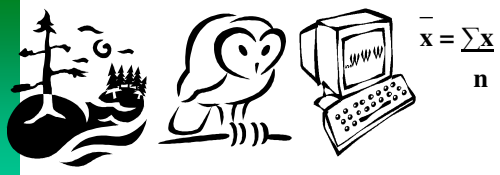
Region One
Vegetation Classification, Mapping, Inventory and Analysis Report



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Eastside R1-VMap Accuracy Assessment (Lewis and Clark, Helena, Custer and Gallatin National Forests)

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R1-VMap Eastside Accuracy Assessment

The Northern Region (R1) of the United States Forest Service (USFS) is responsible for managing vegetation for a variety of uses while maintaining the integrity of ecosystem function over regional and local scales. Effective resource planning, analysis and monitoring strategies, in turn, require reliable, consistent and continuous existing vegetation data products. In meeting this need the R1 Geospatial Group has recently produced a vegetation map product called R1-VMap. It is a spatially explicit, thematic, polygon-based product derived from remotely sensed data that contains information about the extent, composition, and structure of vegetation across National Forest System land in R1.

To ensure that R1-VMap data are interpreted appropriately, users of the data should have a clear understanding of map elements and their associated reliability. An assessment of map accuracy should be conducted before important management decisions are undertaken with the mapped data. Estimates of overall map accuracy and confidence of individual map classes can be inferred from an error matrix derived from the comparison of known reference sites to mapped data. This document describes a procedure applied by the USFS Northern Region (USFS R1) to assess the thematic accuracy of mapped vegetation classes of the R1-VMAP eastside product, using aerial photo interpretations and Forest Inventory and Analysis (FIA) plots as components of reference data. Included are a general overview of the accuracy assessment process, results, discussion of the results and, in the appendices, error matrices calculated for: 1) the entire eastside project (Helena, Custer, Lewis and Clark and Gallatin National Forests), 2) The Lewis and Clark National Forest, 3) the Lewis and Clark Island Units 4) the Lewis and Clark Rocky Mountain Front, 5) the Helena National Forest, 6) the Gallatin National Forest, and 7) the Custer National Forest.

OVERVIEW

A fundamental component of any map accuracy assessment is the comparison of known characteristics of particular sites to those portrayed by a given map. The areas or locations of comparison are referred to as sample sites, and in the final analysis the assessment of map accuracy is based on how many times the reference and map elements correspond to one another in the set of samples.

A first step in the accuracy assessment process, then, is the collection of reference data at a variety of sites. Once collected, information contained in the reference data are compared to those illustrated at the same locations on the map. In this assessment, ground based FIA plot data are used as a guide for photo interpretation, to which the results of classified remotely sensed data are compared. Forest Inventory and Analysis data have been collected in a standardized, grid-like fashion across the United States for approximately 70 years. Data collected by FIA contain information about forest characteristics such as species composition, size-class, canopy coverage, health, and growth rates to name just a few. Having been collected in a consistent manner and distributed across the landscape as a network of points the information recorded by the FIA program provides a base from which an independent, systematic, assessment of R1-VMap class accuracy can be conducted.

As part of this accuracy assessment process, the locations of the FIA data plots are intersected with map polygons. Forested polygon(s) (10% and greater tree cover) were interpreted to dominance group 6040, tree canopy class and tree size class (see 'The Region 1 Vegetation Classification System and its Relationship to Inventory Data and the Region 1 Existing Vegetation Map Products' at http://fsweb.r1.fs.fed.us/forest/inv/classify/r1_ex_veg_cmi_4_09.pdf) using FIA plot information to assist with photo interpretation. In some cases, the FIA data were not representative of the polygons. Photo interpretation was still completed for these polygons, but the FIA data were less informative, leading to a potentially less accurate final interpretation. Selected polygons that are in non-forest cover types were not assessed beyond a 'non-forest' cover call because no FIA information is available in these areas.

After completion of photo-interpretation for all FIA intersected polygons, comparisons of these data to the mapped elements are then tabulated and presented in an error matrix. Rows of the error matrix represent values of the map, and columns represent values of the reference data. Tabulated values across the diagonal of the matrix describe the number of times map and reference data sites have equal values. Conversely, the off-diagonal table elements quantify errors of either inclusion or exclusion of particular classes. Errors of inclusion are shown on the horizontal axis of classes, while errors of exclusion are shown on the vertical axis. Large numbers of inclusion or exclusion between two or more classes indicate a high degree of confusion and result in a lower quality map. To illustrate these concepts, an error matrix quantifying the level of agreement in a theoretical lifeform map is given below as Table 1.

Table 1. *Error matrix of a theoretical lifeform map, with overall map accuracy of 74%*

		Reference Data Classes				
		Forest	*Shrub*	*Herbaceous*	*Water*	**Map Total**
Map Data Classes	*Forest*	**65**	4	22	24	115
	Shrub	6	**81**	5	8	100
	Herbaceous	0	11	**85**	19	115
	Water	4	7	3	**90**	104
	Ref. Total	75	103	115	141	434

Once an error matrix table has been created, several useful measures of map accuracy can be computed, including overall, producer, and user metrics. Overall accuracy is a common metric that describes how well the map compares to a reference dataset as a whole. Producer accuracy focuses on errors of exclusion and thus is a term that describes the number of samples that were incorrectly classed. User accuracy, on the other hand, is based on errors of inclusion and therefore reflects the probability that a feature of the map actually represents that category on the ground. Although, as the name implies, user's accuracy is most useful to map users, producer's accuracy can be of benefit too in that it gives indication of how a well a mapped class is covered on the map (i.e. if a specific class has a producer's accuracy of 100%, we know all occurrences of this type are correctly mapped and not part of another class) Regardless of the measurement used, the robustness of the metric is largely dependent on the number of samples that were used for comparison. In the best case scenario a similar number of samples will be avail-

able for each map class, and each class will have a large number of samples, which generally means more than 30 instances.

Overall Accuracy is computed by dividing the total number of correct samples by the total number of assessment sites found in the bottom right cell of the error matrix table.
It is often the most commonly reported accuracy measure because it takes advantage of samples from all classes. Not all map classes will have large enough samples available for comparison. With Table 1 as an example, it can be seen that 434 sites were evaluated against their known condition on the ground. By adding the total number of times mapped classes were in agreement with their known condition and dividing that total by the total number of sites that were evaluated the overall accuracy of the map can be assessed as follows:

[*Forest* (**65**) + *Shrub* (**81**) + *Herbaceous* (**85**) + *Water* (**90**) = 321] / 434 = **74%**

Producer Accuracy is the probability of a reference site being correctly classified, and is calculated by dividing the total number of correctly mapped sites for a class by the total number of reference sites for that class. Using data from Table 1, Producer's class accuracy values are assessed as follows in Table 2:

Table 2. *Computation of Producer Map Accuracy*

Map Class	# of correct sites	# of all reference sites	Relative Accuracy (%)
Forest	**65** divided by	**75**	**= 87**
Shrub	**81** divided by	**103**	**= 79**
Herbs	**85** divided by	**115**	**= 74**
Water	**90** divided by	**141**	**= 64**

