National Park Service
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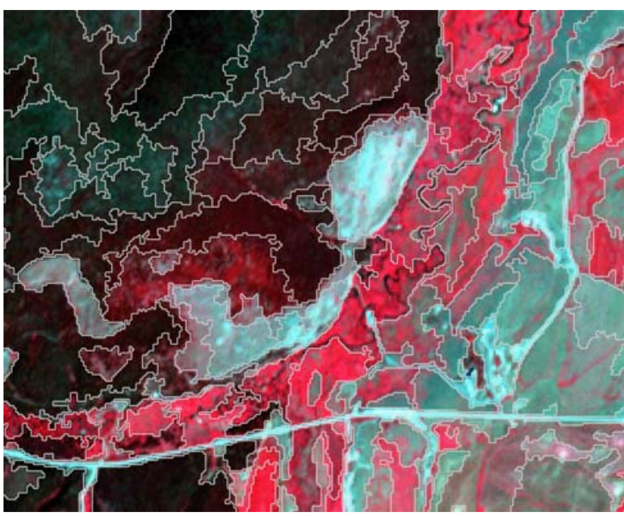
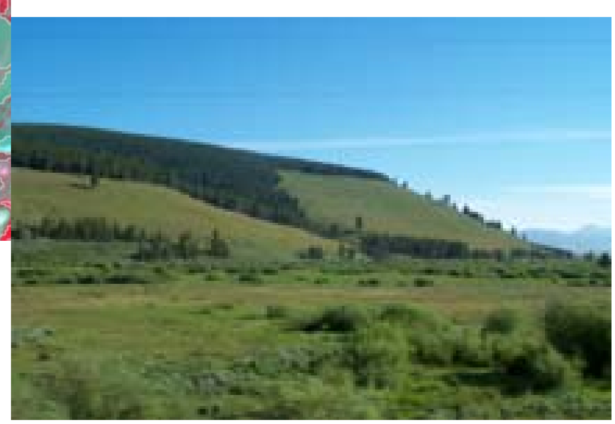
Moscow, Idaho

Land cover classifications for Big Hole National Battlefield, Whitman Mission National Historic Site, and Lake Roosevelt National Recreation Area using ASTER imagery

Natural Resource Technical Report





ON THE COVER
Mosaic of ASTER imagery, eCognition segmentation, and landscape photo at Big Hole National Battlefield.
Photo by Gina M. Wilson.

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Natural Resource Report

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September 2006

U.S. Department of the Interior
National Park Service
Upper Columbia Basin Office
Moscow, Idaho

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Please cite this publication as:

Wilson, G.M. 2006. Land cover classifications for Big Hole National Battlefield, Whitman Mission National Historic Site, and Lake Roosevelt National Recreation Area using ASTER imagery. Natural Resource Technical Report. National Park Service, Moscow, Idaho.

NPS D-XXX, September 2006

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Abstract

Information on the spatial distribution of land cover and its changes is desirable for many planning, management and monitoring programs at local, regional and national levels. In 2005 the National Park Service Upper Columbia Basin Network Inventory and Monitoring Program (UCBN) desired updated land cover information for three of their nine parks, Big Hole National Battlefield (BIHO), Whitman Mission National Historic Site (WHMI), and Lake Roosevelt National Recreation Area (LARO). In a collaborative effort with those parks, the University of Idaho, Landscape Dynamics Lab (LDL) conducted field data collection and image classification using the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and eCognition software. A total of 13 unique classes were mapped at BIHO, 14 classes at WHMI, and 12 classes at LARO with overall accuracies of 93.8%, 97%, and 89.5%, respectively. The results from this project demonstrate the ability to obtain cost-effective landcover classifications appropriate for long-term monitoring.

Acknowledgements

The success of this project would not be possible if not for the cooperation of Tim Fisher with BIHO, Roger Trick with WHMI and Jerald Weaver with LARO. We sincerely thank Leona Svancara, Scott MacDonald, Mike Russell and Blaine Krumpe for their assistance with data collection.

Introduction

In 2005 the National Park Service Upper Columbia Basin Network Inventory and Monitoring Program (UCBN) desired updated land cover information for three of their nine parks, Big Hole National Battlefield (BIHO), Whitman Mission National Historic Site (WHMI), and Lake Roosevelt National Recreation Area (LARO). In a collaborative effort with those parks, the University of Idaho, Landscape Dynamics Lab (LDL) conducted field data collection and image classification using the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER).

The UCBN identified the following goals for land cover classifications:

1. Determine the current (approximately year 2000) spatial distribution and size of land cover types within and surrounding UCBN parks at a thematic resolution most appropriate for long-term monitoring and management.
2. Identify, map and monitor changes in land cover pattern within and adjacent to UCBN parks.
3. Enable network staff and resource managers to assess land use impacts and make better informed resource management decisions.
4. Provide base-level support for various vital sign monitoring
5. Provide a cost effective product with resolution and accuracy standards similar to the NPS/USGS Vegetation Mapping Program (0.5 ha mmu, >80% accuracy/class).

Information on the spatial distribution of land cover and its changes is desirable for many planning, management and monitoring programs at local, regional and national levels. Land cover maps are readily available in different classification systems and scales throughout the world, but seldom at the required spatial detail and accuracy standards.

The standard pixel-based classification techniques such as maximum likelihood classification method have been extensively used in the thematic information extraction since the early beginnings of imagery classification. Pixel-based classification has mainly focused on the single pixel, not the object, which can lead to a variety of errors. For instance, it can be difficult to effectively extract land cover types when different land cover types bear similar spectral characteristics (e.g., willow and aspen) or the same land cover classification has different spectral responses (e.g., across an elevational gradient). Many pixel-based classifications produce a characteristic salt-and-pepper product.

Previously the LDL conducted a classification for the City of Rock National Reserve (CIRO) using ASTER data and a pixel-based hybrid classification (see Wilson 2005). While overall map accuracy was high (89%), confused signatures were still apparent (e.g., aspen and wet meadow grasses). Since that time, new technologies (e.g., eCognition) have been acquired by the LDL which provides different classification techniques (object-oriented, spatial-spectral approaches) that combine spectral information with spatial characteristics to improve classification accuracies (Carr 1996, Ryherd and Woodcock 1996, Arai 1993).

High spatial resolution data with fewer spectral bands in aerial photography and new high spatial satellite images can create classification problems due to greater spectral variation within a class and a greater degree of shadow (Laliberte et al. 2004). However, it does contain much information in the relationship between adjacent pixels, including texture and shape information, which allows for identification of individual objects as opposed to single pixels. Image segments are a way of summarizing information from a contiguous cluster of homogeneous pixels. Each image segment then becomes a unit of analysis for which a number of attributes can be measured. These attributes can include dozens of measures of spectral response, texture, shape, and location (Benz et al. 2004, Thomas et al. 2003). Ecologically, it is more appropriate to analyze objects as opposed to pixels because landscapes consist of patches that can be detected in the imagery with object-based analysis (Laliberte et al. 2004).

Methods

Study Areas

Big Hole National Battlefield is located in southwestern Montana, 16 km (10mi) east of the town of Wisdom on the North Fork of the Big Hole River (longitude 113°38'37"W, latitude 45°38'15"N). Historically this area was one of the sites of the Nez Perce War of 1877. The 265 hectare (655 acre) area is characterized by a Lodgepole pine forest with mixed conifer species including Douglas-fir and Ponderosa pine and sagebrush steppe containing Big sagebrush and Idaho fescue. Willow and various sedge species dominate the floodplain while the bench area is primarily grassland containing Idaho fescue and bluebunch wheat grass. The area in recent years has been attacked by insects and disease, however it should be noted that much of that activity has occurred outside the BIHO boundary. The elevation ranges from 1870m to 2010m.

