MELCD LAND COVER ACCURACY

REPORT

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Prepared for:

State of Maine

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1 Overview

1.1 Introduction

This report presents the results of the Maine Land Cover Map (MeLCD 2004). The document reviews briefly how the map was created and then presents more information about how the accuracy assessment was performed including a discussion of where major sources of confusion were found and possible sources of this confusion.

1.2 Creation of Map

The land cover map assessed in this document was primarily derived from Landsat Thematic Mapper 5 and 7 imagery, from the years 1999-2001. This imagery constitutes the basis for the National Land Cover Dataset (NLCD 2001) and the NOAA Coastal Change Analysis Program (C-CAP). This land cover map was refined to the State of Maine requirements using SPOT 5 panchromatic imagery from 2004. The Landsat imagery used was for three seasons: early spring (leaf-off), summer, and early fall (senescence) and was collected with a spatial resolution of 30 m. The SPOT 5 panchromatic imagery was collected at a spatial resolution of 5 m during the spring and summer months of 2004. The map was developed in two distinct stages, the first stage was the development of a state wide land cover data set consistent with the National Oceanic & Atmospheric Administration's (NOAA) Coastal Change and Analysis Program (C-CAP) land cover map. The second stage was:

a) the update to 2004 conditions
b) a refinement of the classification system to Maine specific classes (See Table 2 to see this refined classification scheme, and
c) a refinement of the spatial boundaries to create a polygon map based on 5 m imagery.

Image analysis techniques used in production of the map were a combination of supervised classification using Classification and Regression Tree (CART) algorithms and spatial modeling. The use of three Landsat image dates provided the ability to discriminate specific elements of the landscape. For example; the spring imagery was useful for the classification of wetlands and the separation of conifers and broadleaf species and the fall imagery was useful for the discrimination of broadleaf species. After the creation of the NOAA C-CAP base map, Sanborn used image segmentation to refine the spatial boundaries of the land cover classes, using a merge of the Landsat leaf on imagery and the SPOT 5 imagery. The segments produced by this process were labeled using automated methods to build the final Maine land cover dataset (MeLCD). After the completion of the classification, the map was extensively reviewed by Sanborn analysts and specific classes were modeled and edited by hand to remove class confusion.

1.3 Collection of data for the accuracy database

The MeLCD accuracy database was assembled through a combination of photo interpretation and field verified ground visits. The final accuracy database consists of a total of 1671 points. Table 1 below shows the break out of how the accuracy assessment database was compiled.

Point Type	Number of Points
Sanborn Supplied Field Sites	315
State of Maine Supplied Field Sites	190
Sanborn Photointerpreted Sites	390
State of Maine Photointerpreted Sites	776
Photointerpreted Site Total	*1166*
Field Site Total	*505*
Accuracy Site Total	**1671**

Table 1: MeLCD accuracy database distribution by source of collection.

Initially, approximately 1500 reference data sample points were selected at random in order to assist the State of Maine field crews in selecting field sites and destination planning. Field sites were visited by the State of Maine field crews in the late summer of 2005. Both photointerpreted and field sites were checked to ensure that each represented a homogenous feature on the SPOT imagery so that the points conformed to the MeLCD MMU requirements. The minimum mapping unit (MMU) used for the Accuracy Assessment refers to the requirement that an Accuracy Assessment point must fall in the center of a 0.89 acre area that consists of one and only one cover type. If these criteria are not met it will result in confusion/error caused by positional/spatial accuracy of the map rather than the thematic accuracy of the map.