User Accuracy is the probability that a feature on the map actually represents that category on the ground, and is calculated by dividing the number of agreements for a category by the total number of sites that were mapped into that category. Using data from Table 1, User class accuracy values are assessed as follows in Table 3:

Table 3. *Computation of User Map Accuracy*

Map Class	# of correct sites	# of all mapped sites	Relative Accuracy (%)
Forest	**65** divided by	**115**	**= 57**
Shrub	**81** divided by	**100**	**= 81**
Herbs	**85** divided by	**115**	**= 74**
Water	**90** divided by	**115**	**= 87**

For a more detailed description of the accuracy assessment process used to complete the east-side R1-VMap accuracy assessment see: 'R1-VMap Accuracy Assessment Procedures for Region 1' at this link: http://www.fs.fed.us/r1/gis/image/R1-VMap-aa-procedures-v11.pdf

Results

For the eastside R1-VMap assessment, there were a total of 1037 samples available for assessment. Of these, 688 of the samples were forested, and 349 samples were non-forested.

For the forested portion of the eastside R1-VMap, accuracy assessment error matrices are completed for these areas:

- The entire eastside project—encompasses the Custer, Gallatin, Lewis and Clark, and Helena National Forests (see Appendix A)
- The Lewis and Clark National Forest (see Appendix B)
    - The Island Units—Highland Snowy and Littlebelt Mountain Ranges (see Appendix C)
    - The Rocky Mountain Front—Rocky Mountain Ranger District (see Appendix D)
- The Helena National Forest (see Appendix E)
- The Gallatin National Forest (see Appendix F)
- The Custer National Forest (see Appendix G)

In each of the forested analysis areas, error matrices have been constructed for dominance type plurality 60, dominance type plurality 40, four classes of tree canopy cover (10-24.9%, 25-39.9%, 40-59.9%, 60-100%), and four classes of tree size (DBH 0-4.9", DBH 5-9.9", DBH 10-14.9, DBH >= 15".)

For additional information to R1-VMap classes assessed, see 'The Region 1 Existing Vegetation Maps Products (VMap) Release 9.1.1' at http://www.fs.fed.us/r1/gis_VMap_UsersGuide_9.1.1.pdf.

Given the limited information available for non-forest data, the only assessments completed for these were lifeform assessments of 'tree' (10% or greater tree cover) verses 'non-tree' (less than 10% tree cover). The error matrices for these assessments are shown in appendix I of this document. Appendix H also contains a cross-validation assessment of two non-forest grass cover types ('grass-bunch' and 'grass-single stem') and the litter classes ('0-59.9% litter', '60-89.9% litter' and '90% > litter'.) These cross-validations were completed by withholding a percentage of the field data used to create these classes. Since these field data were opportunistically sampled, they could not be used to generate an official accuracy assessment as given for the forested eastside accuracy assessment. Rather, this ancillary assessment has been included to give some indication of assessment for these additional classes The other life-form non-forest classes were not assessed.

Discussion

Overall Accuracy is a measure of the agreement between the sampled sites and mapped classes corresponding to those sites. It is simply the sum of the number of sites that agree divided by the total number of sites that were compared. As such, Overall Accuracy says nothing about individual class accuracy; rather it provides the interpreter with a measure of classification quality as a whole. It is important to consider that the value of this measure is influenced by the number of comparisons that are made in each of the classes. This can be overcome by either making the sample size the same for each class or by normalizing the elements of the error matrix. To be meaningful, each class being compared would have at least thirty samples. When such criteria are not met, assessment of classes with small sample sizes is not very meaningful or realistic, and the Overall Accuracy statistic is probably the most meaningful measure of map accuracy. Since it may not be possible to create more samples if FIA data are not available, an area-weighted normalization may be the most effective way to distribute equal weight to all classes being compared. For assessment of the Eastside Forest R1-VMap 2008 dataset, the latter approach was selected.

It is unfortunate, but an assessment of individual class accuracy cannot be conducted when there are an insufficient number of reference samples available. In such cases users of the map should be aware that while the error in some map classes is not quantified in an error matrix, it can be assessed either through additional reference data collection, or via systematic field review of the classification.

Specifics on Error Matrices

Accuracy assessment number are a function of the number of comparisons, the number of map classes, and the accuracy of the comparisons. Due to the large number of classes and relatively few comparisons in each class, high dominance type accuracy values are difficult to obtain. The dominance types are the most difficult to achieve good accuracies. However, even these results are acceptable in most areas. The Gallatin National Forest is one of the areas where dominance type is less than acceptable. Dominance type for the Gallatin is currently being reworked with a different classification technique, but given the combinations and complexities of tree species on the Gallatin National Forest, additional field data may help to enhance classification accuracy. To make higher increases in accuracies beyond the classification technique, additional field data may be needed.

Dominance Error matrices

Table 2. *Aggregations of tree dominance group 6040 types into tree dominance 60% plural ity and tree dominance 40% mid-level plurality classes. Note: XXXX = current Region 1 preferred PLANTS Database code for a tree species (e.g., ABLA, PIPO).*

Dominance Group 6040	Dominance 60% Plurality	Dominance 40% Plurality
XXXX	XXXX	MX-XXXX
XXXX-HMIX	HMIX	MX-XXXX
XXXX-IMIX	IMIX	MX-XXXX
XXXX-TMIX	TMIX	MX-XXXX
HMIX	HMIX	HMIX
IMIX	IMIX	IMIX
TMIX	TMIX	TMIX

Table 2 shows how the Dominance Group 6040 is aggregated into the Dominance 60% Plurality and Dominance 40 Plurality groups. Any R1-VMap polygon with species equal to 60% canopy cover or more get the actual species label for that polygon (e.g. ABLA, PIPO) and any species-mixed classes are place in 'IMIX' if the overall species composition are shade intolerant or 'TMIX' if the overall species composition are shade tolerant. Although error matrices presented are for the Dominance 40 and 60 plurality classes, the data that was actually mapped were the Dominance 6040 classes that were then collapsed to the Dominance 60 and 40 plurality classes.

Dominance 60 Error Matrices

For the dominance 60 plurality, the TMIX and IMIX are largely responsible for the poor overall accuracies of the error matrices. Because they collapse all mixed species into either 'IMIX' or 'TMIX' representing many different types of species, it is unlikely that these measures would have high accuracies. The accuracies that are most useful for the dominance 60 error matrices are the user's accuracies for the individual species classes. These provide an indication of how accurately the dominance types with 60% canopy cover represent mapped on the ground.

Dominance 40 Error Matrices

As Table 2 shows, Dominance 40% plurality classes consolidate all single species classes and single species-mixed species. This creates a map or inventory compilation with classes that are based on greater than or equal to 40% canopy cover.