Whitman Mission National Historic Site (WHMI) is located approximately seven miles (11.3 km) west of the city of Walla Walla, Washington (latitude 46º02′N, longitude 118º27′W) on the Walla Walla River. The 98.15 acre (39.75 ha) historic site is on a portion of the original land settled by Marcus and Narcissa Whitman, Presbyterian missionaries, in 1836. The area is characterized by intensively managed lawns, grasslands and sparse sagebrush on the hillsides, and floodplains.

Lake Roosevelt National Recreation Area (LARO) is located along the Columbia, Kettle, and Spokane Rivers in northeastern Washington. The recreation area surrounds the Franklin D. Roosevelt Lake created in 1942 with the construction of Grand Coulee Dam. The park encompasses approximately 81,000 acres with the majority being lake surface water. The northern portion of LARO contains mainly Ponderosa pine forest mixed with Douglas-fir, some Lodgepole pine and Grand fir. Grasslands, sagebrush steppe and agricultural lands dominate the area in the southern portion of LARO.

Surrounding lands were included in the mapping effort. Within the constraints of the satellite scene boundaries, blocks of approximately 16 km^2 and x km^2 were extracted and mapped for BIHO and WHMI, respectively and a buffer of approximately 2 km was developed and mapped for LARO. The total area mapped for each site was 1520 ha, 661 ha, and 142,968 ha for BIHO, WHMI, and LARO, respectively.

Data Collection

Lists of potential land cover types were developed for each park prior to field data collection. These lists were based on known species lists, extant classifications, UCBN long-term monitoring objectives, and park management needs. The lists of potential land cover types generally followed classifications from the state Gap Analysis Projects and Anderson Level II (Anderson et al. 1976) hierarchy with additional detail and separation in those classes where it was thought more information could be extracted from the imagery while still maintaining accuracy standards.

Field data was collected by UCBN and LDL personnel in July and August 2005 using ArcPad (ESRI, 2002) on handheld Windows CE based PC's with GPS receivers. Custom data entry forms were created within ArcPad for on-the-fly GIS data collection. Data was automatically usable within any ESRI GIS program. Plot locations were targeted to incorporate a broad variety of land cover types. Locations were found by walking through accessible portions within the park unit and observing areas of uniform vegetation at least $30m^2$ in size. Other samples sites were taken adjacent to the parks on existing roads. While accessibility within and around WHMI was good given the extensive road network surrounding the private lands, accessibility to lands surrounding BIHO was limited. At LARO, accessibility both inside and outside the park boundaries was limited due to private lands.

A total of 133 plots were sampled at BIHO, 133 plots at WHMI, and 263 plots at LARO. In addition, 57 polygons were sampled based on the 2002 aerial photography for LARO.

Imagery

The classification process was based on ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer) satellite imagery. The ASTER sensor obtains data across 14 spectral channels with a swath width of 60km (Rowan and Mars 2003) and a temporal resolution of 16 days (Abrams 2000). The sensor is comprised of three radiometers, each responsible for measuring different portions of the electromagnetic spectrum (Abrams 2000). The visible and near infrared (VNIR) radiometer collects data in three spectral channels between 0.52 – 0.86µm. The VNIR instrument is also equipped with a separate backward looking channel in the near infrared portion of the electromagnetic spectrum (channel 3B), inclined 27.60 from nadir, which provides stereo viewing capability (Abrams 2000). The thermal infrared (TIR) radiometer obtains data in four spectral channels between 8.125 – 11.65µm with a spatial resolution of 90m, and the short wavelength infrared (SWIR) radiometer obtains data across six spectral channels between 1.60 – 2.430µm with a spatial resolution of 30m (Figure 4).

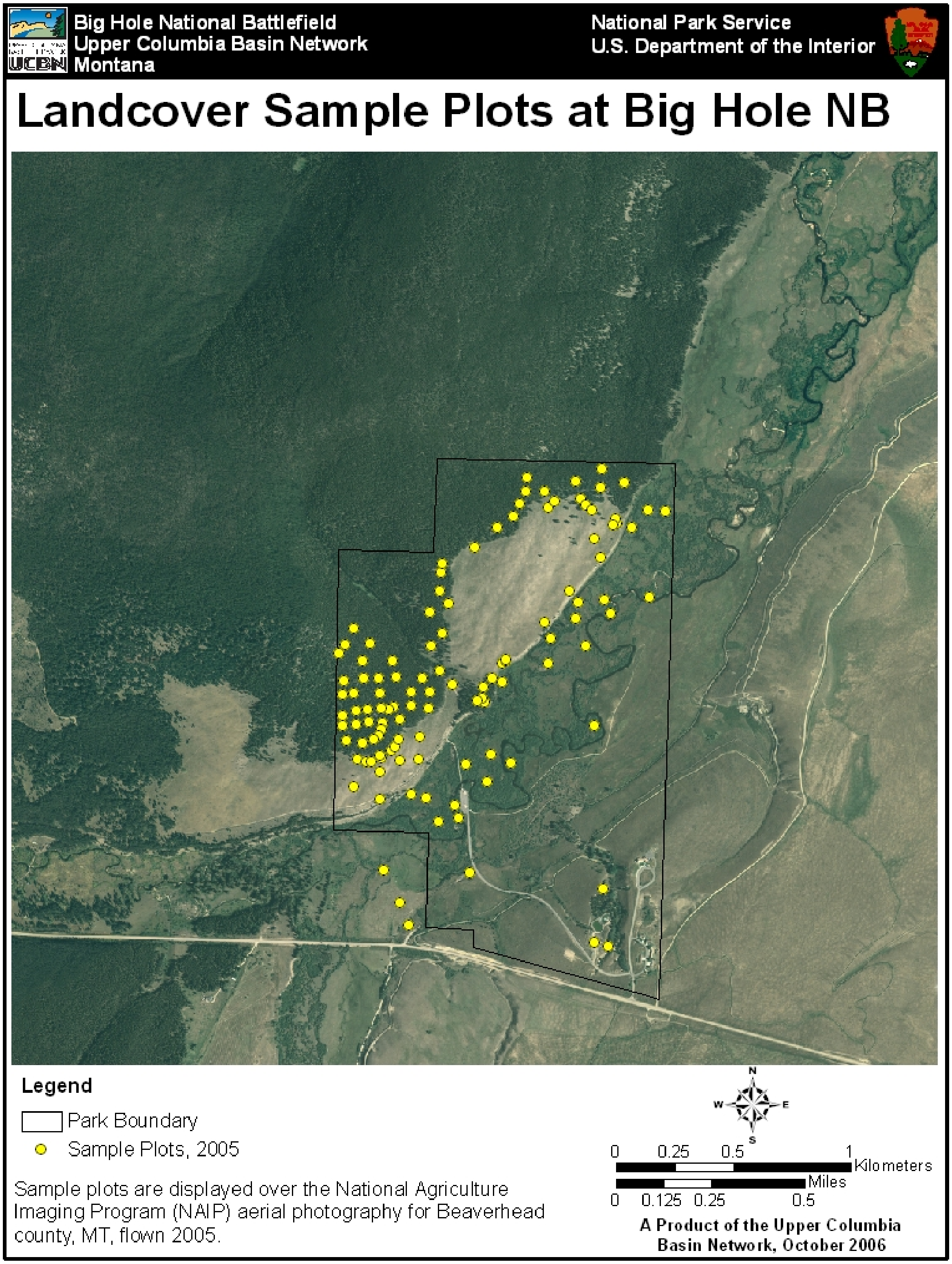

Figure 1. Landcover sample plots collected at Big Hole National Battlefield, 2005.

