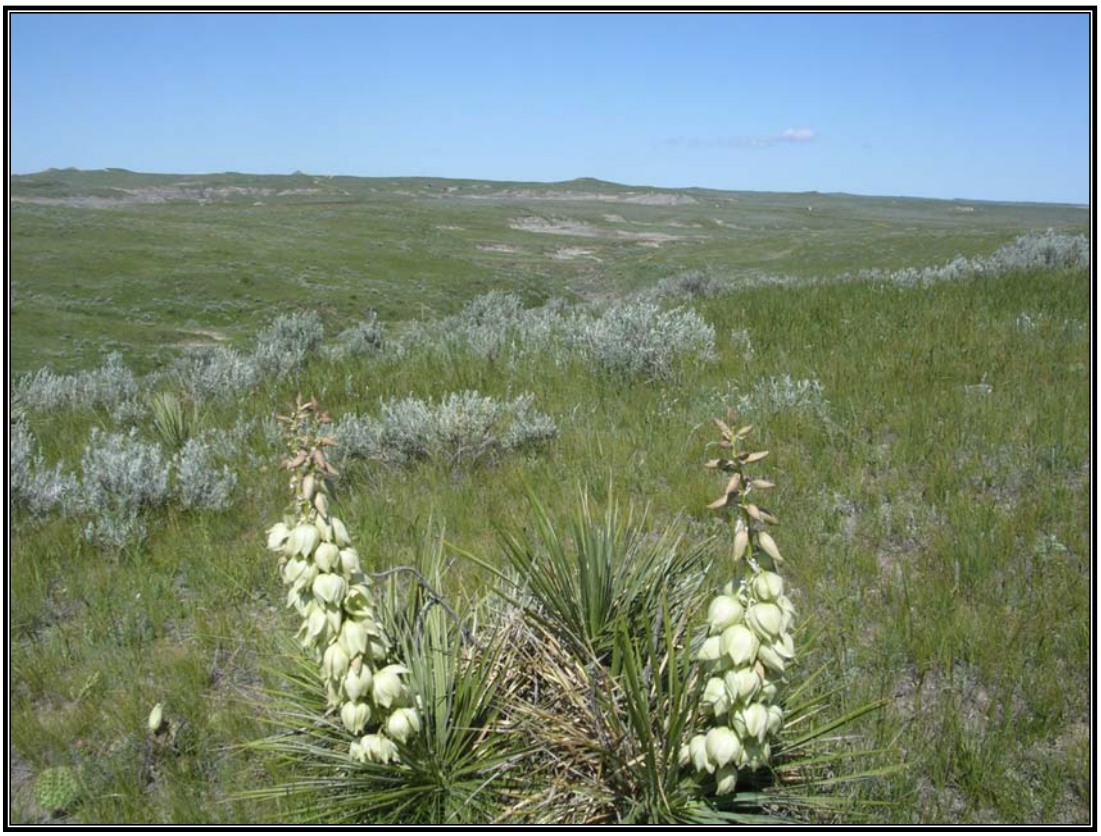
MAPPING SAGEBRUSH FOR SAGE GROUSE HABITAT
IN
BUTTE AND HARDING COUNTIES, SOUTH DAKOTA



FINAL REPORT SEPTEMBER 2007

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Science Applications International Corporation
Under Contract with the Bureau of Reclamation

Technical Memorandum No. 86-68260-08-01
Remote Sensing and GIS Group
Technical Service Center
Bureau of Reclamation
Denver, CO

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The Remote Sensing and Geographic Information Group, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other governmental clients.

This report was prepared for the United States Bureau of Reclamation, Upper Colorado Region by the Remote Sensing and GIS Group of the Bureau of Reclamation's Technical Service Center, Denver, CO as Technical Memorandum No. 86-68260-08-01

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ACKNOWLEDGMENTS

The project staff of the BOR-RSGIG wishes to acknowledge Dan Cogan and Dave Ode for their part in making this research study a success. It was the forethought of these individuals in 2003 that understood the necessity in developing a cost effective methodology to map the habitat associated with sagebrush communities. Their review and comments on the original draft of this report were also found to be invaluable. We would also like to thank Jim Weigel in the USBR Bismarck office for co-funding this study for two years. Without his help utilizing Technical Assistance to the States funding this project would not have moved forward. Thank you very much!

EXECUTIVE SUMMARY

In 2006 and 2007, the Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIG) in collaboration with the South Dakota Department Game, Fish & Parks mapped sagebrush and other land cover within and intersecting publicly owned lands in the western portions of Butte and Harding Counties in South Dakota.. The study tested the viability of using high resolution multi-band color infrared digital imagery along with object oriented image processing for the identification and mapping of sagebrush over a large area in a cost effective manner. The objective of the study was to cost effectively collect and analyze imagery to determine the extent of sagebrush vegetation communities at a level of detail to assess vegetation community relationships. The costs incurred by using the methodology represented in this study to map the aforementioned land classes are estimated at $0.54 per-acre compared to the $2.00 per-acre using traditional methodologies. Note that the thematic accuracy obtained by the traditional methodology is greater than the methodology used in this study.

Sagebrush represents an important ecosystem service to western South Dakota, especially for sage grouse and other associated obligate plant and animal species that depend on this vegetation assemblage. The big sagebrush shrub community is considered the most threatened of all communities in South Dakota, mainly due to the conversion to grasslands or croplands (Peterson 1995) and the invasion of exotic grasses. Within the study area *Artemesia* species vary from the herbaceous sageworts and wormwoods to two woody species, silver sagebrush (*A. cana*) and Wyoming big sagebrush (*A. tridentata*).

The ADS40 digital imagery was acquired on September 4, 2006. Processing and delivery of the final image product took 4 months, with a delivery date of December 28, 2006. The imagery was delivered as a series of 451 individual tiles in GeoTIFF format. Each image tile was composed of the infrared, red and green spectral bands. From September 18, 2006 through September 21, 2006 represenitive locations distributed throughout the study area were visited and ground truthed. Coordinates were monumented using a hand held real-time differentially corrected global position system unit (GPS) along with landcover information pertaining to land cover composition and estimated canopy cover density. Dominant land cover types within the study area including areas representing sage, grasses, sparse vegetation and riparian assemblages.

The sum acreage calculated for each class within or intersecting publicly owned lands:

1) Wetland - 249 polygons = 511 acres
2) Open Water – 746 polygons = 1,091 acres
3) Riparian - 1659 polygons = 4,946 acres
4) Sage Riparian – 1450 polygons = 6,603 acres
5) Sage – 12108 polygons = 160,088 acres

INTRODUCTION

The Bureau of Reclamation=s Remote Sensing and Geographic Information Group (RSGIG) in collaboration with the South Dakota Department Game, Fish & Parks has successfully completed the mapping of sagebrush and other land cover within and intersecting publicly owned lands found in a study area representing the western portions of Butte and Harding Counties in South Dakota. It has been established that there is a need for monitoring potential sage grouse habitat within the known range of the species. This effort tested and confirmed the viability of using high resolution multi-band color infrared digital imagery along with object oriented image processing in the identification and mapping of sagebrush over a large area in a cost effective manner. Our objective was to collect and analyze imagery of the study area that would allow for the determination of sagebrush vegetation communities at a level of detail that would provide land and resource managers the information required to make decisions regarding future conservation actions.

1.1 PROGRAM BACKGROUND

Vegetation is a sensitive indicator of multiple environmental factors, including precipitation, temperature, soil, geology, water quality, and wind. In summery, vegetation affects a number of important processes, including snow accumulation, soil moisture depletion, surface runoff, infiltration, and erosion (Knight, 1990). Vegetation input to streams (coarse- particulate organic material) and inputs of chemicals applied to vegetation are additional factors affecting stream quality.

Sagebrush occurs along the western edge of South Dakota and represents a transition zone from mixed grass prairie to the East and sage steppe to the West (SDOU 1991). Sagebrush creates important habitat for many obligate species including sage grouse (*Centrocercus urophasianus*), brewer's sparrow, sage thrasher, and sage sparrow (Lewis 2004). South Dakota sagebrush communities are faced with increasing pressure from fragmentation, exotic species invasions, and agricultural treatment. These effects coupled with impacts on sage by fire, chemicals, and mechanical operations pose a serious threat to the long-term viability of the sagebrush ecosystems and the species that depend upon on them (Knick et al. 2003).