The consolidated classes of the 40% plurality classes are all reasonable groups to be tested for accuracy given the mapping process used, thus all measures of accuracy are valid in these matrices. All overall accuracies for these error matrices are 63% or greater, except the Gallatin

which is being reworked. As an additional observation, the Rocky Mountain Front of the Lewis and Clark has significantly lower accuracy than the Island units due to limited access.

In terms of individual species accuracies (both for the dominance 60 and dominance 40) PIPO, PICO, PSME and PIAL were mapped reasonably well with accuracies up to 75%. Accuracies for PIEN and ABLA tend to be lower (8-25% respectively). This may be largely related to a scarcity of both classification and assessment data.

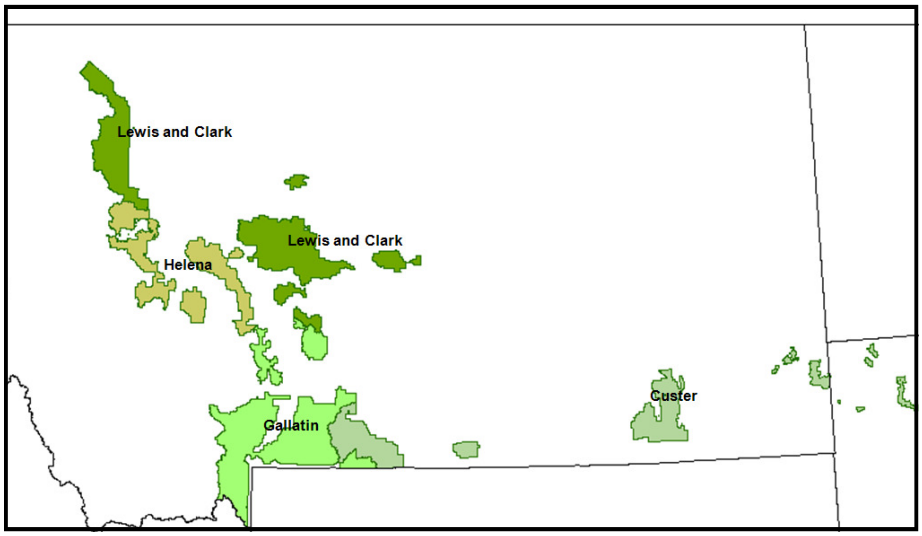
Tree Canopy and Size

For all error matrices, most of the accuracies for tree canopy and size are good, ranging in values from 63 to 78% with a mean of 70% for overall accuracies. For tree canopy, tree canopy class '25-39.9%' is somewhat less accurately mapped with accuracies between 54 to 60%. The other classes range in value from 53-80% with a mean accuracy of 70%.

Non-forest Accuracy Assessment and Cross Validation

An accuracy assessment of 'tree' (10% and greater tree cover) and 'non-tree' (less than 10% tree cover) was completed for the entire eastside R1-VMap project and each of the individual forests. All of these accuracies were quite high with the lowest overall accuracy at 87% and the highest at 90%.

All other components of the non-forest data were not validated with independent accuracy assessment data. In most cases, there was not enough data to do any kind of additional assessment. A portion of the non-forest data were cross-validated by withholding a small percentage of the field data. The area completed for this assessment included all of the eastside R1-VMap except the Custer Sioux and Ashland Ranger District areas. As mentioned earlier, the non-forest cover types assessed using this procedure were: two non-forest grass cover types ('grass-bunch' and 'grass-single stem') and the litter classes ('0-59.9% litter', '60-89.9% litter' and '90% > litter'.) Overall accuracy for the two mapped grass classes was 75% (this give no indication of how well grass was mapped overall, but instead gives indication of how accurate these two classes are within the larger grass class.) For the litter classes, overall accuracy was 65% with poorest accuracy in the highest litter class (90% > litter) with a user's accuracy of 57% and the lowest litter class (0-59.9% litter) having the highest user's accuracy at 81%



Appendix A: Eastside R1-VMap Accuracy Assessment Error Matrices (Assessment of the Custer, Helena, Lewis and Clark, and Gallatin National Forests)

Eastside R1-VMap (Custer, Helena, Lewis and Clark, and Gallatin National Forests)
Accuracy Assessment Tables

Dominance Type 60 Accuracy Assessment Error Matrix

Mapped Classes	DOM60	Reference Data											
		ABLA	IMIX	JUOC	PIAL	PICO	PIEN	PIFL2	PIPO	POTR5	PSME	TMIX	Grand Total
	ABLA	1	1			3	1					6	12
	IMIX	2	41		11	22	8	2	1	1	24	31	143
	JUOC					1							1
	PIAL	1	2		10	1	2	1				6	23
	PICO	8	16		6	107	5	3	1	1	26	20	193
	PIEN	1	3		1	4	1					1	11
	PIFL2		1					1				1	3
	PIPO		1	1		1			35		9		47
	POTR5					1				3			4
	PSME	2	42	1	1	20	5	4			85	12	172
	TMIX	1	8		2	6	2				1	28	48
	Grand Total	16	115	2	31	166	24	11	37	5	145	105	657

Area Weighted Overall Accuracy = 52%

Class	Producer's Accuracy	User's Accuracy
ABLA	NA *	NA
IMIX	35%	29%
PIAL	32%	43%
PICO	64%	55%
PIEN	NA	NA
PIFL2	NA	NA
PIPO	95%	74%
POTR5	NA	NA
PSME	59%	49%
TMIX	27%	58%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 classes

Eastside R1-VMap (Custer, Helena, Lewis and Clark, and Gallatin National Forests)
Accuracy Assessment Tables

Dominance Type 40 Accuracy Assessment Error Matrix

Mapped Data	DOM40	Reference Data										
		IMIX	MX-ABLA	MX-JUOC	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-PIPO	MX-POTR5	MX-PSME	Grand Total
	IMIX					3						3
	MX-ABLA	1	3		8	14	11				2	39
	JUOC					1						1
	MX-PIAL	2	8		30	1	4	1				46
	MX-PICO	2	19		18	143	24	4	1	1	39	251
	MX-PIEN	1	6		3	13	8				1	32
	MX-PIFL2	1				1	2	4			1	9
	MX-PIPO			1		1		1	37		10	50
	MX-POTR5					1				3		4
	MX-PSME	3	7	1	6	46	21	6	3	1	129	223
	Grand Total	10	43	2	65	224	70	16	41	5	182	658

Area Weighted Overall Accuracy = 63%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	6%	8%
MX-PIAL	46%	65%
MX-PICO	64%	57%
MX-PIEN	11%	25%
MX-PIFL2	NA	NA
MX-PIPO	90%	74%
MX-POTR5	NA	NA
MX-PSME	71%	58%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples of that class.