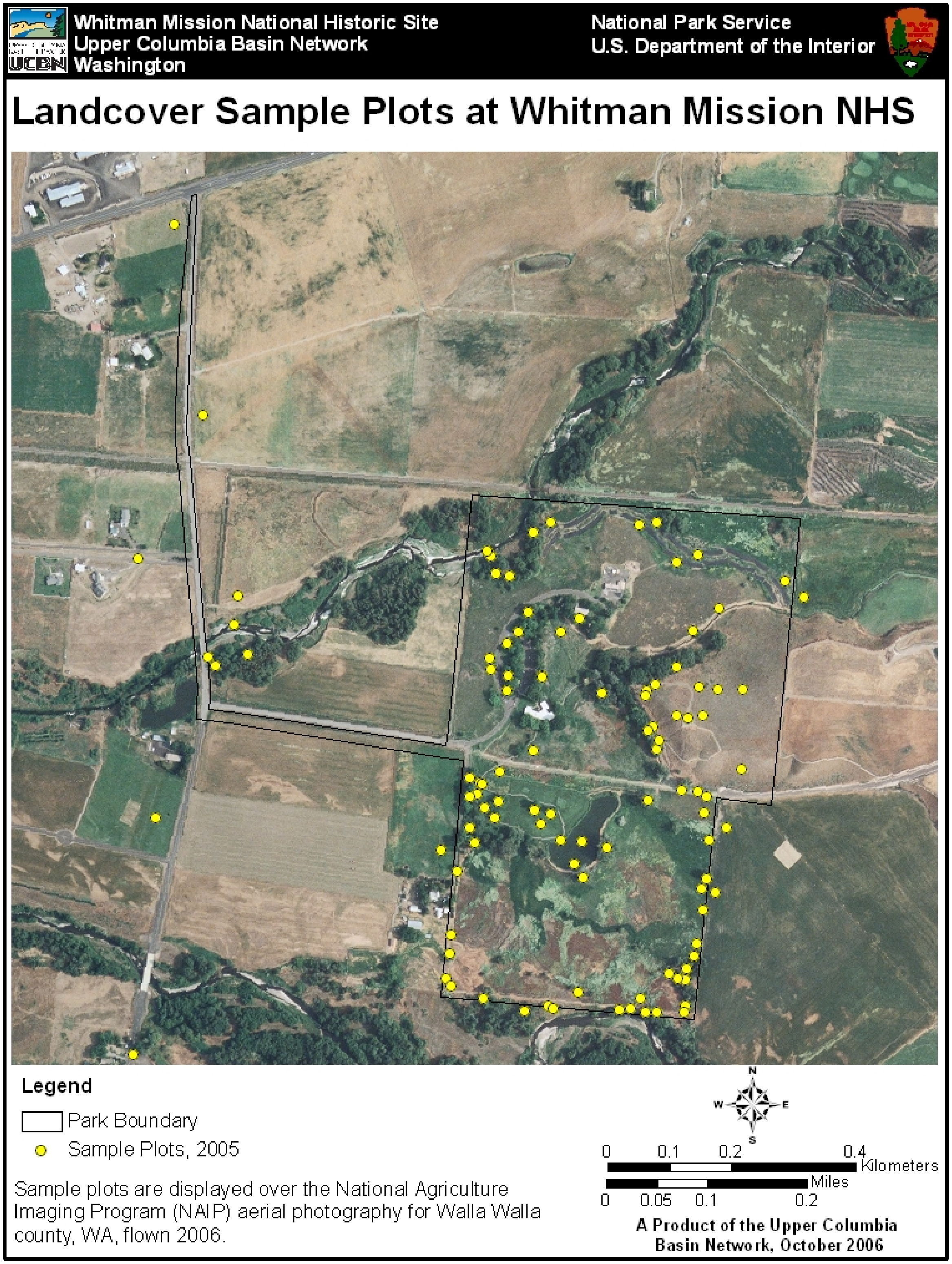

Figure 2. Landcover sample plots collected at Whitman Mission National Historic Site, 2005.

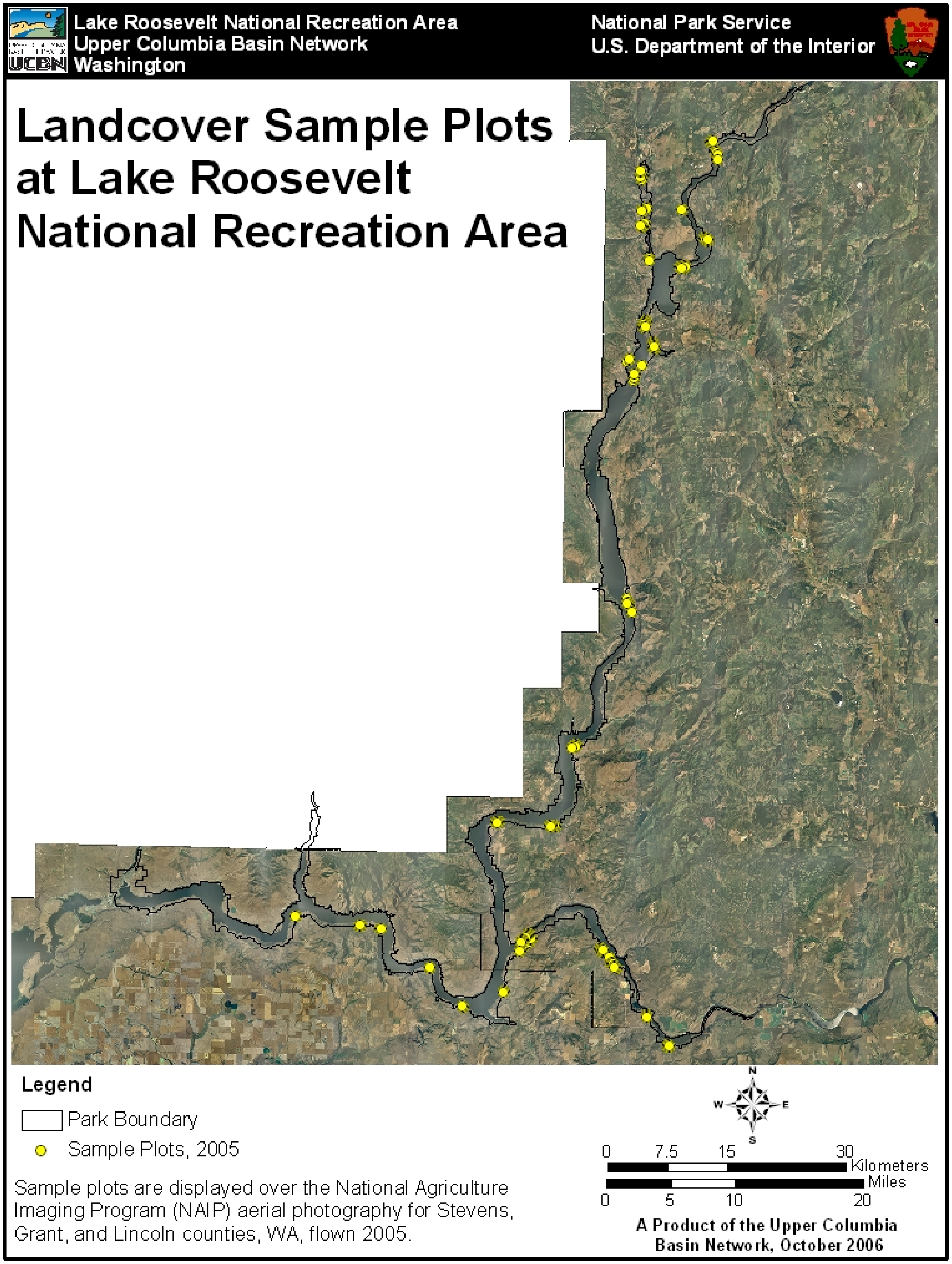

Figure 3. Landcover sample plots collected at Lake Roosevelt National Recreation Area, 2005.