Of particular concern is the steady decline in sage grouse documented in South Dakota and across much of its range. Nationwide it is estimated that sage grouse breeding populations have decreased 47% (Connelly and Braun 1997). In South Dakota the sage grouse are confined to two remnant populations, one located across Harding and Butte Counties in the northwest corner and the other in southwest Fall River County. In both populations, observations have documented the continuing abandonment of active leks and a decrease in male per lek (Connelly et al. 2004). Connelly and Braun (1997) indicated that South Dakota breeding populations declined by 45% when they compared the long-term average of males per lek to the average for 1985-94. Smith (2003) also concluded that South Dakota sage grouse populations underwent a steady decline from 1973-1997, with some recovery from 1997 to 2002.

Recently, local land managers have observed the abandonment of some leks and a reduction in nesting sites and brood sizes (Schenbeck 2005 pers. Comm.).

Sagebrush Distribution

Within the study area *Artemesia* species vary from the herbaceous sageworts and wormwoods to two woody species, the silver sagebrush (*A. cana*) and Wyoming big sagebrush (*A. tridentate ssp. wyomingensis*). Silver sagebrush is found on the steppe habitats, while big sagebrush was lacking on uplands and rare or absent east of Slim Buttes in southeastern Harding County (Lewis 2004, Visher 1916). Of the scrublands of South Dakota, the big sagebrush shrub community is the most threatened, mainly by conversion to grasslands or croplands (Peterson 1995) and the invasion of exotic grasses.

Sagebrush provides an important ecosystem service to western South Dakota. Richards and Caldwell (1987) identified the ability of *Artemesia tridentata* to hydraulically lift water from deep in the soil into the upper soil profile; capture snow (Tweit 2000); hold soil from erosion (Lewis 2004); and provide forage for pronghorn antelope (*Antilocapra Americana*), mule deer (*Odocoileus hemionus*), pygmy rabbits (*Brachylagus idahoensis*), and sage grouse (Lewis 2004). Additional ecosystem services include cover for all of the above species, and nesting sites for sage grouse and other obligate birds including Sage Thrasher (*Oreoscoptes montanus*), Brewer's Sparrow (*Spizella breweri*), and Sage Sparrow (*Amphispiza belli*) (Paige and Ritter 1999).

Spatial patterns of natural sagebrush recruitment are generally unrelated to proximity of a potential seed source, suggesting that occasional events in the tail of the seed dispersal curve are disproportionately important in influencing patterns of seedling abundance. Furthermore, seedlings tended to occur in clumped distributions at small spatial scales. These combined results support a "nucleation" pattern of sagebrush reestablishment, in which a small amount of seed reaching microsites appropriate for germination and establishment are far more important in influencing recovery than a large amount of seed dispersed adjacent to an unburned edge or island. Future efforts at accelerating big sagebrush reestablishment can likely be improved by ensuring the successful establishment of fewer individuals across the burned landscape, rather than planting large islands or mass seeding for individuals unlikely to survive germination and establishment (Forman et al. 2007).

Sagebrush Vegetation Community Characteristics

Understanding the relationships of the sage steppe community within the study area is important in order to put into context the results of the study and the potential changes that may occur to this area as a result of adjacent agricultural conversion, climate change, and land management activities. Following is a summary of previous ecological work done on this ecosystem.

South Dakota lies in a vegetational transition zone between eastern and western United States (SDOU 1991). Tall grass prairie and mixed-grass prarie meet in eastern South Dakota (Brown 1985), and in western South Dakota, mixed-grass prairie meets the sage prairie (SDOU 1991) forming what is referred to as the sage steppe. Much of western North and South Dakota are classified as part of the wheatgrass-needlegrass physiognomic type grading into the sage steppe physiognomic type, often described as a grassland with shrubs (Kuchler 1964, Lewis 2004).

Kantrud and Kologiski (1983) labeled the sagebrush area of South Dakota as transition, a patchy area of mixed stands of shrubs and grasses between shrub steppe and pure grassland, with *A. tridentata* assuming a shorter growth form than in the shrub steppe region to the west.

Western South Dakota is a semi-arid region with few trees and varied soil types. This results in habitats that support short grasses, low herbs with several species common in the West reaching their eastern range limit, including the sagebrushes (*Artemesia* spp.).

Understanding the relationships of the sage steppe community within the study area is important in order to put into context the results of the study and the potential changes that may occur to this area as a result of adjacent agricultural conversion, climate change, and land management activities.

Study Area

The study area includes the western portions of Harding and Butte Counties from approximately 5 miles below Belle Fourche up to the North Dakota border and is bounded on the east by highway #85 and on the west by the Wyoming and Montana state borders, approximately 1,350,000 acres. The study area encompasses more than 50% of the known current sage grouse range within Harding and Butte Counties (figure 1). The decision to limit the study area to an area west of highway #85 was based on costs involved with imagery acquisition and the overall biological opinion that the vast majority of sage grouse reside west of highway #85.

1.2 PROGRAM PURPOSE

This study represents the culmination of a larger effort that was initiated in 2003. The objectives of this study are to 1) develop an effective, cost efficient and repeatable mapping procedure, and 2) transfer this knowledge to the South Dakota Department of Game, Fish and Parks.

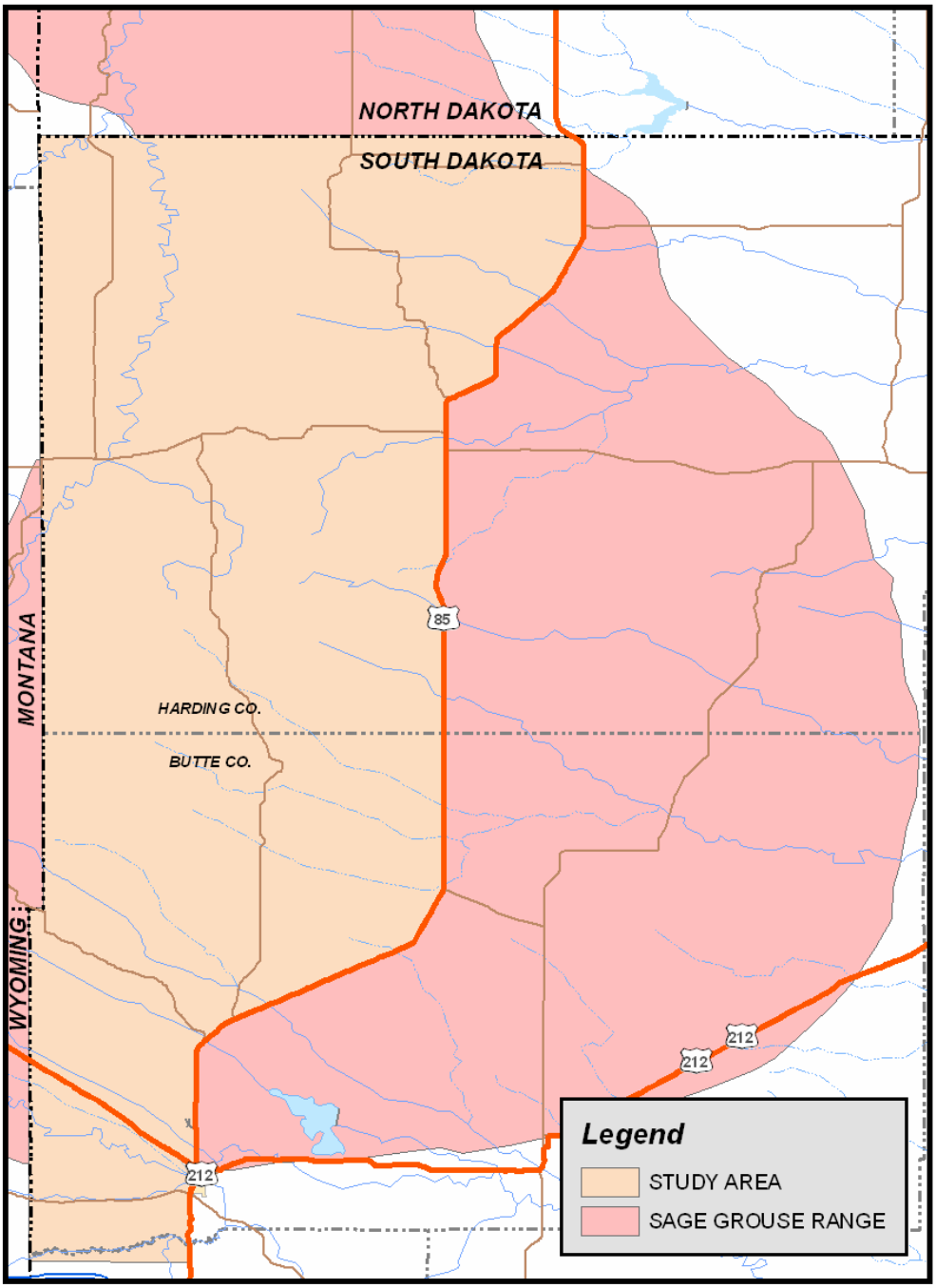
The project was divided into three phases:

Phase I. Evaluation and comparison of different remote sensing methods for mapping sagebrush and associated types across the study area using existing 1:12,000-scale ortho-photography. This was accomplished using identified pilot study sites in the study area.