Eastside R1-VMap (Custer, Helena, Lewis and Clark, and Gallatin National Forests)
Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9"	19	15	13		47
	DBH 5-9.9"	16	147	39	13	215
	DBH 10-14.9"	12	82	216	18	328
	DBH >= 15"	3	18	33	20	74
	Grand Total	50	262	301	51	664

Area Weighted Overall Accuracy = 69%

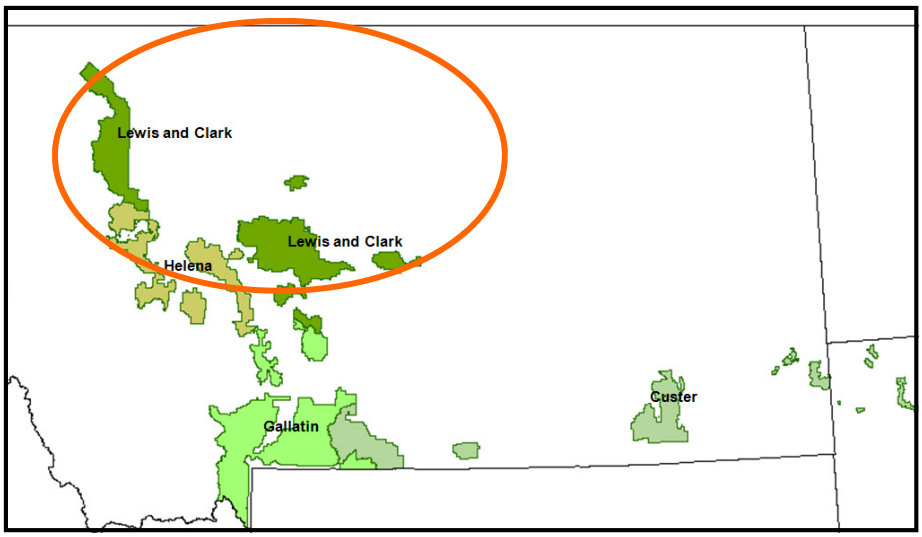
Class	Producer's Accuracy	User's Accuracy
DBH 0-4.9"	38%	40%
DBH 5-9.9"	56%	68%
DBH 10-14.9"	72%	66%
DBH >= 15"	39%	27%

Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-24.9%	TCC 25-39.9%	TCC 40-59.9%	TCC >= 60%	Grand Total
	TCC 10-24.9%	59	9	9	1	78
	TCC 25-39.9%	20	86	35	18	159
	TCC 40-59.9%	13	31	195	41	280
	TCC >= 60%	3	8	40	96	147
	Grand Total	95	134	279	156	664

Class	Producer's Accuracy	User's Accuracy
TCC 10-24.9%	62%	76%
TCC 25-39.9%	64%	54%
TCC 40-59.9%	70%	70%
TCC >= 60%	62%	65%

Area Weighted Overall Accuracy = 69%



Appendix B: R1-VMap Accuracy Assessment Error Matrices for the Lewis and Clark National Forest

Lewis and Clark National Forest R1-VMap Accuracy Assessment Tables

Dominance Type 60 Accuracy Assessment Error Matrix

Mapped Classes	DOM60	Reference Data										
		ABLA	IMIX	PIAL	PICO	PIEN	PIFL2	PIPO	POTR5	PSME	TMIX	Grand Total
	ABLA		1		1							2
	IMIX	1	10	1	7	5	2	1		10	8	45
	PIAL			1			1				1	3
	PICO	6	9	2	54	4	2		1	5	14	97
	PIEN	1			4	1						6
	PIFL2						1				1	2
	PIPO		1		1			4		8		14
	POTR5				1				2			3
	PSME	2	13		8	3	3			34	2	65
	TMIX	1		1	2	1					7	12
	Grand Total	11	34	5	78	14	9	5	3	57	33	249

Area Weighted Overall Accuracy = 52%

Class	Producer's Accuracy	User's Accuracy
ABLA	NA	NA *
IMIX	29%	22%
PIAL	NA	NA
PICO	69%	56%
PIEN	NA	NA
PIFL2	NA	NA
PIPO	NA	NA
POTR5	NA	NA
PSME	60%	52%
TMIX	21%	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Lewis and Clark National Forest R1-VMap Accuracy Assessment Tables (continued)

Dominance Type 40 Accuracy Assessment Error Matrix

Mapped Data	DOM40	Reference Data									
		IMIX	MX-ABLA	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-PIPO	MX-POTR5	MX-PSME	Grand Total
	IMIX	0									0
	MX-ABLA		1	1	3	2				1	8
	MX-PIAL			3		1	1				5
	MX-PICO	2	12	6	66	15	3		1	9	114
	MX-PIEN		1		5	3					9
	MX-PIFL2				1	2	3			1	7
	MX-PIPO				1		1	5		9	16
	MX-POTR5				1				2		3
	MX-PSME	1	4	1	15	7	4	2		53	87
	Grand Total	3	18	11	92	30	12	7	3	73	249

Area Weighted Overall Accuracy = 65%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	NA	NA
MX-PIAL	NA	NA
MX-PICO	72%	58%
MX-PIEN	10%	NA
MX-PIFL2	NA	NA
MX-PIPO	NA	NA
MX-POTR5	NA	NA
MX-PSME	73%	61%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Lewis and Clark National Forest R1-VMap Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9"	11	9	9		29
	DBH 5-9.9"	14	72	21	3	110
	DBH 10-14.9"	4	29	53	1	87
	DBH >= 15"	2	5	11	3	21
	Grand Total	31	115	94	7	247

Area Weighted Overall Accuracy = 65%

Class	Producer's Accuracy	User's Accuracy
DBH 0-4.9"	35%	NA
DBH 5-9.9"	63%	65%
DBH 10-14.9"	56%	61%
DBH >= 15"	NA	NA

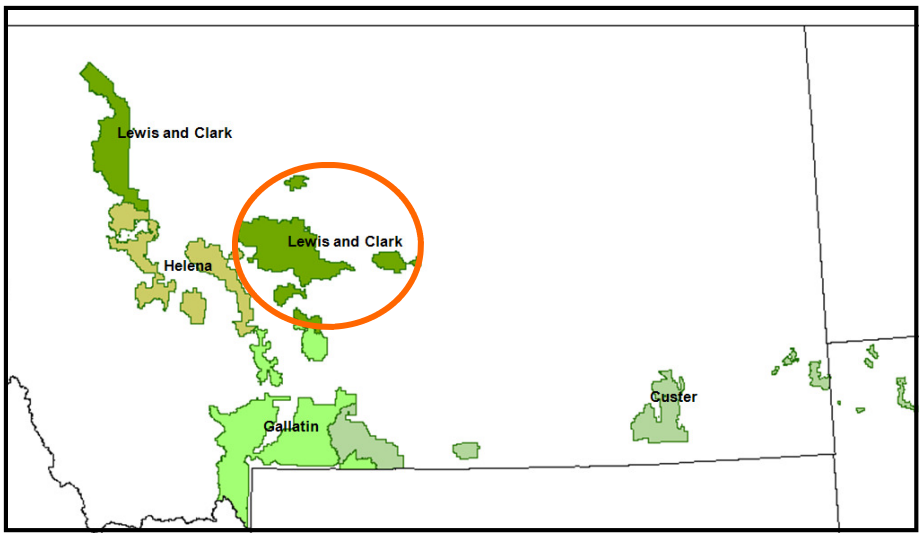
Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-24.9%	TCC 25-39.9%	TCC 40-59.9%	TCC >= 60%	Grand Total
	TCC 10-24.9%	5	2	3		10
	TCC 25-39.9%	3	23	13	4	43
	TCC 40-59.9%	4	14	80	14	112
	TCC >= 60%		6	29	47	82
	Grand Total	12	45	125	65	247