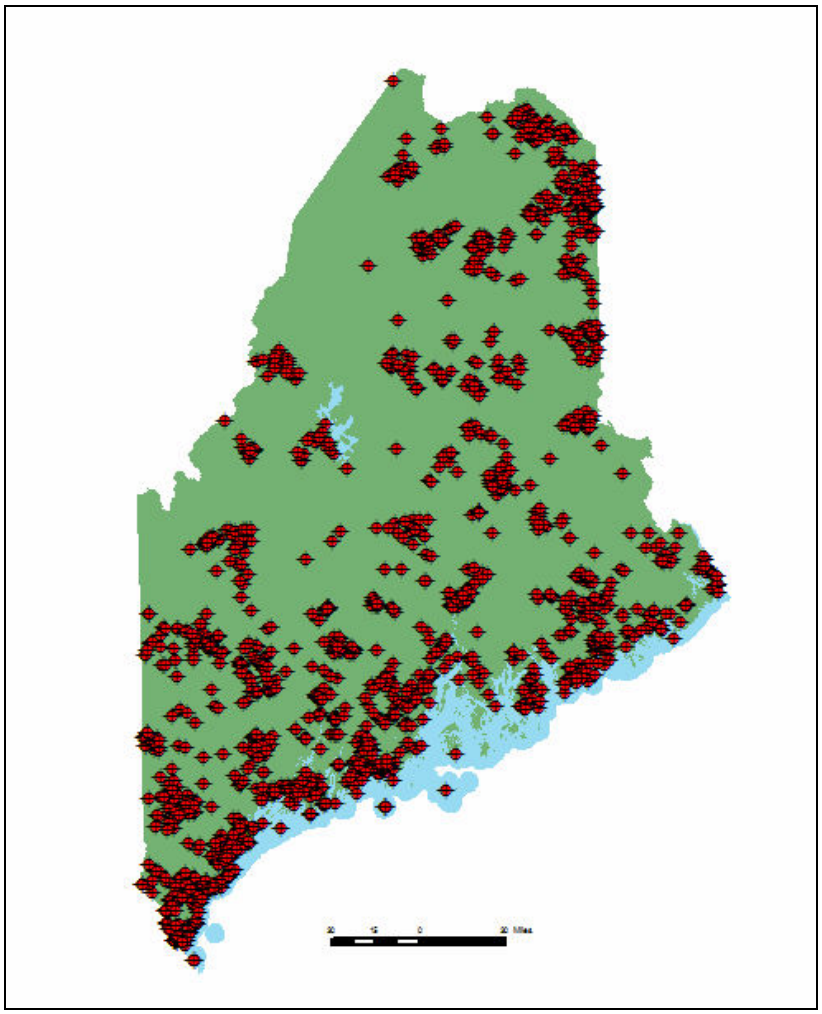

Figure 1: Spatial distribution of MeLCD accuracy sites.

The use of fuzzy accuracy assessment methodologies are considered to be a necessary part of accuracy assessment or any sort of categorical interpretation (Congalton and Green, 1999). The MeLCD classification scheme was designed to be mutually exclusive, such that a given feature or area can be classified into one and only one class, but labeling of the ground features into one class can be difficult to make a positive determination from aerial photography, and occasionally from the ground as well. Gopal and Woodcock (1994) state that "The assumption underlying fuzzy set theory is that the transition from membership to non-membership is seldom a step function". Therefore, while a 100% Alder/Willow wetland can be easily labeled Shrub wetland and a 100% Cattail wetland can be called Emergent Wetland, a 49% shrub and 51% emergent wetland would be difficult to label definitively (Congalton and Green, 1999), thus the need for fuzzy interpretations. In addition, in the case of the Maine classification system, the same current status on the ground could have resulted from different causes, and thus be classified differently in the Maine classification system. An example of this is the Heavy Cut class. An observer unaware of previous management could classify what looked like a shrub/scrub area into shrub/scrub. However that area could also be labeled as forest regeneration (based on a significant increase in canopy (1995 – 2001)) or heavy cut (based on significant decrease in canopy (1995-2001)). Unless the observer verified the

previous conditions, this call would need to have those options for a correct call based on observations from previous imagery. Thus the need for a fuzzy accuracy assessment is pivotal to the true understanding of the accuracy of the map and its confusion.