Phase II. Utilize analytical technology to perform initial assessment of the entire study area.

Phase III. Conduct field and laboratory review of the analytical approach, complete density evaluation of sagebrush stands and develop the final product.

FIGURE I



DATA DEVELOPMENT

At the onset of the sage mapping project it was determined that to identify and map sagebrush in a cost effective manner the mapping methodology would have to incorporate an automated technique that would replicate the traditional photo interpretation and digitizing approach at a reduced time and cost with acceptable reductions in accuracy and level of detail. After extensive research, two specific new technologies were determined to be the most effective tools to achieve our mapping goals, (1) the high resolution ADS40 digital color infrared photography and (2) the eCognition object oriented image processing software.

The ADS40 sensor platform, a product of Leica Geosystems, is a relatively inexpensive way to develop high resolution georeferenced imagery. The all digital ADS40 image acquisition and production process can reduce ground control requirements, processing, and production costs when compared to traditional methodologies.

The review of the technical research literature indicated that high resolution (0.3 meter) color infrared imagery derived from the ADS40 platform would provid the best opportunity to identify and map sagebrush. Langs (2004) study finding a high correlation (R2 = 0.7404) between classifying sagebrush in the field compared to classifying sagebrush through image processing using 0.3 meter color infrared imagery supported our findings.

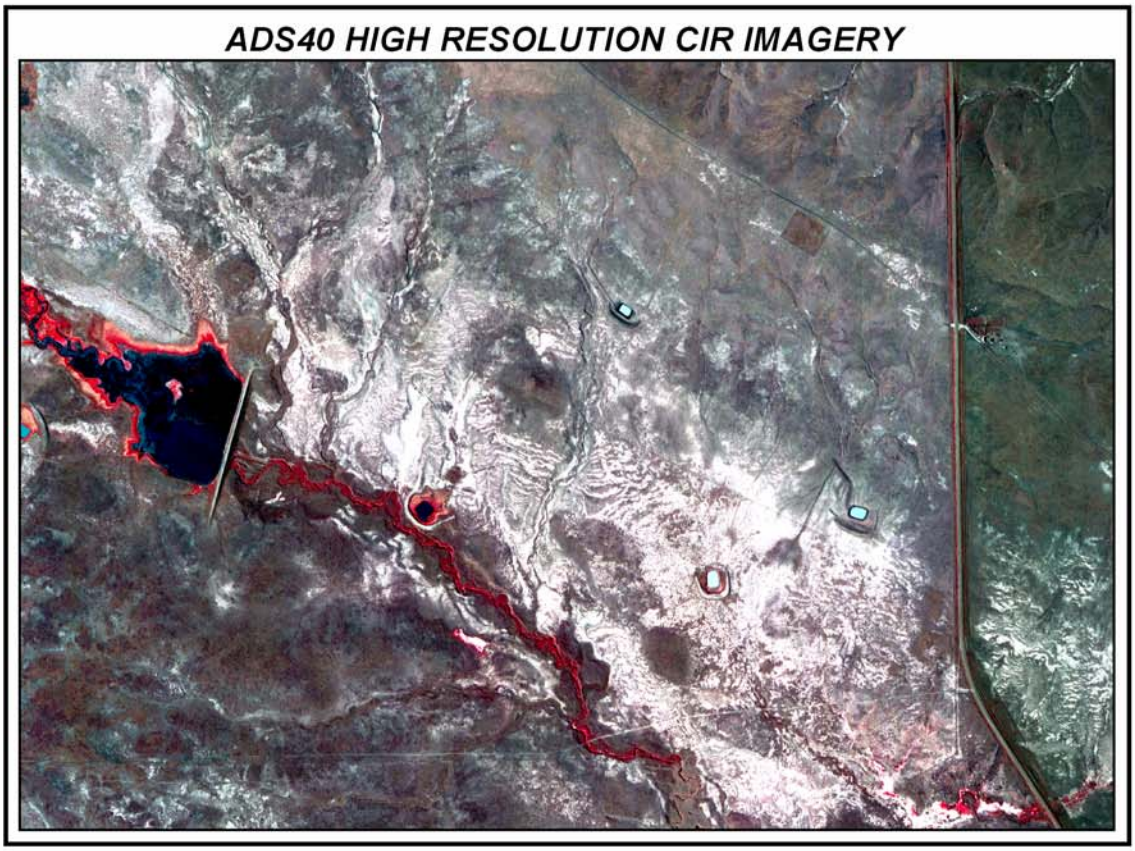
Cogan and Ode (2005) concluded that, “Recent developments in image processing and map spatial modeling techniques show promise in helping to cost-effectively and consistently sagebrush and sage grouse habitat. Of particular interest is the development of software that can tease out important semantic information by creating objects and examining their relationships to one another. At the forefront of this discipline is eCognition, a German software program that moves beyond classifying pixels to working with image objects created by segmentation algorithms. The advantage of this program is that it allows consistent, homogeneous image object extraction at any desired resolution and scale with results that mimic manual photo interpretation. eCognition also features a set of interfaces which make information about image objects, features and classification transparent and accessible.”

The data development for this project involved seven separate phases. Phase one, the ADS40 digital imagery was acquired and processed by the aerial photography contractor. Phase two, the collection of ground truth data was performed concurrent with the image acquisition and processing, to be used as training data for image processing. Phase three, the ADS40 imagery was segmented and classified with the eCognition software generating a first cut classified polygon data base. Phase four, heads-up photo interpretation was performed eCognition on classified data that fell within or was intersected by public lands, to refine the initial eCognition classification. Phase five, a random field check was performed to assess the thematic accuracy of the data development process. Phase six, development of canopy densities for sage classes. Phase seven, post processing and finalizing the data base.

2.1 IMAGE ACQUISTION

The ADS40 digital imagery was acquired on September 4, 2006 by Horizons Inc., Rapid City, South Dakota. Processing and delivery of the final image product took 4 months, with a delivery date of December 28, 2006. The imagery was delivered as a series of 451 individual tiles in GeoTIFF format. Each image tile was composed of the infrared, red and green spectral bands and is approximately .5 gigabit in size (figure 2).

FIGURE 2



Upon delivery the imagery was inspected for smears, unusual color variations, positional accuracy, study area coverage and other contractual specifications. Minor color variations were found between North/South flight lines, but were deemed as an acceptable byproduct of the ADS40 data collection methodology.

2.2 GROUND TRUTHING

Groundtruthing is defined as the process of collecting land cover information in the field in order to correlate imagery data to actual features and land cover on the ground. Ground truth data facilitates the calibration of digital imagery data, and aids in the classification and analysis of what is being remotely sensed. When the identity and location of land cover types are known through a combination of field work, maps, and personal experience, the spectral characteristics of these areas are used to train the image processing software using decision rules to classify the entire image.