Subsystem	Band No.	Spectral Range (µm)	Spatial Resolution, m	Quantization Levels
VNIR	1	0.52-0.60	15	8 bits
	2	0.63-0.69		
	3N	0.78-0.86		
	3B	0.78-0.86		
SWIR	4	1.60-1.70	30	8 bits
	5	2.145-2.185		
	6	2.185-2.225		
	7	2.235-2.285		
	8	2.295-2.365		
	9	2.360-2.430		
TIR	10	8.125-8.475	90	12 bits
	11	8.475-8.825		
	12	8.925-9.275		
	13	10.25-10.95		
	14	10.95-11.65		

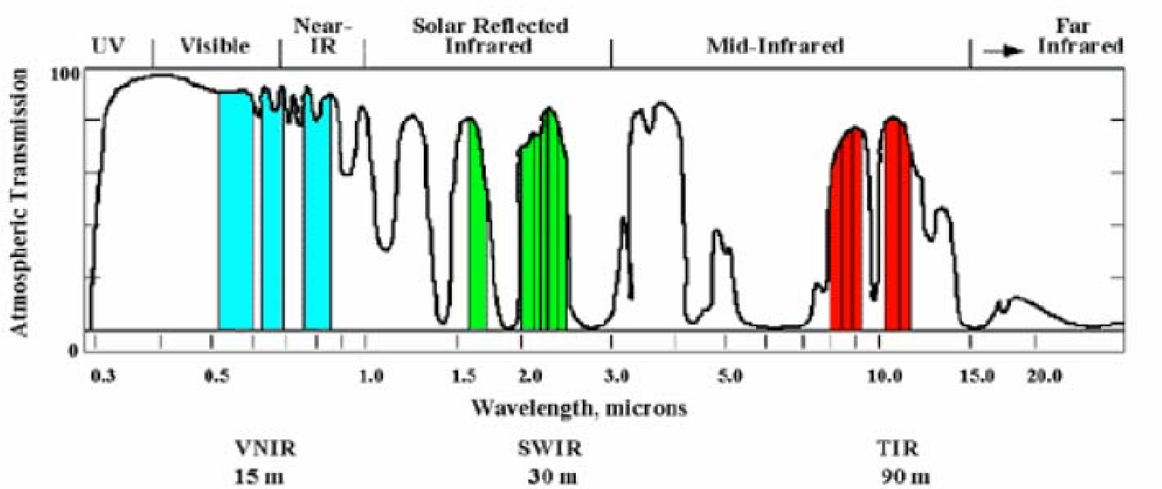

Figure 4. ASTER sensor information and spectral band wavelengths.

ASTER imagery in the visible/near infra-red (VNIR) was acquired for all parks from the Land Processes Digital Active Archive Center, EROS Data Center, USGS. The images were geometrically registered using a nearest neighbor resampling method and co-registered pixel to pixel to an absolute accuracy of 15 meters to their appropriate UTM zones in WGS84 datum (Table 1).

Radiometric correction was done using ENVI 4.2 software from RSI Inc. Boulder, Colorado. The images for all parks were converted to exo-atmospheric reflectance. By converting the images from raw digital numbers to surface reflectance, the image can be directly comparable to other images. This allows a user to broaden a study's spatial extent by image mosaics as was needed for LARO. It also allows for direct comparisons of two similar but geographically distant sites. Reflectance is as much scientific measure as temperature or weight. Converting to reflectance allows some degree of inter-scene comparison to be performed because the reflectance values are computed taking into account the actual amount of radiation that reaches the earth's surface and determining what percentage of that radiation is reflected back to the satellite. No atmospheric correction was done on the scenes.

Table 1. Dates of ASTER imagery used in the land cover classifications.

Park	Date/Scene(s)	Projection
BIHO	August 4, 2002 (1)	UTM12 WGS84
WHMI	August 13, 2001 (1)	UTM11 WGS84
LARO	May 9, 2001 (1)	UTM11 WGS84
	June 23, 2001 (1)	
	September 27, 2001 (4)	

Image Segmentation

Image segmentation is the process of completely partitioning an image into non-overlapping regions. The segmentation algorithm is a bottom-up, region-growing technique starting with one pixel object. Based upon the homogeneity decisive factor of size, distance, texture, spectral similarity and form and the heterogeneity to the neighboring regions, the object is segmented into a region. Because eCognition software provides a patented technique for multiresolution segmentation, the exact methods used to determine segments is somewhat of a “black-box.” However, thresholds applied to decide whether objects are merged into larger objects are user-defined. Adjacent and similar pixels are aggregated into separate segments on condition that the spectral and spatial heterogeneity is minimized within the iteratively defined thresholds. The spectral heterogeneity is determined by the change of a weighted standard deviation of the spectral values while the spatial heterogeneity is determined by the smoothness and compactness. The most important component to multiresolution segmentation is scale and the resulting hierarchical classification is scale dependent.

Segmentation parameters used in eCognition for each of the parks are shown in Table 2. Level 1 represents the coarser, object-level segmentation (Figure 5a) and Level 2 represents the pixel-level or finder segmentation (Figure 5b).

Table 2. Segmentation parameters entered into eCognition for each of the study sites.

Park	Level	Scale	Color	Shape	Compact.	Smooth.
BIHO	1	22	0.6	0.4	0.2	0.8
	2	10	0.7	0.3	0.3	0.7
WHMI	1	10	0.5	0.5	0.3	0.7
	2	5	0.7	0.3	0.3	0.7
LARO	1	125	0.6	0.4	0.4	0.6
	2	75	0.5	0.5	0.2	0.8