Fuzzy interpretations were made and added to the database when warranted and agreed to by the State of Maine, i.e. when the interpretations from the DOQQs were ambiguous. 14% of the interpretations, or 237 out of 1671. If any of the fuzzy accuracy assessment calls matched the map, then that sample would be considered a positive match. This fuzzy accuracy assessment methodology is represented in the error matrices shown in this report.

The use of the error or confusion matrix, allows the user of the map to understand the individual map accuracies of each land cover class which are plainly described along with errors of omission (errors of exclusion) and commission (errors of inclusion) (Congalton and Green, 1999). Additionally, per class accuracies are stated as a User's and Producer's percentage. User's accuracy is defined as the proportion of pixels assigned to a class that are correctly classified. The producer's accuracy is the proportion of the land in each class was correctly identified. For example, the producer's accuracy of the Pasture/Hay is reported as 75.4% while its user's accuracy is reported as 66.7%. Meaning that although 3 times in 4 the map correctly identifies Pasture/Hay, only 2 times in 3 will the area on the map that is mapped as Pasture/Hay actually be Pasture/Hay on the ground. The other 1 out of 3 times it would probably be cultivated crops or grassland/herbaceous.

It also must be noted that observations on the clear cut class (cut between 2001 – 2004) and forest regeneration class can not be made due to the lack of sufficient number of reference points to predict the class's accuracy with a reasonable degree of certainty. It is generally accepted that a minimum number of 30 points per class are needed to reliably predict the accuracy of any particular class. The low number of samples for these classes is due to either very few areas of that particular class exist, or that areas of the particular class were geographically clustered in a small area and not distributed over the state. While the accuracies for the above classes can not be predicted with certainty, their reference data are still reported as a factor in the maps overall accuracy. The error matrix is summarized in Table 2.

	Developed, High Intensity	Developed, Medium Intensity	Developed, Low Intensity	Developed, Open Space	Cultivated Crops	Pasture/Hay	Grassland/Herbaceous	Deciduous Forest	Evergreen Forest	Mixed Forest	Scrub/Shrub	Wetland Forest	Wetlands	Roads - Runway (Temp Class)	Unconsolidated Shore	Bare Land	Open Water	Blueberry Fields	Clear-Cut (Temp for 121)	Light Partial Cut	Heavy Partial Cut	Forest Regeneration	Alpine	Producer's Accuracies Totals	Producer's Accuracies Percentage	(User + Producer) / 2
Developed, High Intensity	**79**	2	3	1	1				1					1		4					1			79/93	84.9%	84.5%
Developed, Medium Intensity		**6**	3	7										1										60/71	84.5%	79.3%
Developed, Low Intensity	*3*	*7*	**37**	*7*	*1*								*1*	*1*						*1*		*1*		37/59	62.7%	67.6%
Developed, Open Space	2	3	2	**78**	1	3	1			1				1										78/92	84.8%	81.8%
Cultivated Crops	1		2		**89**	11	1						1											89/105	84.8%	78.3%
Pasture/Hay			1	2	7	**52**	3	1								1		1		1				52/69	75.4%	71.1%
Grassland/Herbaceous		*2*			*10*	*8*	***14***				*4*													14/38	36.8%	44.4%
Deciduous Forest				1				**53**	2	19	1									4				53/80	66.3%	69.5%
Evergreen Forest									**78**	14														78/92	84.8%	74.9%
Mixed Forest				*1*	*1*	*1*		*9*	*15*	***106***			*1*							*2*		*1*		106/137	77.4%	71.4%
Scrub/Shrub				1	2	1	1	1	1	4	**4**	3				1				3	1			40/59	67.8%	69.0%
Wetland Forest					1				5	3		**48**	1		1					2	2			48/63	76.2%	70.6%
Wetlands			1	1	1		4	1	3	5		23	**18**	3	18	1	4			3	2			180/250	72.0%	84.2%
Roads - Runway (Temp Class)	*6*					*1*			*2*	*1*				***34***								*1*		34/45	75.6%	79.3%
Unconsolidated Shore	*1*	*2*	*1*						*2*	*1*			*3*		***48***		*5*							48/63	76.2%	72.4%
Bare Land	*2*	*5*			*7*	*1*					*2*					***49***		*2*	*1*	*6*	*9*		*3*	49/87	56.3%	71.9%
Open Water															3		**66**							66/69	95.7%	91.9%
Blueberry Fields					*1*		*1*	*3*			*4*							***55***		*1*				55/65	84.6%	89.7%
Clear-Cut (Temp for 121)								*1*												*1*				NA	NA	NA
Light Partial Cut			*1*					*3*	*2*	*1*	*2*								*2*	***15***	*3*			15/29	51.7%	43.7%
Heavy Partial Cut					*2*			*1*	*2*	*2*	*1*									*3*	***46***			46/57	80.7%	76.3%
Forest Regeneration									*1*	*3*	*2*								***1***			***8***		8/15	53.3%	57.4%
Alpine							*2*		*6*	*2*	*1*											*2*	***18***	18/31	58.1%	71.9%
User's Accuracies																										
Totals	79/94	60/81	37/51	78/99	89/124	52/78	14/27	53/73	78/120	106/162	40/57	48/74	180/187	34/41	48/70	49/56	66/75	55/58	NA	15/42	46/64	8/13	18/21			
Percentage	84.0%	74.1%	72.5%	78.8%	71.8%	66.7%	51.9%	72.6%	65.0%	65.4%	70.2%	64.9%	96.3%	82.9%	68.6%	87.5%	88.0%	94.8%	NA	35.7%	71.9%	61.5%	85.7%	***Overall Accuracies***	***1253/1671***	***75.0%***