From September 18, 2006 through September 21, 2006 in excess of 90 accessable locations, evenly distributed throughout the study area were visited and ground truthed (figure 3). Coordinates were monumented using a hand held real-time differentially corrected global position system unit (GPS) along with landcover information pertaining to land cover composition and estimated canopy cover density. Our ground truth effort focused on collecting information on the dominant land cover types within the study area, such as, areas representing sage, grasses, sparse vegetation and riparian zones. While the field objective was to primarily to identify areas of sage, it was just as important, in regards to the upcoming classification process, to identify land cover that were not sage. Areas visited were restricted to those accessible from public lands. No ground truthing was attempted on private lands.

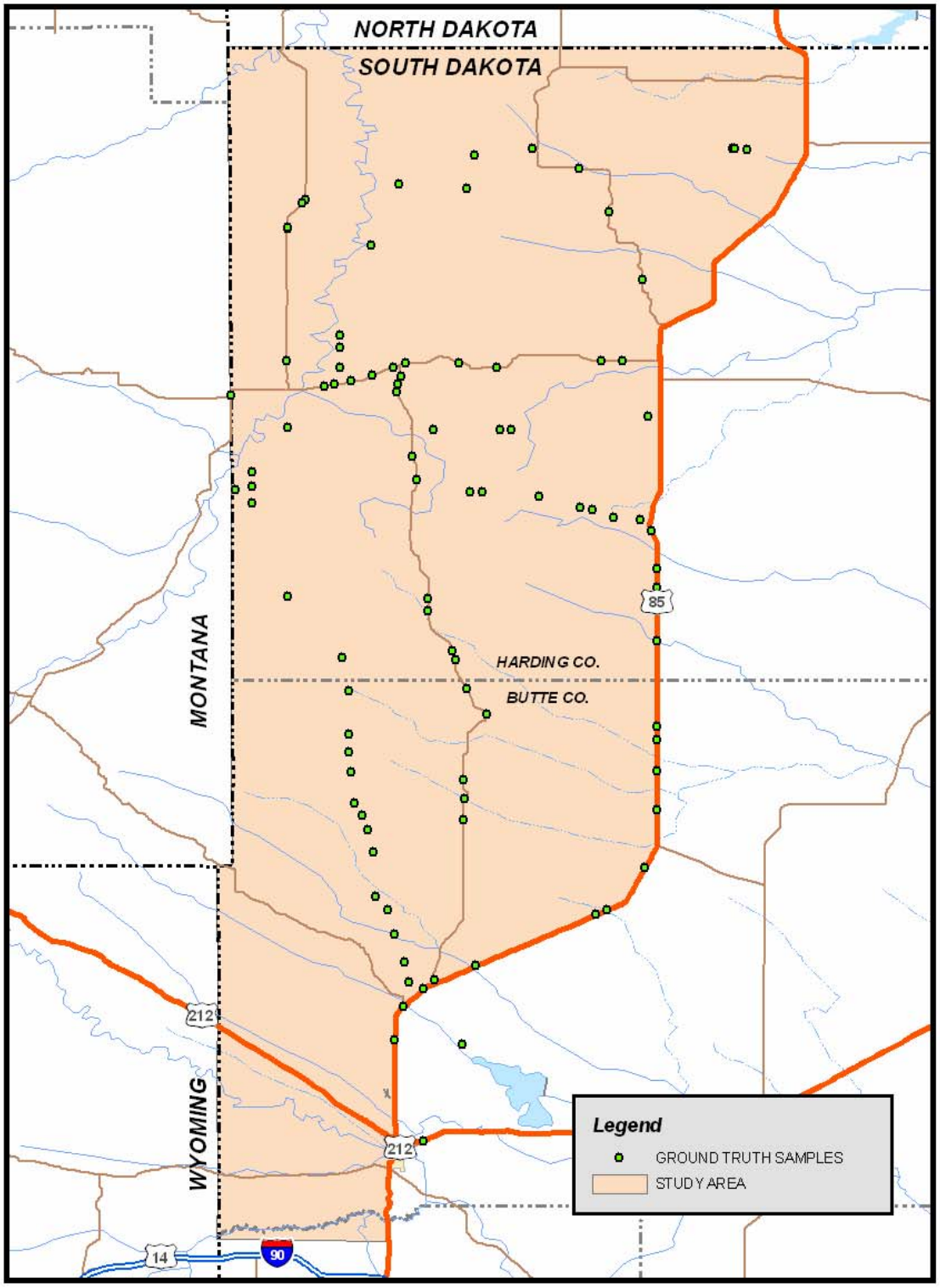
2.3 IMAGE PROCESSING

The processing of the ADS40 imagery was composed of several steps to generate a final classified object/polygon file. At the onset, it was evident that processing 451 individual image tiles would be impractical and could lead to computer integration errors. It was determined that for analytical efficiency and accuracy, the ADS40 imagery needed to be merged / mosaiced into a more user-friendly number of files but still be compatible with the image size limitations of the eCognition software. Creating a user-friendly and eCognition compatible image could be accomplished by:

1) Limiting the number of tiles used in the mosaic
2) Processing the image mosaic to a lower resolution

Limiting the number of tiles used in the mosaic would be the fail safe option although it would dictate that approximately 45 separate images be processed at the current resolution. This would have increased the image processing costs to an estimated factor of nine.

FIGURE 3


NORTH DAKOTA
SOUTH DAKOTA
MONTANA
WYOMING
HARDING CO.
BUTTE CO.
85
212
212
14
90
Legend
GROUND TRUTH SAMPLES
STUDY AREA

Processing an image mosaic to a lower resolution would create a data set that would be compatible to the eCognition size limitations. The risk with this option is that spectral information that might be invaluable in the classification process could also be reduced in quality or lost to the analysis.

A series of tests that were run comparing the spectral values and homogeneity of object files created from the original .3m x .3m imagery to a degraded .9m x .9m image revealed no significant difference between the object spectral values between the compared resolutions. Also during this evaluation process it was determined that a image created by mosaicing 90 tiles degraded to a 0.9m x 0.9m resolution would fall within the eCognition file size limitations. Based on these findings, it was decided to use both methods in such a way to produce a practical number of image files with a minimal loss of spectral information. In the end, five 0.9m x 0.9m images (Site #1 through Site #5) were created that together represented the entire study area (figure 4).

As a matter of practice as well supported by our literature review a Normalized Difference Vegetation Index (NDVI) was derived from each of the 5 image mosaics by calculating the ratio between the red and infrared bands. An NDVI is a spectral feature that exploits the strong differences in plant reflectance and has been shown to be directly related to the photosynthetic capacity (Sellers 1985 and Myneni et al. 1995).

The next step in the progression of the image processing procedure was segmentation. Segmentation is the generation of homogeneous image objects (polygons) from user defined parameters, at this point the image processing transitions from pixel base process to an image object process. It is this step that separates eCognition from most other image processing software.

The initial advantage of generating image objects is that it automates the polygon drafting and transfer stage of the traditional photo interpretation process. This equates to an estimated 70% to 80% savings in processing time and costs. Note, the thematic accuracy achieved through the eCognition process is most likely less than what would be achieved through the traditional photo interpretation process.