Area Weighted Overall Accuracy = 70%

Class	Producer's Accuracy	User's Accuracy
TCC 10-24.9%	NA	NA *
TCC 25-39.9%	51%	54%
TCC 40-59.9%	64%	71%
TCC >= 60%	72%	57%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class



Appendix C: R1-VMap Accuracy Assessment Error Matrices for the Lewis and Clark National Forest—Island Units

Lewis and Clark National Forest (Island Units) R1-VMap Accuracy Assessment Tables

Dominance Type 60 Accuracy Assessment Error Matrix

Mapped Classes	DOM60	Reference Data										
		ABLA	IMIX	PIAL	PICO	PIEN	PIFL2	PIPO	POTR5	PSME	TMIX	Grand Total
	ABLA	0	1									1
	IMIX		5		4	2	2	1		8	2	24
	PIAL			0			1				1	2
	PICO		3	1	36	1	2			1	6	50
	PIEN				1	0						1
	PIFL2						0					0
	PIPO		1		1			4		8		14
	POTR5				1				1			2
	PSME		12		3	1	2			31	1	50
	TMIX				1						2	3
	Grand Total	0	22	1	47	4	7	5	1	48	12	147

Area Weighted Overall Accuracy = 63%

Class	Producer's Accuracy	User's Accuracy
ABLA	NA	NA *
IMIX	NA	NA
PIAL	NA	NA
PICO	69%	56%
PIEN	NA	NA
PIFL2	NA	NA
PIPO	NA	NA
POTR5	NA	NA
PSME	65%	62%
TMIX	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Lewis and Clark National Forest (Island Units) R1-VMap Accuracy Assessment Tables (continued)

Dominance Type 40 Accuracy Assessment Error Matrix

Mapped Data	DOM40	Reference Data								
		MX-ABLA	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-PIPO	MX-POTR5	MX-PSME	Grand Total
	MX-ABLA			2					1	3
	MX-PIAL		1			1				2
	MX-PICO	1	3	42	4	2			4	56
	MX-PIEN			1	1					2
	MX-PIFL2			1	1	2			1	5
	MX-PIPO			1		1	5		9	16
	MX-POTR5			1				1		2
	MX-PSME			7	3	3	2		46	61
	Grand Total	1	4	55	9	9	7	1	61	147

Area Weighted Overall Accuracy = 85%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	NA	NA
MX-PIAL	NA	NA
MX-PICO	76%	75%
MX-PIEN	NA	NA
MX-PIFL2	NA	NA
MX-PIPO	NA	NA
MX-POTR5	NA	NA
MX-PSME	75%	75%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Lewis and Clark National Forest (Island Units) R1-VMap Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9"	3	7	9		19
	DBH 5-9.9"	7	45	9	3	64
	DBH 10-14.9"	2	11	37		50
	DBH >= 15"	1	2	7	2	12
	Grand Total	13	65	62	5	145

Area Weighted Overall Accuracy = 70%

Class	Producer's Accuracy	User's Accuracy
DBH 0-4.9"	NA	NA
DBH 5-9.9"	69%	70%
DBH 10-14.9"	60%	74%
DBH >= 15"	NA	NA

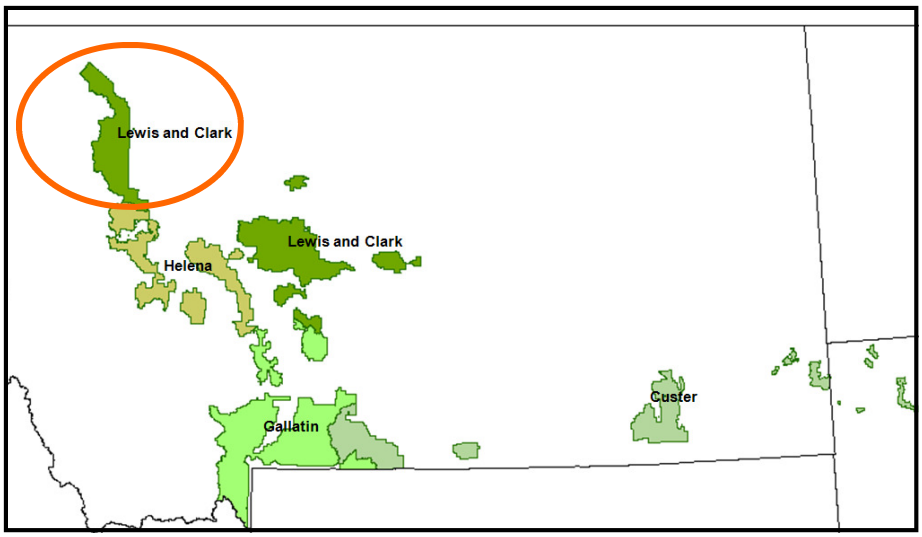
Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-	TCC 25-	TCC 40-	TCC >=	Grand
	TCC 10-24.9%	5	1	1		7
	TCC 25-39.9%	1	5	7	1	14
	TCC 40-59.9%	3	6	44	9	62
	TCC >= 60%		3	19	40	62
	Grand Total	9	15	71	50	145

Area Weighted Overall Accuracy = 74%

Class	Producer's Accuracy	User's Accuracy
TCC 10-24.9%	NA	NA *
TCC 25-39.9%	NA	NA
TCC 40-59.9%	62%	71%
TCC >= 60%	80%	65%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class



Appendix D: R1-VMap Accuracy Assessment Error Matrices for the Lewis and Clark National Forest—Rocky Mountain Front

Lewis and Clark National Forest (Rocky Mountain Front) R1-VMap Accuracy Assessment Tables

Dominance Type 60 Accuracy Assessment Error Matrix

Mapped Classes	DOM60	Reference Data									
		ABLA	IMIX	PIAL	PICO	PIEN	PIFL2	POTR5	PSME	TMIX	Grand Total
	ABLA				1						1
	IMIX	1	5	1	3	3			2	6	21
	PIAL			1							1
	PICO	6	6	1	18	3		1	4	8	47
	PIEN	1			3	1					5
	PIFL2						1			1	2
	POTR5							1			1
	PSME	2	1		5	2	1		3	1	15
	TMIX	1		1	1	1				5	9
	Grand Total	11	12	4	31	10	2	2	9	21	102

Area Weighted Overall Accuracy = 38%

Class	Producer's Accuracy	User's Accuracy
ABLA	NA	NA *
IMIX	NA	NA
PIAL	NA	NA
PICO	26%	38%
PIEN	NA	NA
PIFL2	NA	NA
PIPO	NA	NA
POTR5	NA	NA
PSME	NA	NA
TMIX	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Lewis and Clark National Forest (Rocky Mountain Front) R1-VMap Accuracy Assessment Tables (continued)