Table 2: Error Matrix for all collected accuracy points. The Kappa statistic takes into account the probability that classes will be mapped correctly purely by chance. Clearcut and forest regeneration classes do not have a sufficient number of reference points to predict accuracy with any real certainty.

2 Error Matrix Observations

This section reviews the error matrix and explains the definition of classes and discusses why errors have been found in the map, what are their causes and looks at their significance from a map user perspective. The focus for this section is on classes that are lower than 70% accurate in the map.

To help understand the significance of these errors it is helpful to look at the area distribution of land cover across the state. Table 3 shows this land cover distribution.

	Class Area (sq.mi)	Area as Percentage
Developed, High Intensity	99.2	0.28%
Developed, Medium Intensity	95.4	0.27%
Developed, Low Intensity	169.1	0.48%
Developed, Open Space	175.1	0.50%
Cultivated Crops	742.8	2.11%
Pasture/Hay	644.8	1.83%
Grassland/Herbaceous	57.9	0.16%
Deciduous Forest	4,726.4	13.42%
Evergreen Forest	6,617.6	18.79%
Mixed Forest	8,894.1	25.26%
Scrub/Shrub	1,182.5	3.36%
Wetland Forest	1,560.8	4.43%
Wetlands	815.9	2.32%
Roads - Runway	433.2	1.23%
Unconsolidated Shore	225.3	0.64%
Bare Land	41.1	0.12%
Open Water	4,209.1	11.95%
Blueberry Field	100.9	0.29%
Clear-Cut	163.9	0.47%
Light Partial Cut	2,284.2	6.49%
Heavy Partial Cut	1,199.3	3.41%
Forest Regeneration	767.7	2.18%
Alpine Tundra	10.3	0.03%
Total	**35,216.5**	**100.00%**

Table 3: Distribution of land cover across the State of Maine

3 Notes On Problematic Classes

3.1 Grassland

"Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. Characteristic land cover features: Prairies, meadows, fallow fields, clear-cuts with natural grasses, and undeveloped lands with naturally occurring grasses."