FIGURE 4

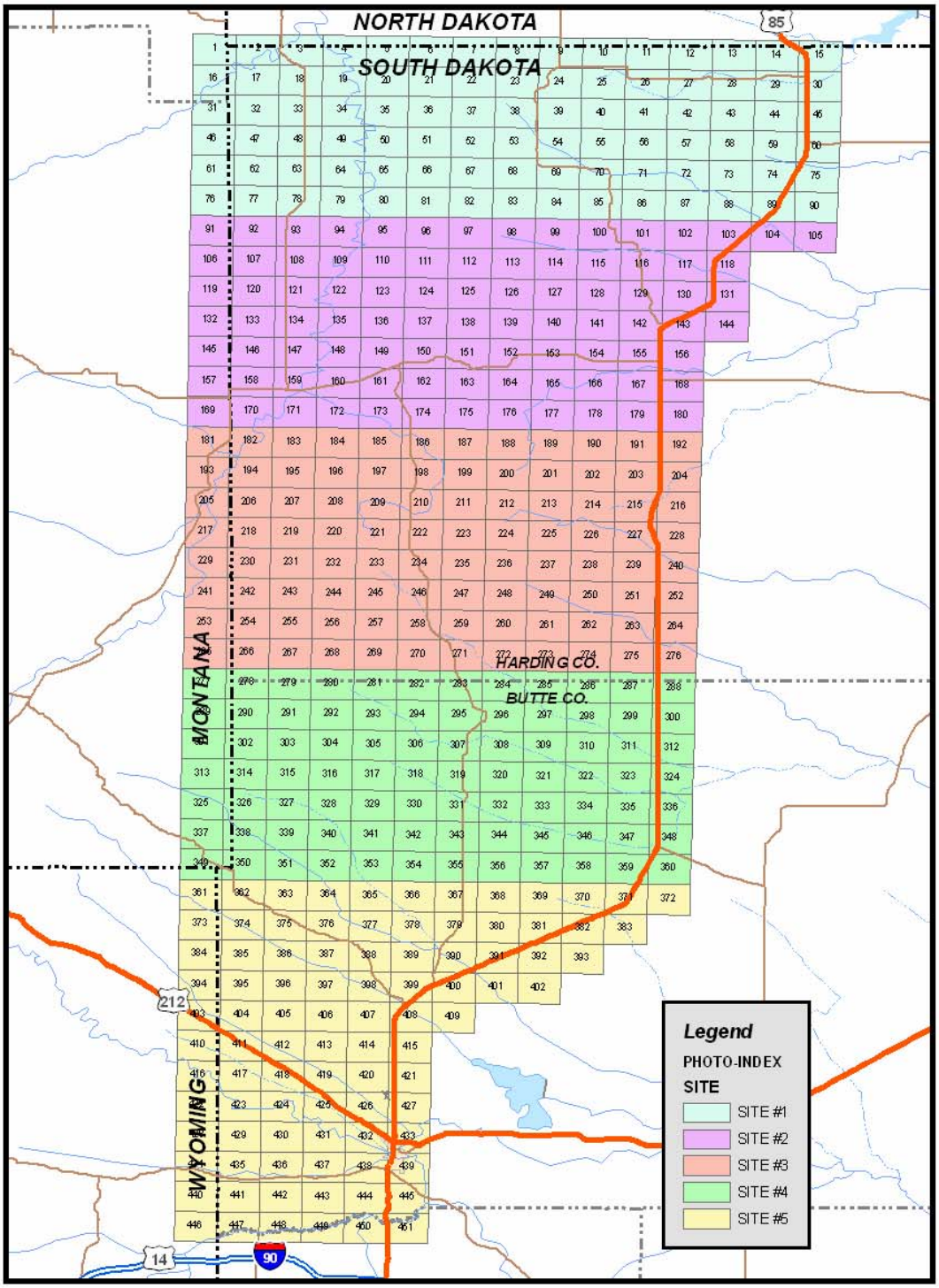

NORTH DAKOTA
SOUTH DAKOTA
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PHOTO-INDEX
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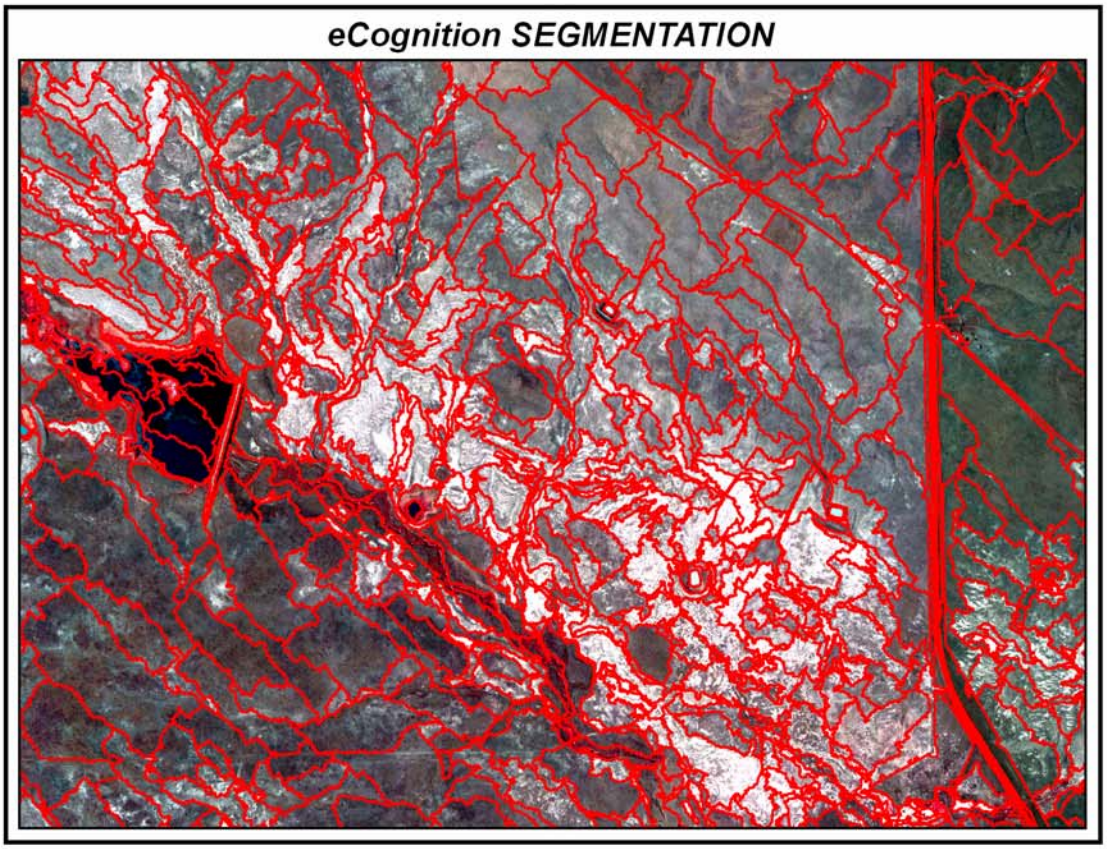
SITE #2
SITE #3
SITE #4
SITE #5

Using segmentation parameters documented in the Bureau of Land Management (BLM) research report "Mapping Sagebrush/Grasslands from Landsat TM-7 Imagery: A Comparison of Methods" (Fisher et al. 2002) as a starting point for our segmentation parameter selection, a series of segmentation tests were performed on a representative sample image to define the segmentation parameters that would produce an object file that represented the homogeneity and detail required for this study (figure 5). As was found in the BLM report weighting the IR and Red bands equally as 1.0, the green band as 0.5 and the NDVI layer as 2.0, along with lower compactness weights and higher smoothness weights produced an object file that captured the detail necessary for this study. The final scale parameter used in our segmentation increased by a factor of 10 compared to the BLM study, it is assumed that this is a result of differences in image resolutions. Segmentations were performed on all five site images, creating 5 object files unique to each site, using the following weighted parameters:

