0.0	1
SU	100.0	100.0	5
SV	87.5	100.0	8
T	55.6	100.0	9
T/HxL	100.0	50.0	1
T/NHxA	100.0	100.0	1
T/NHxB	100.0	66.7	4
T/R	100.0	100.0	2
V	88.9	100.0	9
W	100.0	100.0	5

Appendix B2. Number of polygons sampled and producers' accuracy for secondary vegetation classes employed by photo interpreters at CRMS.

Second Vegetation Class	No. Sampled	Producers' Accuracy
CHx	1	100.0
CHxA	2	100.0
Dd	5	100.0
F	2	100.0
F/S	1	100.0
G	2	100.0
HI	6	100.0
Hth	3	33.3
HxA	1	100.0
HxJ	1	0.0
HxL	3	100.0
MAL	1	100.0
MALc	5	40.0
MALt	1	100.0
MOr	5	60.0
MOr/Sb	3	100.0
NHx	4	75.0
NHxA	2	100.0
NHxB	16	100.0
NHxB/T	1	100.0
NHxBe	1	0.0
NHxR	4	75.0
NHxY	2	100.0
OmH	7	57.1
OmHA	2	0.0
OmHr	1	100.0
OzH	4	100.0
OzHf	3	33.3
PI	9	88.9
PIs	2	50.0
R	3	33.3
S	15	80.0
S(F)	5	100.0
S/NHxB	1	100.0
S/R	1	100.0
S/Sb	1	100.0
Sb	5	80.0
Seep	1	0.0
S-T	1	0.0
T	8	62.5
All classes	141	78.0

Appendix B3. Number of polygons sampled and producers' accuracy for vegetation modifiers employed by photo interpreters at CRSM.

Modifier	No. Sampled	Producers' accuracy
:1	1	100.0
:3	2	100.0
:4	1	100.0
:5	13	100.0
:6	5	100.0
:7	1	100.0
:8	1	0.0
:9	2	50.0
:11	1	100.0
:B	1	0.0
:Bl	2	50.0
:Bol	1	100.0
:Fg	12	66.7
:Fs	1	100.0
:G	1	0.0
:L	4	75.0
:R	6	100.0
:Sn	1	100.0
:T	2	100.0
All modifiers	58	82.8