Dominance Type 40 Accuracy Assessment Error Matrix

Mapped Data	DOM40	Reference Data								
		IMIX	MX-ABLA	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-POTR5	MX-PSME	Grand Total
	IMIX	0								0
	MX-ABLA		1	1	1	2				5
	MX-PIAL			2		1				3
	MX-PICO	2	11	3	24	11	1	1	5	58
	MX-PIEN		1		4	2				7
	MX-PIFL2					1	1			2
	MX-POTR5							1		1
	MX-PSME	1	4	1	8	4	1		7	26
	Grand Total	3	17	7	37	21	3	2	12	102

Area Weighted Overall Accuracy = 43%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	NA	NA
MX-PIAL	NA	NA
MX-PICO	65%	41%
MX-PIEN	NA	NA
MX-PIFL2	NA	NA
MX-PIPO	NA	NA
MX-POTR5	NA	NA
MX-PSME	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Lewis and Clark National Forest (Rocky Mountain Front) R1-VMap Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9"	8	2			10
	DBH 5-9.9"	7	27	12		46
	DBH 10-14.9"	2	18	16	1	37
	DBH >= 15"	1	3	4	1	9
	Grand Total	18	50	32	2	102

Area Weighted Overall Accuracy = 58%

Class	Producer's Accuracy	User's Accuracy
DBH 0-4.9"	NA	NA
DBH 5-9.9"	54%	59%
DBH 10-14.9"	50%	43%
DBH >= 15"	NA	NA

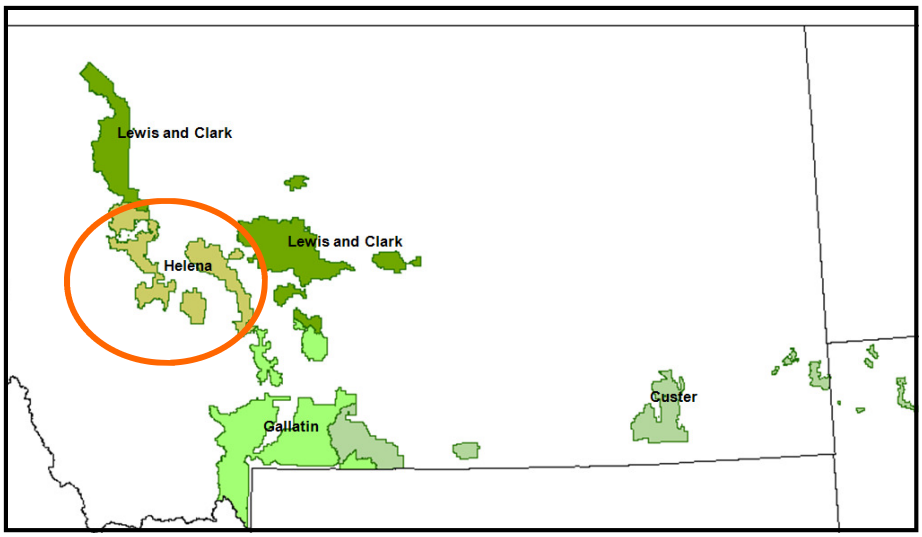
Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-24.9%	TCC 25-39.9%	TCC 40-59.9%	TCC >= 60%	Grand Total
	CTR 10-24.9%		1	2		3
	CTR 25-39.9%	2	18	6	3	29
	CTR 40-59.9%	1	8	36	5	50
	CTR >= 60%		3	10	7	20
	Grand Total	3	30	54	15	102

Area Weighted Overall Accuracy = 70%

Class	Producer's Accuracy	User's Accuracy
TCC 10-24.9%	NA	NA *
TCC 25-39.9%	60%	62%
TCC 40-59.9%	66%	72%
TCC >= 60%	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class



Appendix E: R1-VMap Accuracy Assessment Error Matrices for the Helena National Forest

Helena National Forest R1-VMap Accuracy Assessment Tables

Dominance Type 60 Accuracy Assessment Error Matrix

Mapped Classes	Dom Mid 60	Reference Data									
		IMIX	ABLA	PIAL	PICO	PIFL2	PIPO	POTR5	PSME	TMIX	Grand Total
	IMIX		9	2	5			1	3	1	21
	ABLA										0
	PIAL										0
	PICO	1	3	3	33	1	1		7		49
	PIFL2										0
	PIPO						4		1		5
	POTR5										0
	PSME		7	1	8				26	1	43
	TMIX				2						2
	Grand Total	1	19	6	48	1	5	1	37	2	120

Area Weighted Overall Accuracy = 72%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
ABLA	NA	NA
PIAL	NA	NA
PICO	69%	67%
PIFL2	NA	NA
PIPO	NA	NA
POTR5	NA	NA
PSME	70%	60%
TMIX	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Helena National Forest R1-VMap Accuracy Assessment Tables

Dominance Type 40 Accuracy Assessment Error Matrix

Mapped Data	Dom Mid 40	Reference Data								
		IMIX	MX-ABLA	MX-JUOC	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-PSME	Grand Total
	IMIX	0	2		2	1	1		1	7
	MX-ABLA		3		8	4	2		2	19
	MX-JUOC			0					1	1
	MX-PIAL		4		28	5	1			38
	MX-PICO		1		4	30	11		14	60
	MX-PIEN		3		4	4	12		6	29
	MX-PIFL2							1	1	2
	MX-PSME		1			7	1		48	57
	Grand Total	N/A	14	N/A	46	51	28	1	73	213

Area Weighted Overall Accuracy = 89%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	NA	NA
MX-PIAL	NA	NA
MX-PICO	61%	74%
MX-PIFL2	NA	NA
MX-PIPO	NA	NA
MX-POTR5	NA	NA
MX-PSME	66%	84%
TMIX	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Helena National Forest R1-VMap Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9”	0				0
	DBH 5-9.9”		45	2	5	52
	DBH 10-14.9”	7	16	30	4	57
	DBH >= 15”	1	6	1	6	14
	Grand Total	8	67	33	15	123

Area Weighted Overall Accuracy = 76%

Class	Producer’s Accuracy	User’s Accuracy
DBH 0-4.9”	NA	NA
DBH 5-9.9”	67%	87%
DBH 10-14.9”	91%	53%
DBH >= 15”	NA	NA