SCALE	COLOR	SHAPE	COMP.	SMOOTH	IR	RED	GREEN	NDVI
100	0.8	0.2	0.1	0.9	1	1	0.5	2.0

FIGURE 5

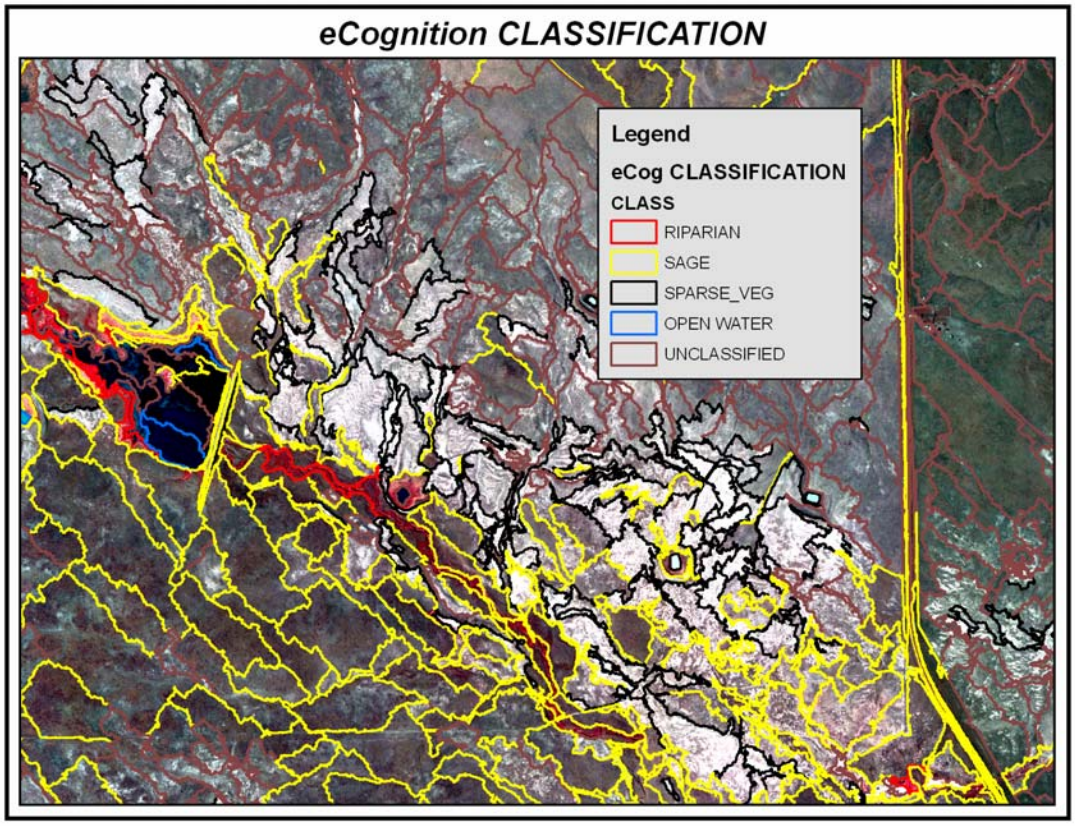


A secondary advantage to using eCognition, is that the software consists of a suite of visual classification tools that promote interaction between user and software. The classification method that was used in this project was essentially an interactive hybrid of a rules based and a supervised classification process. By combining eCognition visualization tools, ground truth data and the spectral values associated with the object polygons, including the unique band selection, band width and statistical operatives, we were able to identify the land cover classes of sage, riparian, open water and sparse vegetation throughout the study area. This analytical process was performed on each of the 5 site image sets to compensate for any spectral variation due to color balance issues between site images. In general the rules applied follows:

CLASS	BAND/LAYER	STATISTICAL OP.
SAGE	NDVI	Mean
RIPARIAN	NDVI	Mean
OPEN WATER	Infrared	Mean
SPARSE VEGETATION	ALL	Sum-Brightness

Once the classification parameters were identified, each representative site object file was classified (figure 6).

FIGURE 6

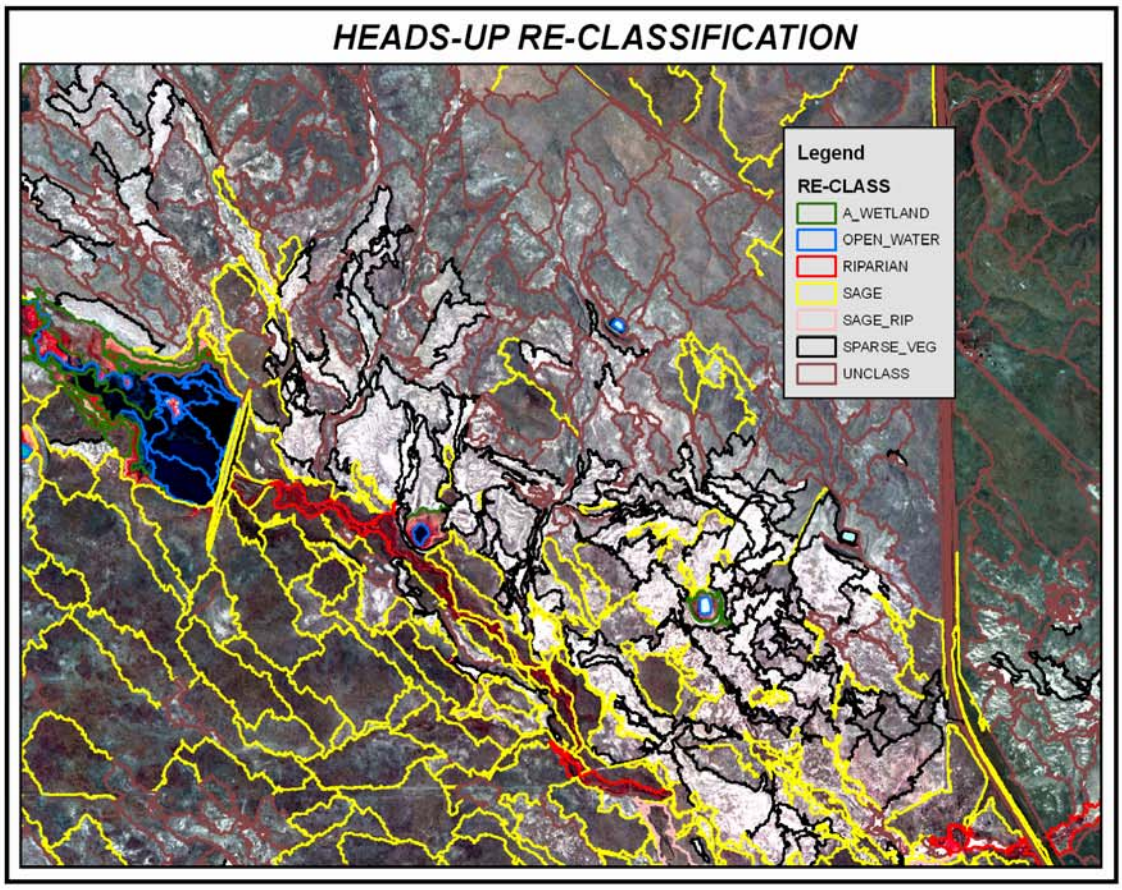


Note, although this project was not designed to identify other land covers, it would be a reasonable assumption that the majority of “UNCLASSIFIED” objects are grasses.

2.4 HEADS-UP PHOTO INTERPRETATION

The process of Heads-up photo interpretation includes panning through the classified object data overlaying the ADS40 imagery and subjectively interpreting and, if necessary, re-classifying objects mis-classified by eCognition, thus refining the initial eCognition classification. As a cost saving measure and as requested by the client, this process was performed only on classified data that fell within and or was intersected by public lands, approximately 316,000 acres. A user driven GIS interface was designed to pan through the data at a designated scale of 1:5,000 and re-classify the object data with a click of the mouse. At the onset of this process it was realized that two classes needed to be added to the overall classification to make the data set more complete and useable (figure 7). A class representing wetland areas interpreted as containing wetland species, frequently found as a perimeter to reservoirs and stock ponds was added to the classification schema and a class representing a mix of sage and riparian was also added as part of the heads-up photo interpretation process. It was found that in some cases objects classified as riparian included patches of sage or areas identified as sage also included patches of riparian, this is essentially an artifact of the segmentation process.

FIGURE 7



2.5 PROJECT CLASSIFICATION DESCRIPTION

The description of the final land cover classes mapped by this project are as follows:

Sage – Throughout the study area, Wyoming big sagebrush (A. tridentate ssp. wyomingensis) may be intermixed with herbaceous sageworts and wormwoods, along with Silver sage (*A. cana*). Native grasses, including western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Stipa* spp.) in this vegetation class is being overtaken by the invasive annual cheatgrass (*Bromus tectorum*).

Sage-Riparian – In areas associated with drainages in the study area, environmental gradients provide habitats that are associated with a mix of sage-riparian vegetation. Along the drainage, more typical riparian vegetation, such as cottonwoods (*Populus fremonti*) and willow (*Salix exigua*) grade into silver sage (*A. cana*) on the floodplain steppe grading up to Wyoming big sage (*A. tridentate ssp. wyomingensis*) on the drier soils higher in elevation. Common associated plants include rabbitbrush (*Chrysothalmus* sp.) and *gutterezia*

Wetland – natural areas of seasonal standing water found in drainages that are located in the study area typically support cattails (*Typha latafolia*) and a variety of sedges and wetland grasses. These areas are seasonally wetted and are often associated with areas of silt and clay.

Riparian – Riparian stands are found on stable bars in floodplains and along streambanks in rolling hills and foothills adjacent to upland plateaus and mesas where the water table is still high but flooding may occur occasionally. Substrates are typically relatively recently deposited alluvium with a stream gradient that is typically gentle with soils sandy to sandy and silt loam. Vegetation commonly found include willows, cottonwoods, cattails and other small shrub species. Note, only areas identified as vigorous riparian vegetation were mapped, dry drainages were not mapped.