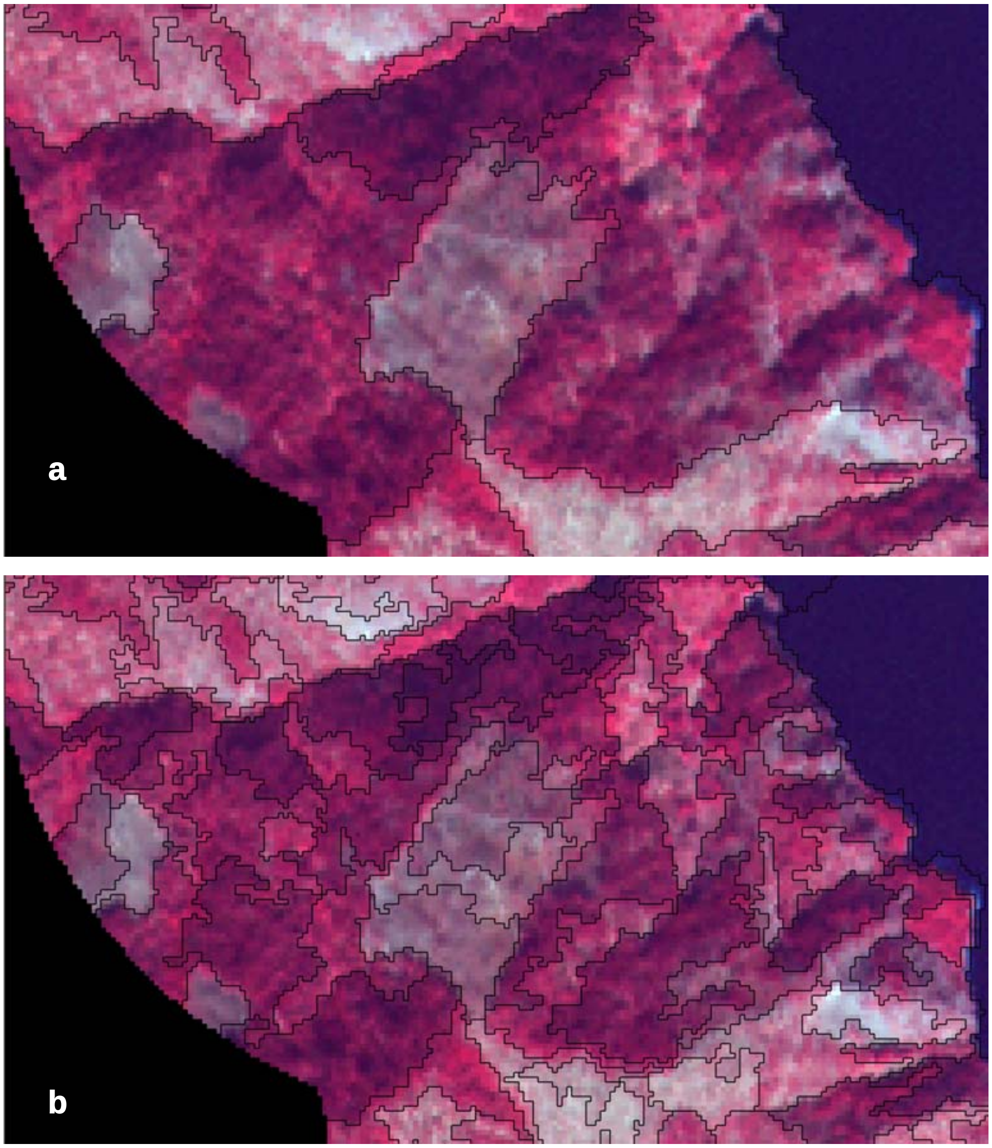

Figure 5. Example of object-level (a) and pixel-level (b) segmentation as produced by eCognition in the Lake Roosevelt NRA classification.

Image Classification

Classification is the process of connecting the classes in a land cover map with the image objects created by segmentation in a scene. The creation of a knowledge base for the classification is called class hierarchy and is the foundation for the classification of the segmented image. The hierarchical network of image objects describes the object's neighbor, its parent object, and its child object (Figure 6). Features inherited from the parent object can transfer to the child object.

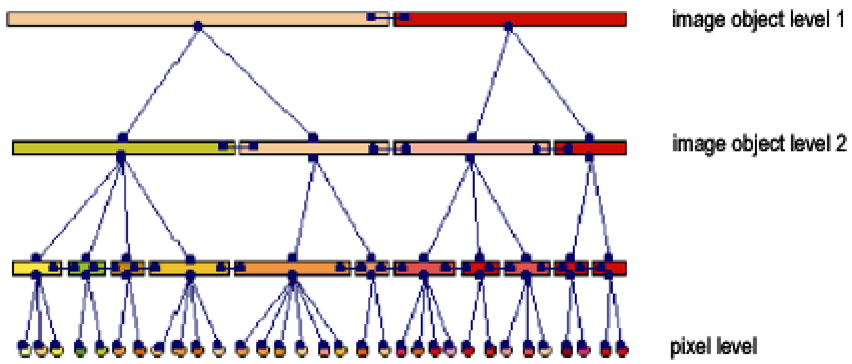

Figure 6. Example class hierarchy network showing the relationships between objects and among levels.

After the process of creating a hierarchical network, a Nearest Neighbor classifier is used to assign each image object to a certain class. Nearest Neighbor classifies image objects in a given feature space and with given samples based on previously collected field data for the class. Next the algorithm looks for the closest sample object in the feature space for each image object. The distance between a sample object and an image object is calculated as:

$$d = \sqrt{\sum_f \left(\frac{v_f^{(s)} - v_f^{(o)}}{\sigma_f}\right)^2}$$

$V^{(s)}$: Feature value of sample object
$V^{(o)}$: Feature value of image object
σ: Standard deviation for the feature values

A class hierarchy was set up by eCognition using the segmented image of each study area and detailed class descriptions of each class collected in the field was composed. As a supervised classification approach, sample objects were manually selected as training sites based upon the GPS field data. When GPS data were unavailable for certain classes, verification was completed using current (within 1 year) aerial photography. After sample data were designated to certain classes, the Nearest Neighbor classification was calculated. In some instances, the preliminary classifications contained misclassifications which were corrected by iteratively identifying more samples using current aerial photography and rerunning the classification process.

Accuracy Assessment

Classifications represent only a generalization of the real landscape types. Therefore, it is necessary to check the accuracy of any land cover classification with ground reference sample data (Ahmad et al. 1992). Ground reference data, representing 30-40% of sampled polygons, and the classification results were compared, statistically analyzed, and error matrices were produced within eCognition. An error matrix analysis provides a natural framework for the convenient display of results that can also be used for analysis. This is an effective tool that presents the overall accuracy of the classification as well as the producer and user accuracy of each category (Congalton et al. 1983). User's accuracy is the probability that a pixel classified on the map actually represents that category on the ground. The overall accuracy of the classification map is determined by dividing the total correct pixels by the total number of pixels in the error matrix. Computing the accuracy of individual categories is done by the total number of correct pixels in a category divided by the total number of pixels of that category as derived from the reference data (Jensen 2005). The Kappa Index of Agreement (KIA) measures the agreement or accuracy between the remote sensing derived classification map and the reference data (Rosenfield and Fitzpatrick-Lines 1986). Bounded between -1 and +1, the overall KIA and KIA per class provide a means for determining the probability that map and reference data agreement is due to chance. Recent aerial photos which were not available at the initiation of the project were also used for comparison purposes.

Results

Land cover classifications

Land cover maps of each study area resulted from the object-oriented image classification approach (Figures 7-9). All three classifications were based on a 15mX15m pixel size; however, the smallest polygon mapped varied in each area depending on landcover type and park management requests. The minimum mapping units for BIHO, WHMI, and LARO were 0.18 hectares, 0.04 hectares, and 2.9 hectares, respectively.

Thirteen unique classes were derived in the final land cover classification for BIHO (Table 3) with the greatest area in lodgepole pine (*Pinus contorta*) / Douglas fir (*Pseudotsuga menziesii*) (690 hectares including open stands) and dry grassland types (252 hectares). Five classes were identified in the riparian to upland sagebrush gradient including one mixed shrub/grass class (95 hectares) that represents transition areas between willow and sagebrush types. One area just north of the visitor center was identified as irrigated grassland. Although it is not currently irrigated, the polygon signature is a result of leaching from historic irrigation ditches and park management requested the polygon be retained.

Table 3. Summary of classification results for Big Hole NB.

CLASS	ACRES	HECTARES
Deciduous	5.8	2.3
Developed	81.2	32.9
Grassland, Dry	621.5	251.5
Grassland, Irrigated	52.3	21.2
Grassland, Wet	395.9	160.3
Lodgepole pine/Douglas fir Open Stand	89.5	36.2
Lodgepole pine/Douglas fir	1618.1	654.8
Mixed Shrub/Grass	235.4	95.3
Pond	0.4	0.2
Riparian	86.3	34.9
Riparian Shrub	322.9	130.7
Sagebrush/Grass	201.8	81.7
Sagebrush	46.6	18.9

At WHMI, 14 classes were derived from the land cover classification (Table 4) including separation of great basin wildrye (*Leymus cinereus*) patches.

Table 4. WHMI classification results

CLASS	ACRES	HECTARES
Agriculture	1012.983	409.940
Buildings	10.002	4.04
Developed	10.013	4.04
Grass	2.201	.89
Grasslands	60.048	24.3006
Great Basin Rye	4.005	1.168
Irrigated Ag	367.336	148.656
Locust	1.303	0.526
Mixed Deciduous	70.062	28.355
Orchard	0.300	0.121
Roads/Parking Lot	40.033	16.24
Sagebrush	4.004	1.62
Shrub Riparian	50.058	20.25
Water	1.101	.445
unclassified	0.388	0.157

The LARO classification identified 12 classes (Table 5), including cloud and cloud shadow (131.5 ha). Excluding water (30,585.5 ha), ponderosa pine (*Pinus ponderosa*) covered the greatest area with open canopy mapped at 37,526.6ha and closed canopy at 21,972.5ha. In the southern portion of the park, sagebrush was most common.

Table 5. Summary of classification results for Lake Roosevelt NRA.

CLASS	ACRES	HECTARES
Agriculture, Irrigated	2938.7	1189.2
Agriculture, Non-irrigated	34,885.6	14,117.7
Bare ground / rock / sand	3220.1	1303.1
Cloud / Cloud shadow	324.9	131.5
Developed	4744.9	1920.2
Grassland	14,307.7	5790.1
Mixed conifer	16,851.8	6819.7
Mixed shrub	4842.9	1959.9
Ponderosa Pine, Closed Canopy	54,295.3	21,972.5
Ponderosa Pine, Open Canopy	92,730.3	37,526.6
Sagebrush	48,561.7	19,652.2
Water	755,578.4	30,585.5

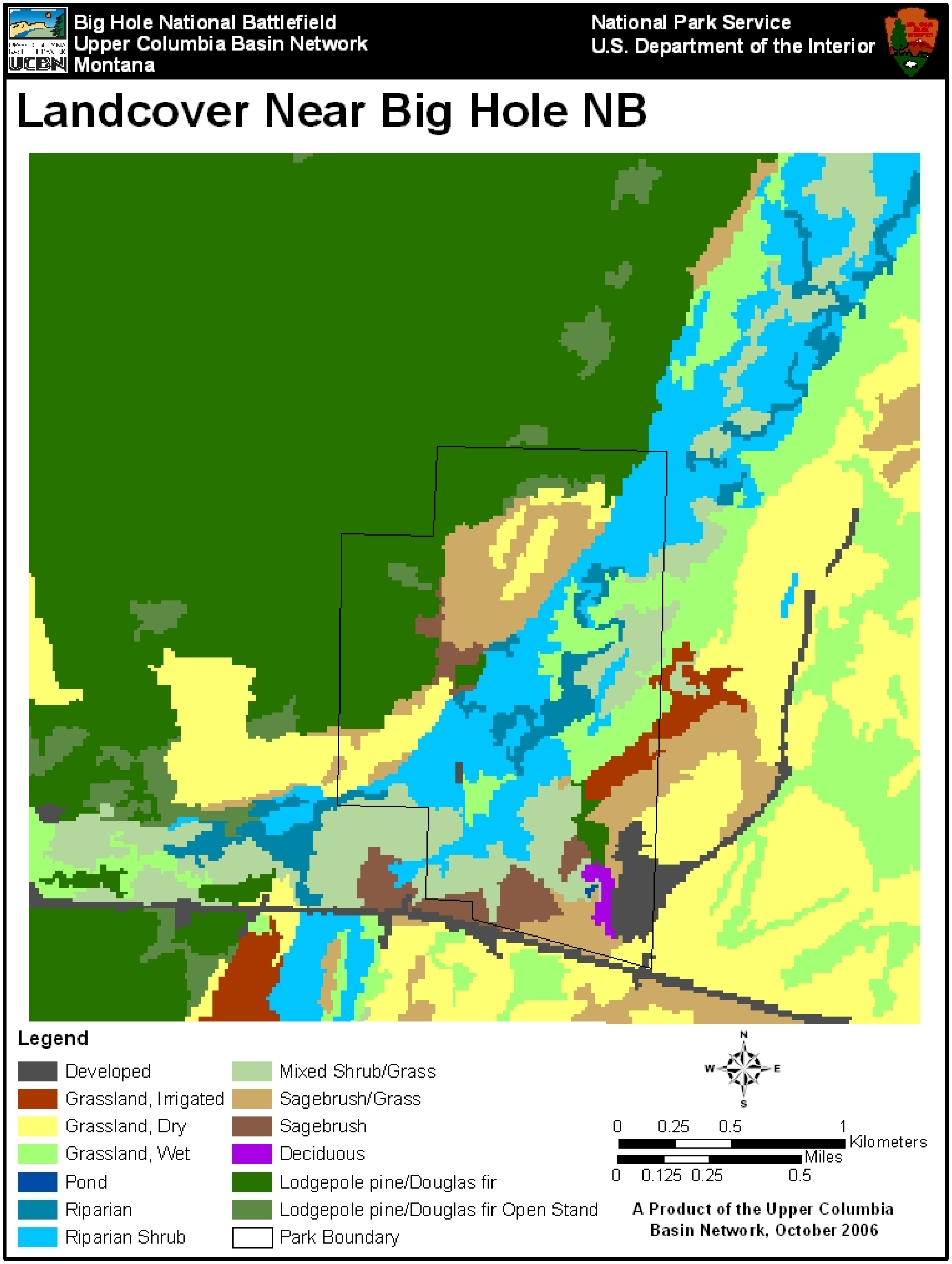

Figure 7. Landcover near Big Hole National Battlefield as determined by object-oriented classification of ASTER satellite imagery.

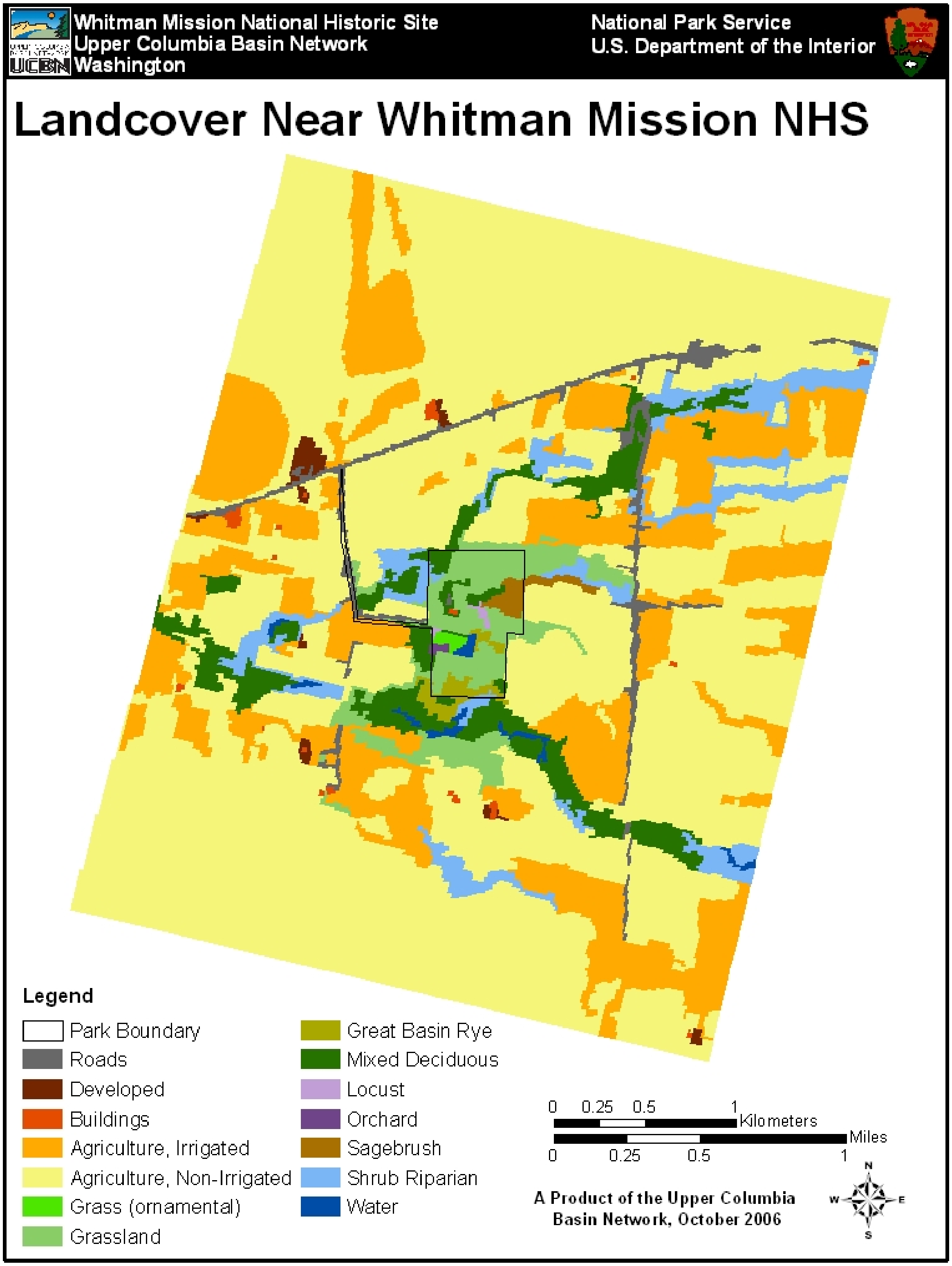

Figure 8. Landcover near Whitman Mission National Historic Site as determined by object-oriented classification of ASTER satellite imagery.

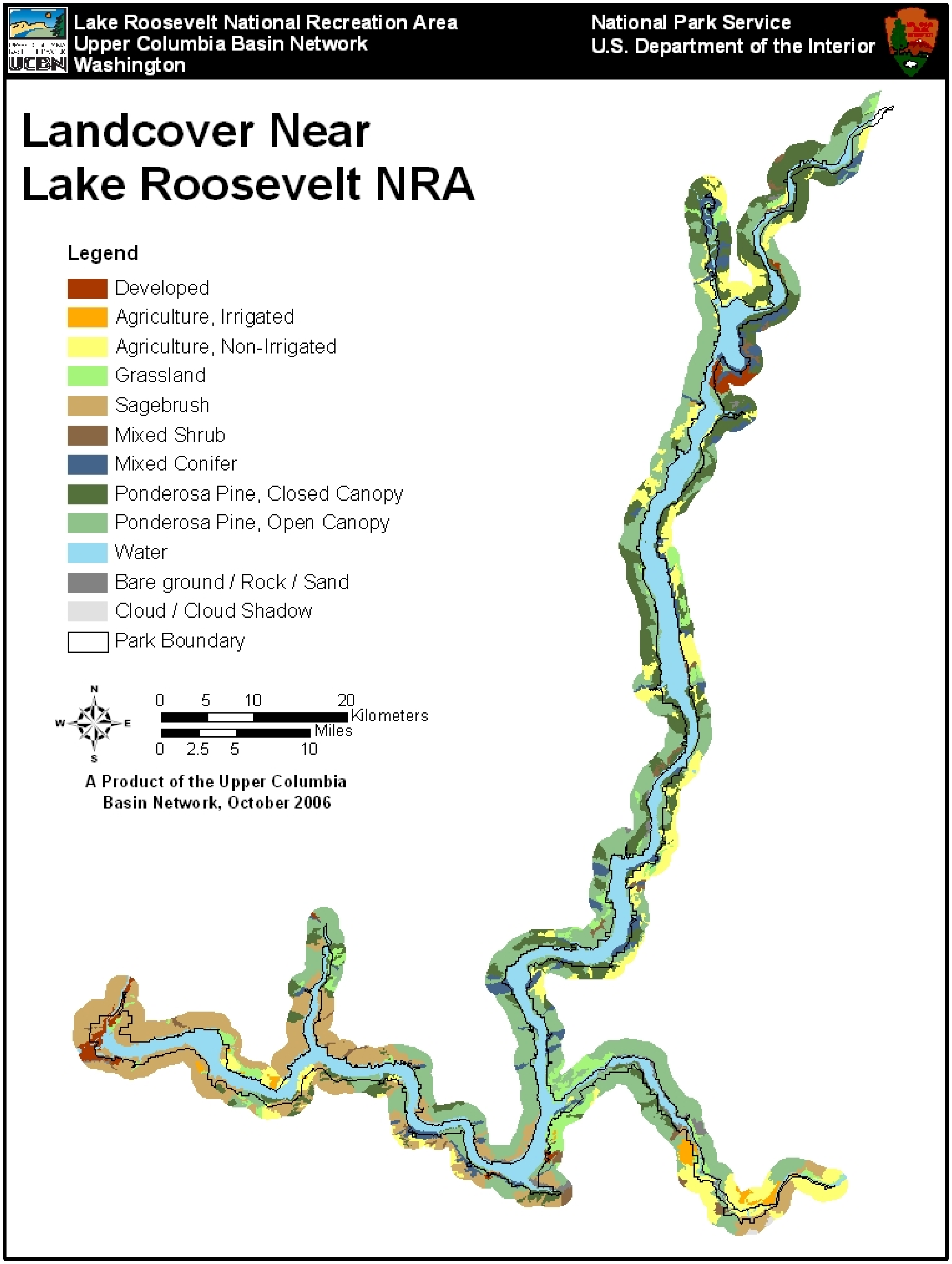

Figure 9. Landcover near Lake Roosevelt National Recreation Area as determined by object-oriented classification of ASTER satellite imagery.

Accuracy Assessment (update BIHO and WHMI)

Accuracy assessments were based on 43 plots for BIHO, 53 plots for WHMI, and 114 plots for LARO. BIHO had an overall classification accuracy of 93.8% (Figure 10). Many of the lower accuracy results (e.g., Irrigated Grassland, Open Stand and Deciduous) were more than likely due to a lack of acceptable number of ground truth points. The timing of the data collected and the imagery was approximately 3 years and climatic differences could have resulted in the collection process. The highest classification results at 99% not surprisingly were the conifer species which dominates the hillside.

The overall classification accuracy at WHMI was 97% (Figure 11). The only classes that were below the target goal of 80% accuracy were Locust and Water. There were very few locust points collected and the spectral signatures between locust and other deciduous trees could be very similar. The 76% accuracy of the water is somewhat perplexing, however there are several shadows in the scene surrounding the mixed deciduous areas and many times water and the darker areas of the imagery can be confused.

For LARO, the overall accuracy was 89.5% with a KIA of 0.884 (Figure 12). All but two of the classes (Sagebrush and Bare ground/rock/sand were at or above 80%. Of the nine Sagebrush sample plots, 2 were misclassified as Open Canopy Ponderosa Pine leading to a Producers accuracy of 0.778 and KIA of 0.759. Given the interspersion of sagebrush and ponderosa pine, this is an understandable error. Similarly, two of the six Bare ground/rock/sand samples were misclassified as Grassland resulting in the lowest Producer accuracy of 0.667 and KIA of 0.647. This is mainly due to a lack of field data. Data for this particular class was collected off aerial photographs and input as samples in eCognition. Perhaps additional samples would increase the accuracies for this class.

Discussion

The results from this project demonstrate the ability to obtain landcover classifications appropriate for long-term monitoring while maintaining a high standard of accuracy and sustaining cost and time efficiency. The object-oriented, combined spatial-spectral approach, used by eCognition does appear to improve classification accuracies (see also Carr 1996, Ryherd and Woodcock 1996, Arai 1993). In this study, this was especially true in those cover types that were more apt to be defined by shape or texture than by spectral signature. For instance, the amount of detail extracted in riparian and road/developed classes is notable, given the notorious difficulties in mapping these with traditional pixel-based approaches.

The timing of imagery, however, can have a significant effect on the classification output. Unfortunately, ASTER is not taken on a continual basis as the more common Landsat 5 or 7 sensors. While ASTER imagery can be acquired on request, this project relied upon extant scenes. The BIHO scene taken in August of 2002 seemed to be an appropriate image for the forested and major riparian areas; however it was not suitable for the lower floodplains and grassland/sagebrush areas. This proved to be the case at WHMI as well where many of the grassland species had senesced by the August (2001) image date. At LARO, all but two scenes were of late September 2001. These late scenes were located in shrub steppe and grassland areas in the southern portion of the park and limited the ability to differentiate finer thematic classes. The LARO classification also likely experienced the lowest accuracy (89.5% vs 93.8% and 97% for BIHO and WHMI, respectively) because of the low number and limited spatial distribution of field sample plots collected. This was the result of limited accessibility in some areas (private landowners or terrain), time/cost, and lack of field crews (due to budget constraints) to sample the park.

The algorithms in eCognition are proprietary of the software company and thus cannot be manipulated by the user. However, the value of different parameters such as scale, spectral heterogeneity and shape heterogeneity are user-controlled and can be significant factors in the segmentation process. The resolution of the imagery also significantly influences determination of parameter values in the segmentation process. Since the initiation of this project, high resolution aerial photography has become available through the National Agricultural Imaging Program (NAIP) for all three study areas (2005 1m data for BIHO and 2006 1m data for WHMI and LARO). Analysis of these datasets would lend itself to classifications with finer spatial and thematic resolution. In addition, parameter inputs for eCognition, once set for a particular area and a particular imagery type, should remain the same thereby facilitating the use of separate dates in change detections.

While the learning curve is steep and sometimes appears to be more of an art than a science, object-oriented approaches such as those used by eCognition show great promise.

Table 6. Confusion matrix for Big Hole NB landcover classification.

User Class \ Sample	Deciduous	Developed	Grassland, Dry	Grassland, Irrigated	Grassland, Wet	Lodgepole pine / Douglas fir Open Stand	Lodgepole pine / Douglas fir	Mixed Shrub/Grass	Pond	Riparian	Riparian Shrub	Sagebrush/Grass	Sagebrush	Sum
Confusion Matrix														
Deciduous	63	0	0	0	0	0	0	0	0	0	0	0	0	63
Developed	0	1093	0	0	0	0	0	0	0	0	0	0	0	1093
Grassland, Dry	0	0	1700	178	0	0	0	203	0	0	0	0	0	2081
Grassland, Irrigated	0	0	0	447	0	0	0	0	0	0	0	0	0	447
Grassland, Wet	0	0	0	0	425	0	0	0	0	0	0	0	0	425
Lodgepole pine / Douglas fir Open Stand	0	0	0	0	0	170	0	0	0	0	0	0	0	170
Lodgepole pine / Douglas fir	118	0	0	0	0	163	21852	0	0	0	0	0	0	22133
Mixed Shrub/Grass	0	0	0	0	0	0	0	929	0	0	0	0	0	929
Pond	0	0	0	0	0	0	0	0	25	0	0	0	0	25
Riparian	0	0	0	0	23	0	0	0	0	130	0	0	0	153
Riparian Shrub	0	0	0	0	0	0	0	0	0	122	425	0	0	547
Sagebrush/Grass	0	0	0	0	0	0	0	0	0	0	0	1107	0	1107
Sagebrush	0	0	0	0	0	0	0	0	0	0	0	0	264	264
Sum	181	1093	1700	625	448	333	21852	1132	25	252	425	1107	264	
Accuracy														
Producer	0.348	0.9803	1	0.4257	0.9217	0.5105	0.9945	0.7474	1	0.5159	1	0.9217	1	
User	1	1	0.8169	1	1	1	0.9873	0.8114	0.8169	1	0.8168	1	0.8169	
KIA Per Class	0.3467	0.9795	1	0.4168	0.9187	0.5077	0.3467	0.7371	1	0.5137	1	0.9187	1	
Totals														
Overall Accuracy	**0.9379**													
KIA	**0.8537**													

Table 7. Confusion matrix for Whitman Mission NHS landcover classification.

User Class \ Sample	Developed	Roads/Parking Lot	Buildings	Agriculture	Irrigated Ag	Grasslands	Sagebrush	Locust	Mixed Deciduous	Orchard	Shrub Riparian	Grass	Water	Great Basin Rye	Sum
Confusion Matrix															
Developed	73	0	0	0	0	0	0	0	0	0	0	0	0	0	73
Roads/Parking Lot	0	355	0	0	0	0	0	0	0	0	0	0	0	0	355
Buildings	4	0	25	0	0	0	0	0	0	0	0	0	0	0	29
Agriculture	0	0	0	1413	0	0	0	0	0	0	0	0	0	0	1413
Irrigated Ag.	0	0	0	58	1594	0	0	0	0	0	0	0	14	0	1666
Grassland	0	0	0	0	0	128	0	0	17	0	0	0	0	0	145
Sagebrush	0	0	0	0	0	0	166	0	0	0	0	0	0	0	166
Locust	0	0	0	0	0	0	0	69	0	0	0	0	0	0	69
Mixed Deciduous	0	0	0	0	0	0	0	29	472	0	26	0	0	0	527
Orchard	0	0	0	0	0	0	0	0	0	16	0	0	0	0	16
Shrub Riparian	0	0	0	0	0	0	0	0	0	0	439	0	0	0	439
Grass	0	0	0	0	0	0	0	0	0	0	0	58	0	0	58
Water	0	0	0	0	0	0	0	0	0	0	0	0	46	0	46
Great Basin Rye	0	0	0	0	0	0	0	0	0	0	0	0	0	213	213
Sum	77	355	25	1471	1594	128	166	98	489	16	465	58	60	213	
Accuracy															
Producer	0.948	1	1	0.9606	1	1	1	0.704	0.9652	1	0.944	1	0.7767	1	
User	1	1	1	1	1	1	1	0	0.8956	1	1	1	1	1	
KIA Per Class	0.9473	1	1	0.9459	1	1	1	0.7001	0.9613	1	0.9389	1	0.7646	1	
Totals															
Overall Accuracy		0.9716													
KIA		0.9645													

Table 8. Sample based confusion matrix for Lake Roosevelt NRA landcover classification.

User Class \ Sample	Agriculture, Irrigated	Agriculture, Non-irrigated	Bare ground/ rock/sand	Water	Developed	Grassland	Ponderosa Pine, Closed	Mixed Shrub	Sagebrush	Mixed conifer	Ponderosa Pine, Open	Sum
Confusion Matrix												
Agriculture, Irrigated	7	0	0	0	0	0	0	0	0	0	0	7
Agriculture, Non-irrigated	0	12	0	0	0	0	0	0	0	0	1	13
Bare ground / rock / sand	0	0	4	0	0	1	0	0	0	0	0	5
Water	0	0	0	6	0	0	0	0	0	0	0	6
Developed	1	0	0	0	5	0	0	0	0	0	0	6
Grassland	0	0	2	0	0	6	0	0	0	0	0	8
Ponderosa Pine, Closed	0	0	0	0	0	0	5	0	0	1	1	7
Mixed Shrub	0	0	0	0	0	0	0	5	0	0	0	5
Sagebrush	0	0	0	0	0	0	0	0	7	0	0	7
Mixed conifer	0	0	0	0	0	0	0	0	0	10	0	10
Ponderosa Pine, Open	0	0	0	0	0	0	0	0	2	0	10	12
Sum	8	12	6	6	5	7	5	5	9	11	12	
Accuracy												
Producer	0.875	1	0.667	1	1	0.857	1	1	0.778	0.909	0.833	
User	1	0.923	0.8	1	0.833	0.75	0.714	1	1	1	0.833	
KIA Per Class	0.864	1	0.647	1	1	0.843	1	1	0.759	0.895	0.807	
Totals												
Overall Accuracy	**0.895**											
KIA	**0.884**											

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NPS D-XXX, April 2006

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