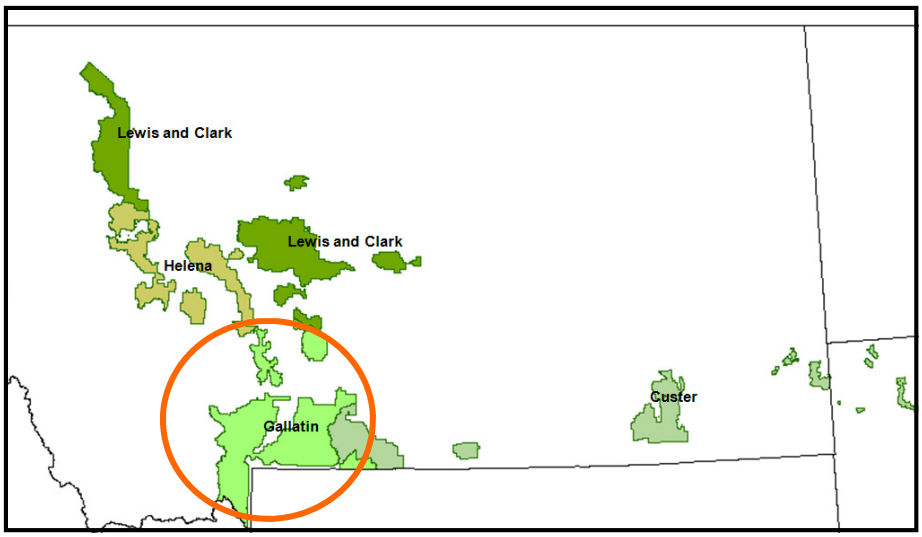
Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-24.9%	TCC 25-39.9%	TCC 40-59.9%	TCC >= 60%	Grand Total
	TCC 10-24.9%	10	2	3	1	16
	TCC 25-39.9%		10	5	9	24
	TCC 40-59.9%	2	3	24	16	45
	TCC >= 60%	2	2	1	33	38
	Grand Total	14	17	33	59	123

Area Weighted Overall Accuracy = 67%

Class	Producer’s Accuracy	User’s Accuracy
TCC 10-24.9%	NA	NA *
TCC 25-39.9%	NA	NA
TCC 40-59.9%	73%	53%
TCC >= 60%	56%	87%

* Producer’s and User’s accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class



Appendix F: R1-VMap Accuracy Assessment Error Matrices for Gallatin National Forest

Gallatin National Forest R1-VMap Accuracy Assessment Tables

Dominance Mid 60 Assessment Error Matrix

Mapped Classes	Dom Mid 60	Reference Data									
		ABLA	IMIX	JUNIP	PIAL	PICO	PIEN	PIFL2	PSME	TMIX	Grand
	ABLA	1				2	1			6	10
	IMIX	1	16		6	8	1		10	16	58
	JUNIPER			0							0
	PIAL		2		8		1			5	16
	PICO	1	3		1	14	1		13	6	39
	PIEN		3							1	4
	PIFL2										0
	PSME		19	1		3	1	1	23	9	57
	TMIX		8			2	1		1	17	29
	Grand Total	3	51	1	15	29	6	1	47	60	213

Weighted Area Overall Accuracy = 41%

Class	Producer's Accuracy	User's Accuracy
ABLA	NA	NA *
IMIX	31%	27%
JUNIPER	NA	NA
PIAL	NA	NA
PICO	48%	36%
PIEN	NA	NA
PIFL2	NA	NA
PSME	60%	49%
TMIX	28%	58%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Gallatin National Forest R1-VMap Accuracy Assessment Tables

Dominance Mid 40 Assessment Error Matrix

Mapped Classes	Dom Mid 40	Reference Data								
		IMIX	MX-ABLA	MX-JUNIP	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-PSME	Grand Total
	IMIX	0				1				1
	MX-ABLA	1	2		6	9	5		1	24
	MX-JUNIP			0						0
	MX-PIAL	1	5		21		1			28
	MX-PICO		6		7	27	7		21	68
	MX-PIEN	1	4		2	7	5		1	20
	MX-PIFL2							0		0
	MX-PSME	2	2	1	2	17	11	2	35	72
	Grand Total	5	19	1	38	61	29	2	58	213

Weighted Area Overall Accuracy = 47%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	NA	NA
MX-JUNIP	NA	NA
MX-PIAL	55%	75%
MX-PICO	44%	40%
MX-PIEN	NA	NA
MX-PIFL2	NA	NA
MX-PSME	60%	49%

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Gallatin National Forest R1-VMap Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9"	6	4	2		12
	DBH 5-9.9"		21	7	5	33
	DBH 10-14.9"	1	29	102	10	142
	DBH >= 15"		5	17	11	33
	Grand Total	7	59	128	26	220

Area Weighted Overall Accuracy = 78%

Class	Producer's Accuracy	User's Accuracy
DBH 0-4.9"	NA	NA
DBH 5-9.9"	36%	64%
DBH 10-14.9"	80%	72%
DBH >= 15"	NA	33%

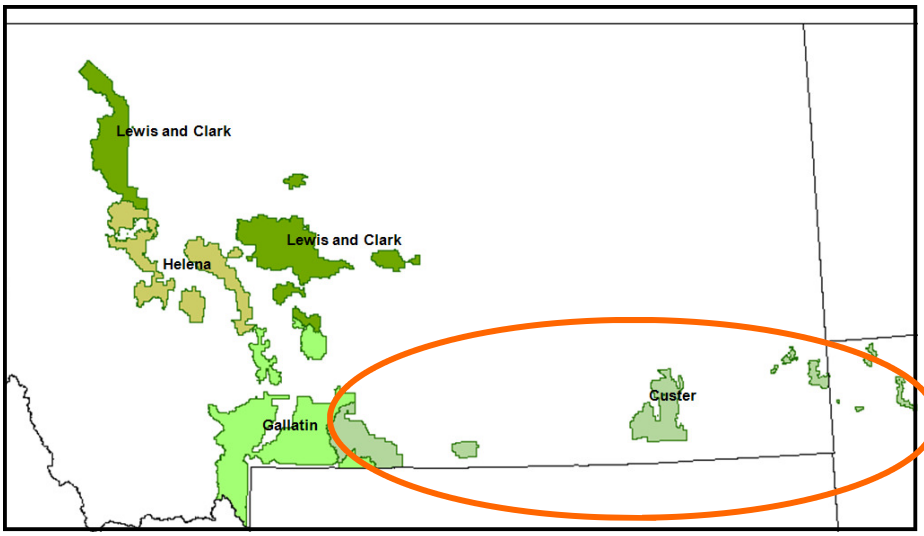
Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-24.9%	TCC 25-39.9%	TCC 40-59.9%	TCC >= 60%	Grand Total
	TCC 10-24.9%	33	5	3		41
	TCC 25-39.9%	8	40	15	4	67
	TCC 40-59.9%	3	11	75	8	97
	TCC >= 60%			5	10	15
	Grand Total	44	56	98	22	220

Area Weighted Overall Accuracy = 77%

Class	Producer's Accuracy	User's Accuracy
TCC 10-24.9%	75%	80%
TCC 25-39.9%	72%	60%
TCC 40-59.9%	76%	77%
TCC >= 60%	NA	NA *

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class



Appendix G: R1-VMap Accuracy Assessment Error Matrices for the Custer National Forest

Custer National Forest R1-VMap Accuracy Assessment Tables

Dominance Type 60 Accuracy Assessment Error Matrix

Mapped Classes \	Dom Mid 60	Reference Data											
		ABLA	IMIX	JUOC	PIAL	PICO	PIEN	PIFL2	PIPO	POTR5	PSME	TMIX	Grand Total
	ABLA	0											0
	IMIX		6		2	2	2				1	6	19
	JUOC			0									0
	PIAL	1			1	1	1						4
	PICO		1			6					1		8
	PIEN				1		0						1
	PIFL2		1					0					1
	PIPO			1					27				28
	POTR5									1			1
	PSME		3			1	1				2		7
	TMIX				1							4	5
	Grand Total	1	11	1	5	10	4	0	27	1	4	10	74

Area Weighted Overall Accuracy = 74%

Class	Producer's Accuracy	User's Accuracy
ABLA	NA	NA *
IMIX	NA	NA
JUOC	NA	NA
PIAL	NA	NA
PICO	NA	NA
PIEN	NA	NA
PIFL2	NA	NA
PIPO	100%	96%
POTR5	NA	NA
PSME	NA	NA
TMIX	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Custer National Forest R1-VMap Accuracy Assessment Tables

Dominance Mid 40 Assessment Error Matrix

Mapped Classes	Dom Mid 40	Reference Data										
		IMIX	MX-ABLA	MX-JUNIP	MX-PIAL	MX-PICO	MX-PIEN	MX-PIFL2	MX-PIPO	MX-POTR5	MX-PSME	Grand Total
	IMIX					1						1
	MX-ABLA				1		4					5
	MX-JUNIP					1						1
	MX-PIAL	1	3		4	1	2					11
	MX-PICO				2	7	1				2	12
	MX-PIEN		1		1	1						3
	MX-PIFL2	1						1				2
	MX-PIPO			1					27			28
	MX-POTR5									1		1
	MX-PSME				1	2	2				6	11
	Grand Total	2	4	1	9	13	9	1	27	1	8	75

Weighted Area Overall Accuracy = 71%

Class	Producer's Accuracy	User's Accuracy
IMIX	NA	NA *
MX-ABLA	NA	NA
MX-JUNIP	NA	NA
MX-PIAL	NA	NA
MX-PICO	NA	NA
MX-PIEN	NA	NA
MX-PIFL2	NA	NA
MX-PIPO	100%	96%
MX-POTR5	NA	NA
MX-PSME	NA	NA

* Producer's and User's accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Custer National Forest R1-VMap Accuracy Assessment Tables (continued)

Tree Size Accuracy Assessment Error Matrix

Mapped Data	Tree Size	Reference Data				
		DBH 0-4.9"	DBH 5-9.9"	DBH 10-14.9"	DBH >= 15"	Grand Total
	DBH 0-4.9”	2	2	2		6
	DBH 5-9.9”	2	9	9		20
	DBH 10-14.9”		8	31	3	42
	DBH >= 15”		2	4		6
	Grand Total	4	21	46	3	74

Area Weighted Overall Accuracy = 72%

Class	Producer’s Accuracy	User’s Accuracy
DBH 0-4.9”	NA	NA *
DBH 5-9.9”	NA	NA
DBH 10-14.9”	67%	74%
DBH >= 15”	NA	NA

Tree Canopy Cover Error Matrix

Mapped Data	Tree Canopy Cover	Reference Data				
		TCC 10-24.9%	TCC 25-39.9%	TCC 40-59.9%	TCC >= 60%	Grand Total
	TCC 10-24.9%	11				11
	TCC 25-39.9%	9	13	2	1	25
	TCC 40-59.9%	4	3	16	3	26
	TCC >= 60%	1		5	6	12
	Grand Total	25	16	23	10	74

Area Weighted Overall Accuracy = 63%

Class	Producer’s Accuracy	User’s Accuracy
TCC 10-24.9%	NA	NA
TCC 25-39.9%	NA	NA
TCC 40-59.9%	NA	NA
TCC >= 60%	NA	NA

* Producer’s and User’s accuracies are not applicable (NA) if the assessment contains less than 30 samples for that class

Appendix H: Tree, Non-tree Accuracy Assessment and other Non-Forest Cross Validation

Eastside R1-VMap Lifeform (Tree, Non-tree) Accuracy Assessment

Mapped Data	Tree Size	Reference Data		
		Non-tree	Tree	Grand Total
	Non-tree	253	26	279
	Tree	96	662	758
	Grand Total	349	688	1037

Overall Accuracy = 88%

Class	Producer's Accuracy	User's Accuracy
Non-tree	72%	91%%
Tree	96%	87%

Helena National Forest Lifeform (Tree, Non-tree) Accuracy Assessment

Mapped Data	Tree Size	Reference Data		
		Non-tree	Tree	Grand Total
	Non-tree	19	3	22
	Tree	14	123	137
	Grand Total	33	126	159

Overall Accuracy = 89%

Class	Producer's Accuracy	User's Accuracy
Non-tree	58%	86%
Tree	97%	90%

Lewis and Clark National Forest Lifeform (Tree, Non-tree) Accuracy Assessment

Mapped Data	Tree Size	Reference Data		
		Non-tree	Tree	Grand Total
	Non-tree	52	15	67
	Tree	29	248	277
	Grand Total	81	263	344

Overall Accuracy = 87%

Class	Producer's Accuracy	User's Accuracy
Non-tree	64%	78%
Tree	94%	90%

Gallatin National Forest Lifeform (Tree, Non-tree) Accuracy Assessment

Mapped Data	Tree Size	Reference Data		
		Non-tree	Tree	Grand Total
	Non-tree	75	3	78
	Tree	29	220	249
	Grand Total	104	223	327

Overall Accuracy = 90%

Class	Producer's Accuracy	User's Accuracy
Non-tree	72%	96%%
Tree	99%	88%

Custer National Forest Lifeform (Tree, Non-tree) Accuracy Assessment

Mapped Data	Tree Size	Reference Data		
		Non-tree	Tree	Grand Total
	Non-tree	107	5	112
	Tree	19	75	94
	Grand Total	126	80	206

Overall Accuracy = 88%

Class	Producer's Accuracy	User's Accuracy
Non-tree	85%	96%
Tree	94%	80%

Cross Validation Assessment—Nonforest Grass (all eastsideR1-VMap except Custer NF)

Map	Mapped Grass Class	Reference data		
		Single stem	bunch	Grand Total
	Grass-single stem	33	13	46
	Grass-bunch	2	12	14
	Grand Total	35	25	60

Overall Accuracy 75%

Class	Producer's Accuracy	User's Accuracy
Grass–Single Stem,	94%	72%
Gras-Bunch	48%	86%

Cross Validation Assessment—Nonforest Litter (all eastsideR1-VMap except Custer NF)

Mapped Data	Litter class	Reference Data			
		0-59.9%	60-89.9%	90% >	Grand Total
	0-59.9%	17	3	1	21
	60-89.9%	3	10	2	15
	90% >	7	13	26	46
	Grand Total	27	26	29	82

Overall Accuracy = 65%

Class	Producer's Accuracy	User's Accuracy
0-59.9%,	63%	81%
60-89.9%	38%	67%
90% >	89%	57%