Open Water - areas of standing water, farm ponds, and reservoirs located in the study area typically supported cattails (Typha latafolia) and a variety of sedges along the edges of the wetted perimeter. These open water areas typically support algae blooms in the summer as they warm. The majority of these open water areas are formed by small earthen dams

2.6 RANDOM FIELD CHECK

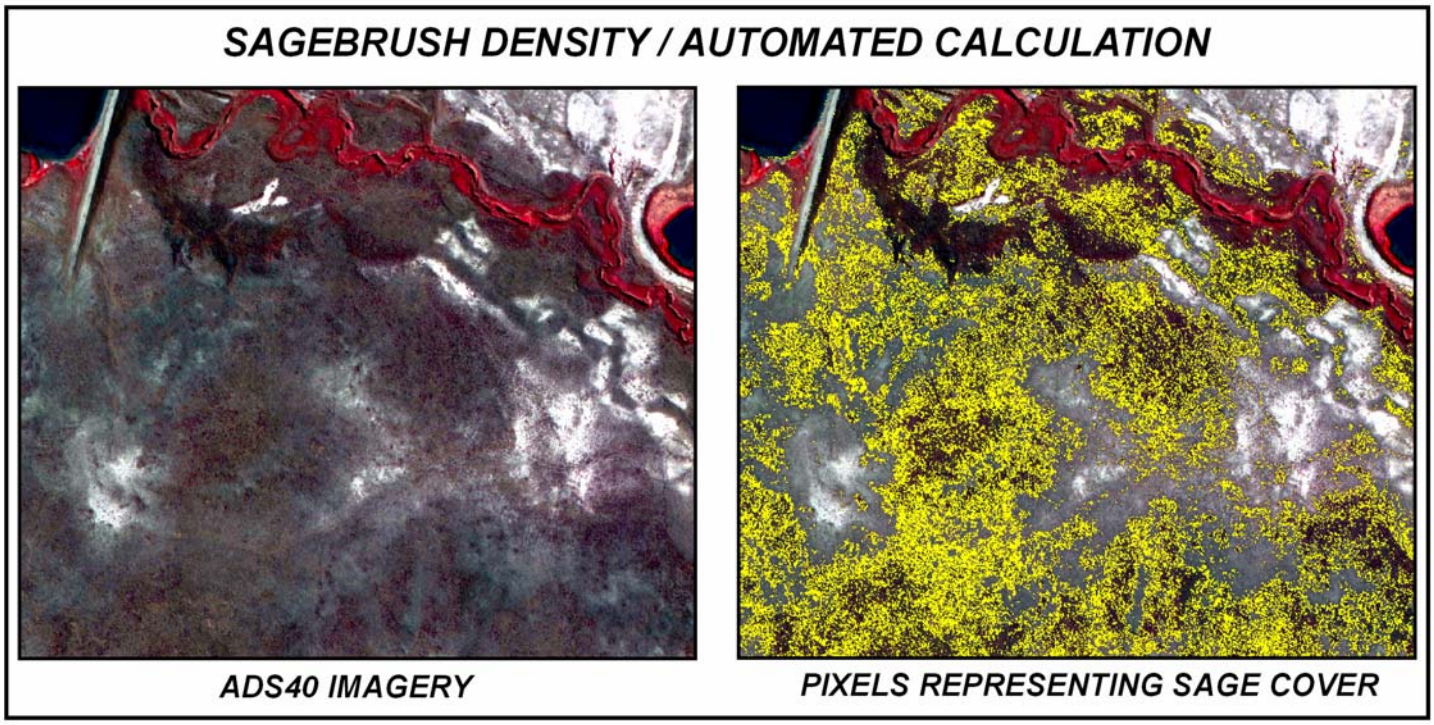
A random field check was performed to assess the quality of the classification process after the initial classification was completed.

Forty out of one hundred randomly selected sites were field checked, three sites were found to be mis-classified. Due to cost constraints, no formal accuracy assessment was contracted or completed for this study.

2.7 CALCULATING CANOPY COVER DENSITY

To further enhance the value of the land cover data, canopy density was generated for both the sage and sage riparian classes. Normally, in a project like this, density values are assigned to polygons by subjectively comparing the density represented on the base imagery to a standard density chart. The traditional method would be cost intensive due to the time it would take to make a density call on approximately 13,500 polygons. This option was considered to be viable only if an automated methodology could not be developed. Fortunately an automated methodology was developed. Using pixel based ERDAS image processing software we performed an unsupervised classification on the 5 site image mosaics, specifying 60 classes. By specifying such a large number of spectral classes to identify a very detailed breakdown of segregated spectral values was produced. The classified image output was then inspected to identify the classes unique to areas of shrubbery. The classified imagery was "Recoded" assigning a pixel value of 0 to none-shrub classes and a pixel value of 2 to classes identified as shrubs. At this point a "Zonal Attribute Function" was performed calculating the number of pixels identified as shrubbery within each polygon and with the pixel size known, calculating the percent canopy cover for each polygon. Polygons classified as sage or sage riparian were then attributed with the calculated canopy density (figure 8).

FIGURE 8



This methodology was checked by comparing canopy densities derived from the traditional methodology to canopy densities based on the automated methodology. Out of the 40 randomly selected polygons checked, the average difference between the two methodologies was 3% to 4%. Because the accuracy canopy densities were not formally assessed it was decided to attribute the final data by density ranges that provided room for error:

1) Densities calculated as less than 10% were attributed as "LOW"
2) Densities calculated between 10% and 20 % were attributed as "MEDIUM"
3) Densities calculated as greater than 20% were attributed as "HIGH"

Note, calculated density never exceeded 40%.

2.8 POST PROCESSING

Several editing steps were needed to finalize the sage data set. All five classified polygon data sets representing the individual sites were merged. Seams between merged sites were edited for inconsistencies. Polygons sharing common boundaries and attributes were dissolved into one. A final thematic accuracy assessment was performed by mimicking the heads-up photo interpretation process described in section 2.4 throughout the entire study area. A sample plot, "Sagebrush Mapping in Portions of Harding and Butte Counties" representing the classes within the final GIS data can be found as a foldout at the back of this report.

RESULTS

Acreages were calculated for each class polygon and added as an attribute to the final GIS data set. The sum acreage calculated for each class within or intersecting publicly owned lands, (approximately 316,000 acres in total) within the study area include:

1) Wetland - 249 polygons = 511 acres
2) Open Water – 746 polygons = 1,091 acres
3) Riparian - 1659 polygons = 4,946 acres
4) Sage Riparian – 1450 polygons = 6,603 acres
5) Sage – 12108 polygons = 160,088 acres

The unmapped portion of the public lands within the study area, approximately 142,761 acres, is assumed to be land cover representing agricultural, grasses or forest.

The final GIS data set in ESRI *Shapefile* format can be found on the CD attached to the back cover of this report. A hard copy of the metadata associated with the final GIS data set can be found in Appendix I at the back of this report.

DISCUSSION

Recent advances in imagery acquisition and processing technology present exciting opportunities for mapping and evaluating vegetation in a cost effective manner. The results produced here represent an effective integration of these new technologies with existing computer digitizing methods and field expertise. This effort successfully tested and confirmed the viability of using high resolution multi-band color infrared digital imagery along with object oriented image processing to identify and map sagebrush. This ability to automate much of the traditional mapping and classification process allowed a large area to be rapidly evaluated for potential sage grouse habitat in the State of South Dakota. The costs incurred by using this methodology are estimated at $0.54 per-acre compared to the $2.00 per-acre using traditional methodologies. Results from this study seem to indicate that our methods can provide land and species managers with a powerful mapping tool to rapidly access vegetation across large landscapes. Although the results are encouraging it should be noted that the thematic accuracy obtained in this study is likely less than the accuracy of a similar product produced by more traditional methods.

Our objective was to collect and analyze imagery of the study area that would allow for the determination of sagebrush vegetation communities at a level of detail that would provide land and resource managers the information required to make decisions regarding future conservation actions.