User's Accuracy – 51.9% (14/27)
Producer's Accuracy – 36.8% (14/38)

The segmentation labeling routine had difficulty extracting grassland features for several reasons:
Class rarity: natural grasslands do not occur within Maine as grassland is typically either a transition cover type from harvested forest back to forest or is actively managed as part of a homestead, and is easily confused with pasture (when there is livestock) and open space developed (when associated with buildings). Grassland only occupies 0.16% of the Maine landscape.
Difficult to extract from the 30m spectral data: Grassland areas from the base NOAA C-CAP land cover were mapped with a producer's accuracy of 65% and a user's accuracy of 80%. As with the MeLCD land cover map, the major sources of confusion were between crop, pasture, and shrubland. When these grassland areas are transitioned into the MeLCD classification scheme, many areas will convert to from grassland to heavy cut. This is due to the classification scheme accounting for canopy loss between 1995 and 2001. The remaining areas are small managed grasslands or natural areas that are scattered within agricultural areas and are easily masked by the confusion with agriculture.
Small average size of grassland samples: Grassland in Maine is also found in relatively small extents. The heavy dependence on the information in the 30 m map for classification make the identification of small areas more problematic than with larger areas. The fact that so much of the grassland accuracy assessment sites fall into these small areas has weighted the accuracy assessment against this class.

3.2 Light Partial Cut

"This type is composed of forestland where less than 50% of the overstory canopy has been removed through harvesting. Harvesting may have occurred previously. May include improvement thinning, light shelterwood and light selection harvests. Forest loss must have occurred after 1995."

User's Accuracy – 35.7% (15/42)
Producer's Accuracy – 51.7% (15/29)
Errors associated with the canopy change map: The light partial cut class is based on a canopy difference assessment between the 2001 Landsat and 1995 Landsat databases. Error attributed to this class can be attributed to several factors. Examination of errors of commission reveal that the canopy difference

methodology was unable to estimate canopy loss between dates to a higher precision than ± 15%. While in general the estimate difference could highlight areas of canopy change, estimation of thematic divisions becomes unreliable near the difference threshold, i.e. 0% and 50%. Areas that have an actual 40% canopy reduction may classified into either light or heavy cut, because of variability in the canopy change estimate. Likewise an area of 15% canopy reduction may not be picked up as was the case in 6 points.
Errors associated with loss of canopy not related to forest harvest: Some canopy reduction was observed in the canopy change mask did not relate to canopy reduction by harvest. In some cases is related to wetland edges, and in some cases it related to expansion of mining.

3.3 Forest Regeneration

"Forested areas previously harvested that have begun to regenerate to forest are included in this type. Seedling to sapling sized trees are expected, possibly with some residual trees present. Species present will vary based on the original site composition, harvesting techniques and site disturbance, and the presence of advance regeneration at the time of harvesting. These sites will return to mature forests. Forest loss and subsequent re-growth must have occurred after 1995."

User's Accuracy – 61.5% (8/13)
Producer's Accuracy – 53.3% (8/15)

Too few accuracy points: The forest regeneration class is short five accuracy points to begin to reliably report the accuracy of the class. Given the additional five points, it may be likely that the class will surpass desired the 70% accuracy. Of note however is the significant increase in class accuracy when including a fuzzy call in the accuracy database. This is due to the uncertainty of he observer in the field in assessing canopy increase in 2004 during a time period between 1995 and 2001. Many points were interpreted as shrub land or forest but were identified as forest regeneration using photo interpretation analysis of the point using the Landsat database. This results in a large increase in accuracy between the deterministic reference database and the fuzzy database. This is generally the case for many points within the database. Analysis of the reference data set after its collection indicate that a proportion of the database needed to include a fuzzy call that in many cases could have superseded the primary call.

4 References

Congalton, R.G., Kass Green 1999. Assessing the accuracy of remotely sensed data: principles and practices. CRC Press

Gopal, S., Woodcock, C. 1994. Theory and methods for accuracy assessment of thematic maps using fuzzy sets. PERS. V60, N2, pp 181