The project was divided into three phases:

Phase I.	Evaluation and comparison of different remote sensing methods for mapping sagebrush and associated types across using existing 1:12,000-scale ortho-photography. Accomplished using identified pilot study sites in the study area.
Phase II.	Utilize analytical technology to perform initial assessment of the entire study area.
Phase III.	Conduct field and laboratory review of the analytical approach, complete density evaluation of sagebrush stands and develop the final product.

Five vegetation assemblages were identified through the study process: Wetlands; Open Water; Riparian; Sage-Riparian; and Sage. Polygons of each vegetation assemblage were delineated through the eCognition process and verified through both a Heads-Up analytical analysis and a refined field check.

Results from the studies show that the utilization of eCognition software integrated with field studies and heads up computer analysis can provide land and species managers with a tool to evaluate large areas of landscape.

Two technical process components were identified during the course of the study that should be addressed in future applications of the eCognition process as associated with vegetation analysis:

1) Request imagery from aerial contractor in file sizes immediately compatible with eCognition
2) Work with aerial contractor to produce an image product with as error free as possible

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APPENDIX I

Metadata

SAGE_MASTER_Dissolve
Metadata also available as

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Distribution_Information
- Metadata_Reference_Information

Identification_Information:
Citation:
Citation_Information:
Originator: Patrick Wright, Contractor for the Bureau of Reclamation
Publication_Date: 09/2007
Title: SAGE_MASTER_Dissolve
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage:
\\IBR8PWRIGHTL1\C$\sage_grouse\intagrate\master_int\SAGE_MASTER_Dissolve.shp
Description:
Abstract:
These data were generated as a cooperative project between the South Dakota Dept. Game, Fish & Parks, Bureau of Land Management and the Bureau of Reclamation for the purpose of mapping sagebrush in portions of Harding and Butte Counties of western South Dakota.
Purpose:
The importance of sagebrush for many obligate species including sage grouse (Centrocercus urophasianus) is well documented. In South Dakota the two remnant sage grouse populations remain in the northwest corner of Harding and Butte counties and the southwest corner of Fall River County. Because of the observed abandonment of some leks and reduction in nesting sites it was deemed important to establish a baseline on the location and quality of potential habitat.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 09/2006
Currentness_Reference: September 2006
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:

West_Bounding_Coordinate: -104.067732
East_Bounding_Coordinate: -103.384492
North_Bounding_Coordinate: 45.952136
South_Bounding_Coordinate: 44.636748
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword: SAGEBRUSH
Theme:
Theme_Keyword: SAGEGROUSE
Place:
Place_Keyword: SOUTH DAKOTA
Access_Constraints: To be determined by South Dakota Dept. Game, Fish & Parks
Use_Constraints: To be determined by South Dakota Dept. Game, Fish & Parks
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Patrick Wright
Contact_Organization: Bureau of Reclamation
Contact_Position: Environmental Scientist / Contract Task Lead
Contact_Address:
Address_Type: mailing address
Address: USBR Denver Federal Center, MC 86-68260,POB 25007
City: Denver
State_or_Province: Colorado
Postal_Code: 80225
Country: USA
Contact_Voice_Telephone: 303-445-2288
Contact_Facsimile_Telephone: 303-445-6337
Contact_Electronic_Mail_Address: pwright@do.usbr.gov
Hours_of_Service: 7:00am to 6:00pm
Security_Information:
Security_Classification_System: To be determined by South Dakota Dept. Game, Fish & Parks
Security_Classification: Unclassified
Security_Handling_Description: To be determined by South Dakota Dept. Game, Fish & Parks
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.1.0.722

Data_Quality_Information:
Attribute_Accuracy:

Attribute_Accuracy_Report:
No formal thematic accuracy check has been performed on data set. An informal check of 38 random polygons identified 3 miss-classified polygons.
Logical_Consistency_Report: 1) Repair Geometry
Completeness_Report:
Data set represents polygons that fall within or intersect public lands as defined by the BLM 100k landownership data base.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
The data set was generated from ADS40 imagery at a relative scale of 1:12,000
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: 33 feet
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: NA
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Title: Horizons Inc. Rapid City S.D.
Source_Scale_Denominator: 1:12,000
Type_of_Source_Media: ADS40 CIR Imagery
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: Sept. 2006
Source_Currentness_Reference: Flight Date
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation:
C:\sage_grouse\sample_data\SHAPEFILES\SITE4_CLIPPED_SB_Dissolve.shp.xml
Cloud_Cover: NA

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 16268

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator

Universal_Transverse_Mercator:
UTM_Zone_Number: 13
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -105.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000256
Ordinate_Resolution: 0.000256
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: SAGE_MASTER_Dissolve
Entity_Type_Definition:
Thematic land cover class defined initially by image processing and refined by photo interpretation
Entity_Type_Definition_Source:
Image processing for entire study area and detailed photo interpretation for public lands
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: SUM_CLASS
Attribute_Definition: Landcover Class

Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: A_WETLAND
Enumerated_Domain_Value_Definition: Identified wetland areas
Enumerated_Domain:
Enumerated_Domain_Value: OPEN_WATER
Enumerated_Domain_Value_Definition: Identified water bodies
Enumerated_Domain:
Enumerated_Domain_Value: SAGE
Enumerated_Domain_Value_Definition: Identified areas of sage
Enumerated_Domain:
Enumerated_Domain_Value: SAGE_RIP
Enumerated_Domain_Value_Definition: Identified areas of sage and riparian vegetation mix.
Enumerated_Domain:
Enumerated_Domain_Value: RIPARIAN
Enumerated_Domain_Value_Definition: Identified areas of riparian vegetation
Attribute:
Attribute_Label: SUM_DENS
Attribute_Definition:
Calculated % canopy cover of classified sage or sage riparian polygons
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: LOW
Enumerated_Domain_Value_Definition: Canopy cover of less than 10%
Enumerated_Domain:
Enumerated_Domain_Value: MEDIUM
Enumerated_Domain_Value_Definition: Canopy cover between 10% and 20%
Enumerated_Domain:
Enumerated_Domain_Value: HIGH
Enumerated_Domain_Value_Definition: Canopy cover of greater than 20%
Attribute:
Attribute_Label: AREA_m2
Attribute_Definition: Area of polygon in square meters
Attribute:
Attribute_Label: Acres
Attribute:
Attribute_Label: Area_dens

Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Christopher Marsh
Contact_Organization: South Dakota Game, Fish and Parks
Contact_Position: Wildlife Biologist

Contact_Address:
Address_Type: mailing address
Address: 523 East Capitol Ave.
City: Pierre
State_or_Province: South Dakota
Postal_Code: 57501
Contact_Voice_Telephone: 605-773-2868
Contact_Electronic_Mail_Address: Christopher.Marsh@state.sd.us
Resource_Description: To be determined by South Dakota Dept. Game, Fish & Parks
Distribution_Liability: To be determined by South Dakota Dept. Game, Fish & Parks
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 375.721
Fees: To be determined by South Dakota Dept. Game, Fish & Parks
Ordering_Instructions: To be determined by South Dakota Dept. Game, Fish & Parks
Turnaround: To be determined by South Dakota Dept. Game, Fish & Parks
Custom_Order_Process: To be determined by South Dakota Dept. Game, Fish & Parks
Technical_Prerequisites: To be determined by South Dakota Dept. Game, Fish & Parks

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Metadata_Reference_Information:
Metadata_Date: 20071113
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Patrick Wright
Contact_Organization: Bureau of Reclamation
Contact_Address:
Address_Type:
REQUIRED: The mailing and/or physical address for the organization or individual.
City: REQUIRED: The city of the address.
State_or_Province: REQUIRED: The state or province of the address.
Postal_Code: REQUIRED: The ZIP or other postal code of the address.
Contact_Voice_Telephone: 303-445-2288
Contact_Facsimile_Telephone: 303-445-6337
Contact_Electronic_Mail_Address: pwright@do.usbr.gov
Hours_of_Service: 6:00am to 7:pm
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998

Metadata_Time_Convention: local time
Metadata_Access_Constraints: To be determined by South Dakota Dept. Game, Fish & Parks
Metadata_Use_Constraints: To be determined by South Dakota Dept. Game, Fish & Parks
Metadata_Extensions:
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile