DESERT LANDSCAPE CONSERVATION COOPERATIVE VEGETATION MAP PILOT REPORT

Miguel A. Pavon

MAP.

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Prepared by:

Author

Miguel A. Pavon

Report Graphics

Miguel A. Pavon

Cover Page Photo Credits:

Rio Grande at Big Bend:	Daniel Pearson
Joshua Trees:	John Fulton
DLCC artisanal lunch:	Aimee Roberson

Contractor: Miguel A. Pavon, under:

USGS

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Contact information:

Miguel Pavon, *Contractor* *MAP* 1312 Richcreek Rd. Austin TX, 78757 Ph. U.S.A: (512) 380-9112 Tel. México: (814) 737-4835 **pavonma@hotmail.com**	**Genevieve Johnson,** DLCC Coordinator Bureau of Reclamation 6150 W. Thunderbird Rd. Glendale, AZ 85306 (623) 773-6206 office **gjohnson@usbr.gov**

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The cooperative part of the DLCC relies on existing and future collaboration and good will of its members. This work will help facilitate and promote partnership and communication among conservation members and entities to support and add value to their efforts to respond to climate change and other stressors and to integrate scientific information into resource management plans and conservation projects on the ground.

Abstract

In summer 2014 the need for an updated, transboundary and adequate resolution vegetation map was recognized in the first international Desert Landscape Conservation Cooperative (DLCC) meeting in Aguascalientes, Mexico. The DLCC science community saw the usefulness of an updated vegetation map. This land cover data provides a snapshot in time that can be accessed in the future and compared with newer data to identify where land practices are working and where additional efforts are needed to address problems that are too large in scope for any one land owner, agency, organization, or individual to solve alone, therefore the need for cooperation. Resource managers and scientists working in the DLCC region have identified Object Oriented Classification as a superior method to cover the need for a comprehensive, binational land cover map to ensure informed resource management decisions. Object-Oriented Image Classification method is a method of classifying objects from moderate to high-resolution satellite images[1].

In 2014-2015, the DLCC invested in a Land Cover Pilot Project to develop a repeatable, efficient methodology that meets the spatial resolution, binational integration, and extent requirements for addressing critical management questions. The method segments the image pixel into objects and utilizes the texture and contexture information of the object rather than only using spectral information relied upon by traditional methods. Additionally, in a pilot area, transboundary Digital Elevation Model (DEM) and slope were used as additional context. Object Oriented Classification software was used to define vegetation classes in a pilot project using Landsat tiles for multiple seasons in two pilot areas.

This pilot methodology will serve as a foundation for a larger follow-on effort covering the span the U.S.-Mexico trans-boundary ecoregions of Mojave Desert, Madrean Archipelago, Sonoran Desert, and Chihuahuan Desert, the whole DLCC area.

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Chapter 1: Introduction

The Desert Landscape Conservation Cooperative (DLCC) is a bi-national partnership between diverse entities, public and private, landscape stewards, in the United States and Mexico. DLCC's Vegetation Map Pilot is a project envisioned initially as a supervised classification of two or three small areas of the DLCC. The pilot project was suggested by Miguel Pavon (MAP) and deemed convenient and necessary at the First International DLCC meeting in Aguascalientes, Mexico (July 2014). In May 2015 collaboration was agreed between BOR, USGS and MAP for the Vegetation Map Pilot project.

Using input from the DLCC Steering committee and members, two pilot areas were defined in a Site Selection Project performed by Cortney Roe, Austin Community College, during her internship at USGS. The selected two pilot areas are covered by a total of 6 Landsat Tiles, two in site A and four in site B. On December 2015, DLCC technical stakeholders advised changing from a supervised classification to an object oriented classification (OOC) method.

This report presents the findings, feasibility, and lessons-learned during the exploration and object oriented classification process and results of the two sites on the United States-Mexico border, this is needed information before considering a full-scale, Vegetation Mapping Project, to include bigger areas or the totality of the Desert LCC region.

1.1 Literature Review

Desertification and shrub intrusion into grasslands in the southwestern United States is of concern because increased shrub cover leads to declines in species diversity, water availability, grazing capacity, and soil organic matter[2]. Such concern extends into Mexico[3,4]. Desertification is one of the major environmental problems facing the countries located in arid and semi-arid climates[5–7]. The Desert Landscape Conservation Cooperative (DLCC) offers avenues, skills, and resources to assemble and coordinate collective action to succeed in landscape conservation, fighting desertification in five states traversing the major desert regions of the Southwestern United States and ten states in Northern Mexico[8].

One common application of remotely-sensed images to landscape management is the creation of maps of land cover, vegetation type, or other discrete classes by remote sensing software. Landsat 8 is the latest NASA satellite in a series that has produced an uninterrupted multispectral record of the Earth's land surface since early 1970s[9–11]. This data series is the longest continuous history and recording of changes in the Earth's surface from space[12,13]. Landsat 8 provides an extended number of spectral bands (two additional bands provided, *Figure 1*) and narrower bandwidths compared to Landsat 7[14]. The push-broom scanner of the Operational Land Imager aboard Landsat 8 produces increased radiometric resolution which is quantized using 12 bits, compared to the whisk-broom scanner of the Thematic Mapper Plus imager on Landsat 7, which is quantized using 8 bits[14,15]. The reflective bands and thermal bands are split into two instruments: the Operational Land Imager (OLI, 8 bands at 30 m. spatial resolution plus one panchromatic band at 15 m.) for the reflective information and the Thermal

Infrared Sensor (TIRS, 2 bands at 100 m., re-sampled and co-registered at 30 m.), for the thermal bands[11,16]. In addition to these fundamental changes, numerous other enhancements were implemented (two push-broom scanners (OLI and TIRS), a deep blue visible channel (band 1), new infrared channel (band 9), new quality assurance band, two bands in the thermal sections of the spectrum, etc.)[13]. USGS provides a graphic comparing the spectral range and bandwidths of Landsat t's ETM+ sensor to Landsat 8's OLI and TIRS[11], *Figure 1*.

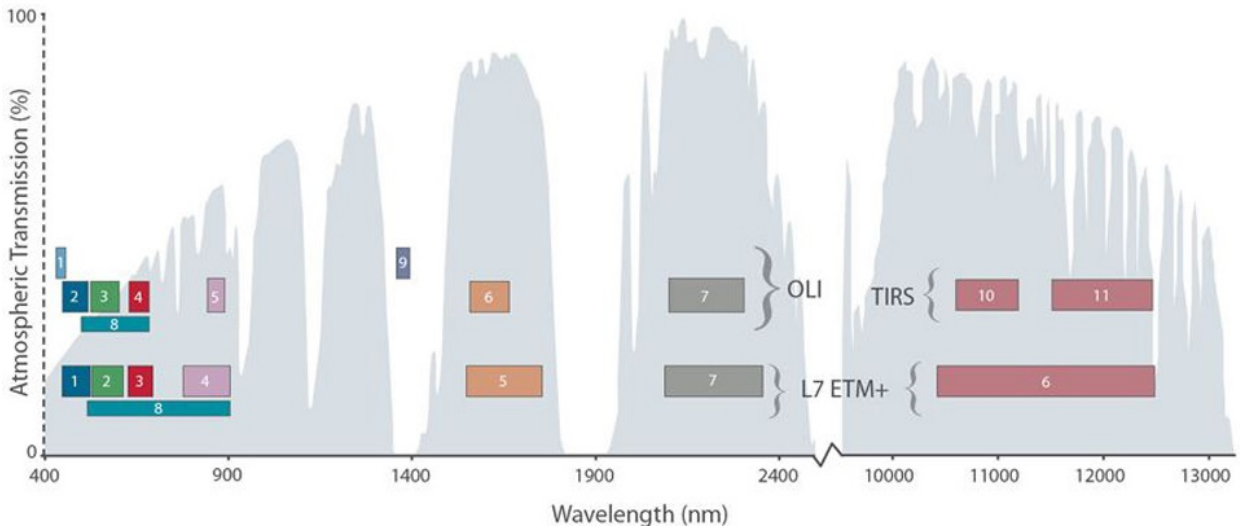

Figure 1. Landsat 8 spectral bands and wavelengths compared to Landsat 7[11]

Bands 2, 3 and 4 of Landsat 8 correspond to the visible blue, green and red wavelengths, what our eyes can see. Of special interest for desert vegetation mapping is band 5 which measures the near infrared, invisible to our eyes but very useful since healthy vegetation reflects it. The chlorophyll content in the spongy mesophyll of the leaf of photosynthetically-active plants scatters this wavelength back into the sensor allowing us to map more precisely than just using the visible wavelengths. Band 6 and 7 cover two regions of the shortwave infrared. This portion of the spectrum can help detect humid from dry terrain, rocks and soils[10,11].

Landsat imagery provides information that is not only multispectral but can be used in a multitemporal collection of granules that can be stacked together. This allows over the course of a year to use phenological differences to effectively discern-map plant communities, and over the course of several years to map broad changes over the landscape [11].

The first instance of remotely sensed image classification dates from 1965[17]. Isodata was then a novel analysis method of remotely sensed data, it was called unsupervised classification[17]. In it, image processing software classifies an image based on natural groupings of the spectral properties of the pixels, without the user specifying how to classify any portion of the image until the final step in the classification, in which the image analyst assigned land cover class labels to the spectral clusters. Better defined classifications systems were developed to set a framework for national use and land cover system in the mid 1970s[18,19]. Computer-assisted methods lead the way to supervised classification[20] and fuzzy supervised classifications[21] in which the user selects representative samples for each land cover class in the digital image.

These samples of land cover classes are called “training sites”. The image software uses the training sites to define statistics which characterize the multispectral measurements representing land cover classes. These statistics are used in a supervised classification to identify the land cover classes in the entire image[22]. In the early 2000s, object-oriented classification began providing a valid alternative to traditional pixel-based methods[1,23–32]. Object-Oriented classification methods do not work with individual pixels but groups of pixels[33], these objects are created via segmentation from pixels that are contiguous and have similar spectral or thematic characteristics. Then the objects are assigned to a specific class according to the class's detailed description in the image classification process[33–37].

Accuracy assessment of classified imagery is an important task in remote sensing[38–41]. Most literature that compares pixel based vs object-based classifications reports that the object-oriented approach gave more accurate results than those achieved with pixel-based algorithms over the same area[22,29,36,37]. The classification accuracy of object-oriented image classifiers generally is higher than that of traditional pixel-by-pixel classifiers[42]. Object-oriented image classification has tremendous potential to improve classification accuracies in landscape land cover[43], and is identified as an alternative leaning to replace pixel-based approaches[44]. A single standardized method of accuracy assessment and reporting may be associated with problems or deficiencies[45]. It is stressed that the widely used target accuracy of 85% can be inappropriate and that the approach to accuracy assessment adopted commonly in remote sensing is pessimistically biased[46]. Use of multitemporal imagery (Landsat 8 in this instance) and the selection of an appropriate classification method are especially significant for improving classification accuracy[47].

1.2 The Land Cover Pilot Project

DLCC science uses geospatial datasets that cover northern Mexico and the southwestern United States, with data at spatial and temporal scales appropriate to land management, scientific research, and discussion of conservation design efforts. Three priority habitats of focus for the DLCC are arid grasslands and shrublands, spring habitats, and stream (riparian) habitats[48]. A land cover map at a landscape scale of 30-meters is required as a foundation for DLCC science in these priority habitats[49].

DLCC working groups [50] work together to respond to Critical Management Questions (CMQs) for conservation planning and design[51]. Currently, the Commission for Environmental Cooperation (CEC) 2010 North American Land Cover dataset with a grid cell resolution of 250 x 250 meters is the land cover data available to the public that spans the DLCC area of interest. There are land cover datasets that cover the U.S. portion or the Mexican portion but not a higher resolution datasets that cover the whole DLCC region. To better manage and conserve resources within the DLCC, a higher resolution land cover dataset, that is consistent along the extent of the DLCC boundaries will allow for landscape-scale analysis, establishing current conditions of the desert landscape, change detection and therefore better-informed science and decision making.

1.3 Study Area

The DLCC is a multinational effort between the United States and Mexico stakeholders, which spans the Mojave Desert, Sonoran Desert, Chihuahuan Desert, and Madrean Archipelago ecoregions.

The DLCC area is complex in slope and topography, it includes three major deserts (Mojave, Sonoran, and Chihuahuan), which contain valley bottoms, and isolated mountain ranges called sky islands. The study area includes high altitude grasslands and shrublands. Elevations range from sea level to over 3,000 m. The DLCC also is served by several large hydrologic systems, counting the lower Colorado, Gila, Rio Grande, San Pedro, Sonora, Yaqui, and Concho Rivers. The topography variety supports equally diverse species composition and habitat for native plants, fish and wildlife, including endemic species that are susceptible to climate change impacts.

Habitats of special interest are arid grasslands and shrublands, spring habitats, and stream (riparian). As a basis for science in these habitats, a land cover map at a landscape scale or a resolution of 30 x 30 meters grid cell size or smaller is required. In order to investigate the resources and processes needed to produce a DLCC land cover map for the extent of the DLCC region, land cover classification was conducted over 2 pilot areas within the DLCC, *Figure 2.* A proposal for DLCC-wide land cover production will be produced based on the products and findings of the pilot area data classification process.

In order to investigate the resources and processes needed to produce this dataset for the extent of the DLCC region, a project has been underway since October 1, 2014, to produce a

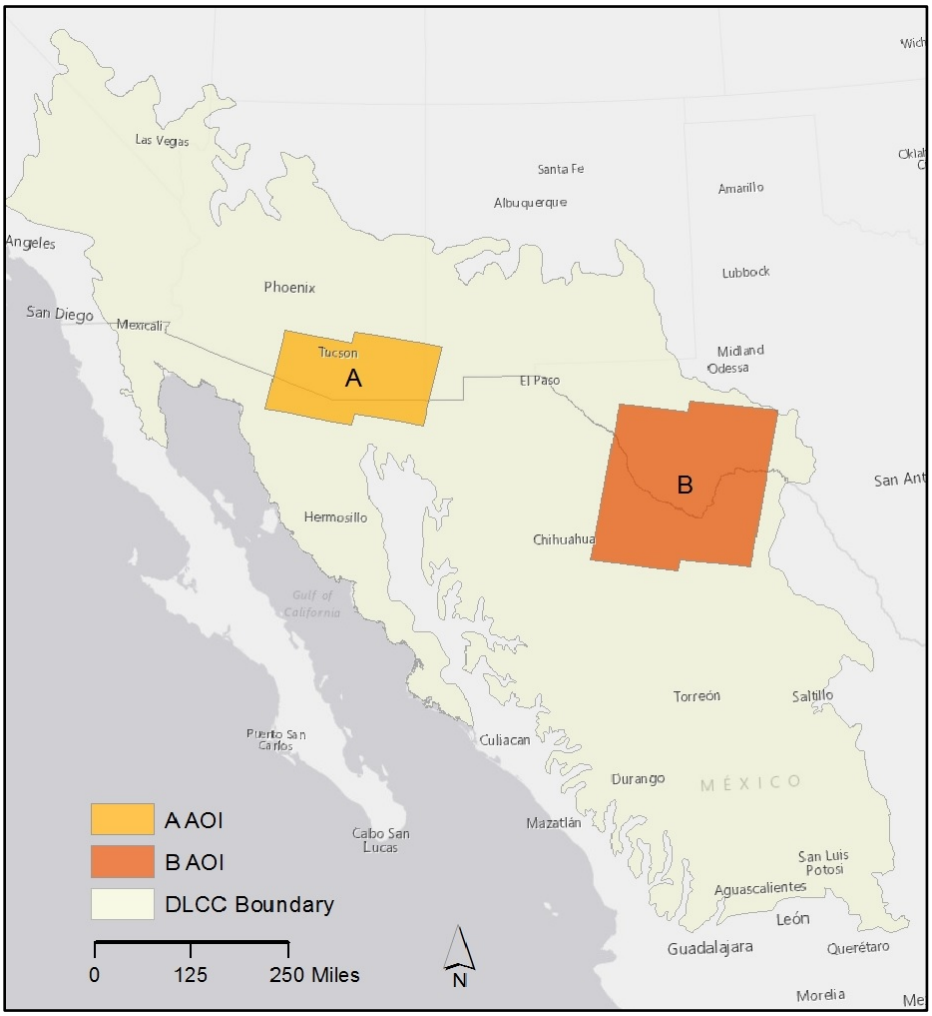

Figure 2. Pilot zones A and B in the context of the DLCC boundary and the U.S.-Mexico International Border.

land cover map for two pilot sites in the DLCC region. There was a site selection study by Courtney Roe (ACC[49]) that was based on the criteria and methods used in the selection of a pilot site, came with recommendations for Site A and B. The procedure for completing the site selection analysis included the following tasks: First, data related to the stakeholder criteria were compiled and pre-processed. Next, the criteria were weighted or ranked. The percent cover of the priority habitats and stakeholder boundaries were assessed, and lastly, the site selection analysis was performed. At the end of the analysis, sites A and B were identified.

The input from Stakeholder nominations guided the criteria for site selection. During the Stakeholder Input session nominations for areas of the Riparian extent around the San Pedro River, the Sky Islands region, the Santa Cruz and San Pedro Rivers, and the Big Bend to Maderas del Carmen. The Landscape Conservation Planning and Design nominations were accepted in July 2015 and included as areas of importance to land cover mapping for the Vegetation Map

Pilot Project. To include the natural boundary of DLCC with political boundaries, the border between the United States and Mexico was a top criterion. Data available for the United States and Mexico vary in resolution and availability, so an assessment along the border is of highest importance for the pilot project.

1.3.1 Ecological Regions

Pilot Site A intersects sections of the Sonoran Desert and the Madrean Archipelago, while Site B is in the Chihuahuan desert. Both pilot instances as defined in the site selection criteria are binational, *Figure 3.* Even when in some instances different land management practices are evident between the two countries (segments of borderline are visible in many imagery datasets), the ecological systems are for the most part border transparent the overall ecological system persists across the international border.

The Sonoran Desert is an arid region that includes areas of California and Arizona in the United States and is shared by the Mexican State that gives its name: Sonora. Winter storms and seasonal humid winds from the Pacific Ocean foster great biodiversity.

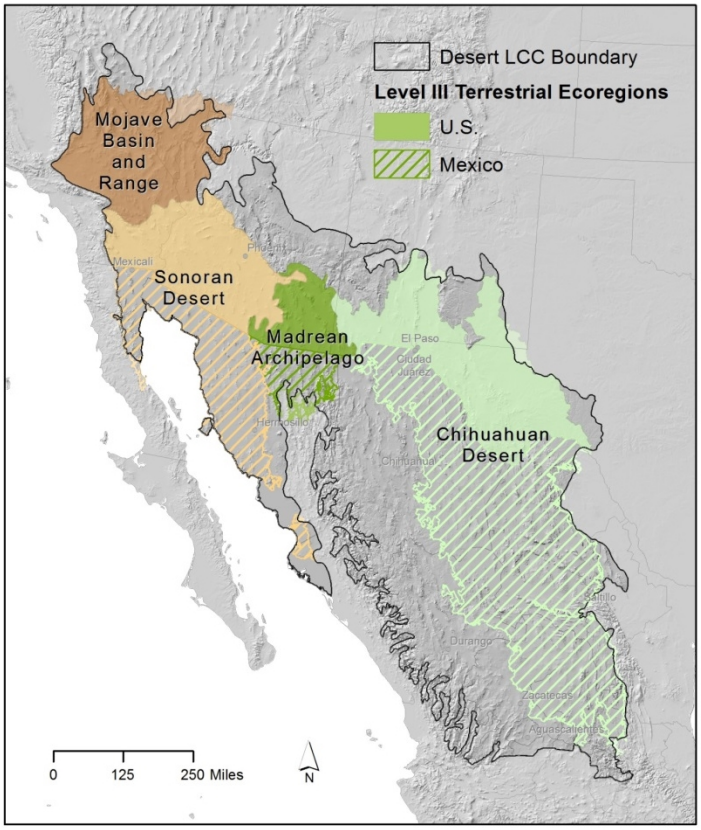

Figure 3. The Desert Landscape Conservation Cooperative spans four terrestrial ecoregions, including three deserts. (Credit: Desert Landscape Conservation Cooperative, http://www.usbr.gov/dlcc/)

The Chihuahuan Desert is an arid ecoregion that covers the US-Mexico border in the central and northern portions of the Mexican Plateau. It covers in the U.S. part of southeast Arizona, southern New Mexico and West Texas, while in Mexico, most of Chihuahua and Coahuila, western Nuevo Leon, eastern Durango, Zacatecas and northwest San Luis Potosi.

Chapter 2: Methodology

2.1 Overview

Object-oriented image classification involves identification of image objects, or segments, that are spatially contiguous pixels of similar texture, color, and tone[24]. This permits for consideration of shape, size, and context as well as spectral content to be used in the image classification. That is, Object-Oriented classification methods do not work with individual pixels but rather with image segments that are contiguous and have similar spectral or thematic characteristics. Image objects are allocated to a particular informational class according to the class's in depth description in the image classification process[33–37].

Object-oriented classifiers more closely resemble the elements of manual photo–interpretation (like the ones used in INEGI's land cover dataset series V). Objects created by segmentation have sizes and shapes that can be measured, as can the distance of one type of object from another (i.e.: a pixel containing the spectral properties of grassland may be in the middle of a pasture or inside a building complex), this can be discerned by ancillary information like distance, elevation, slope or contiguous pixels' information.

Object oriented classification speeds the land cover mapping process by allowing the image analyst to accept the automated classification for the more reliably-mapped land cover classes, while allowing for manual editing, checking and classifying of those areas that cannot be dependably mapped by the automated process[24]. The larger the area of interest, the greater the prospective advantages of semi-automated procedures.

2.2 Site Selection

What is a "priority habitat" for DLCC? The DLCC Priority Habitats are arid grasslands, shrublands, spring habitats, and stream (riparian) environments. Priority data and conservation science needs were identified through criteria defined by the Steering Committee in January 2012[48]. Priority habitats are of significant environmental concern because the flora and fauna are highly stressed by climate change and land use practices. The environmental stressors impact spring and stream flows, channel dynamics in addition to the amount of water and soil moisture required to sustain the grasslands, shrublands, and riparian habitats and their species.

An important part of the site selection process includes stakeholder delineations that were involved in the analysis, those are: Bureau of Reclamation lands, Bureau of Land Management, Sonoran Joint Venture and Rio Grande Joint Venture boundaries[49].

The pilot site selection process and analysis was centered on input criteria from DLCC stakeholders for the best representation of the desert land cover and priority habitats. The

input from the DLCC stakeholders was compiled into a Weighted Matrix[49], *Table 1.* The Weighted Matrix was ranked (with values assigned between 1 and 10) based on the level of importance held by the criteria and based on the datasets used for analysis. Given the enhancements of Landsat 8 previously mentioned and to provide a common reference frame, the proposed study areas are linked to Landsat WRS2 path/row designations

No.	Criteria	Weight (1-10) Level of Importance
1	Is it bi-national? (Does it touch the border?)	10
2	Does it intersect a CEC grassland conservation priority area?	3
3	Does it have field observations (RMBO transect points)?	2
4	Does it have one of the priority habitats present?	4
5	Does it have two of the priority habitats present?	7
6	Does it have three priority habitats present?	9
7	Has the area been nominated for LCPD?	7
8	Does it intersect an area nominated for the veg map pilot?	10
9	Does it overlap with a Federal or JV stakeholder boundary? (Bureau of Reclamation, Sonoran Joint Venture, BLM Focal Areas, and Rio Grande JV) * Note bird conservation regions general align with JV boundaries.	6

Table 1. Weighted Matrix for Site Selection[49]

For Weighted Matrix Criteria numbers 4, 5, and 6 that discuss the number of priority habitats present, during iterations 3, 4, and 5 only one or none of those would receive a score. It was noted after execution of iterations 1 and 2 that the top scores would have not only bigger influence from higher weight factors, but also larger values and still be the specific same Landsat granule results, *Figure 4.*

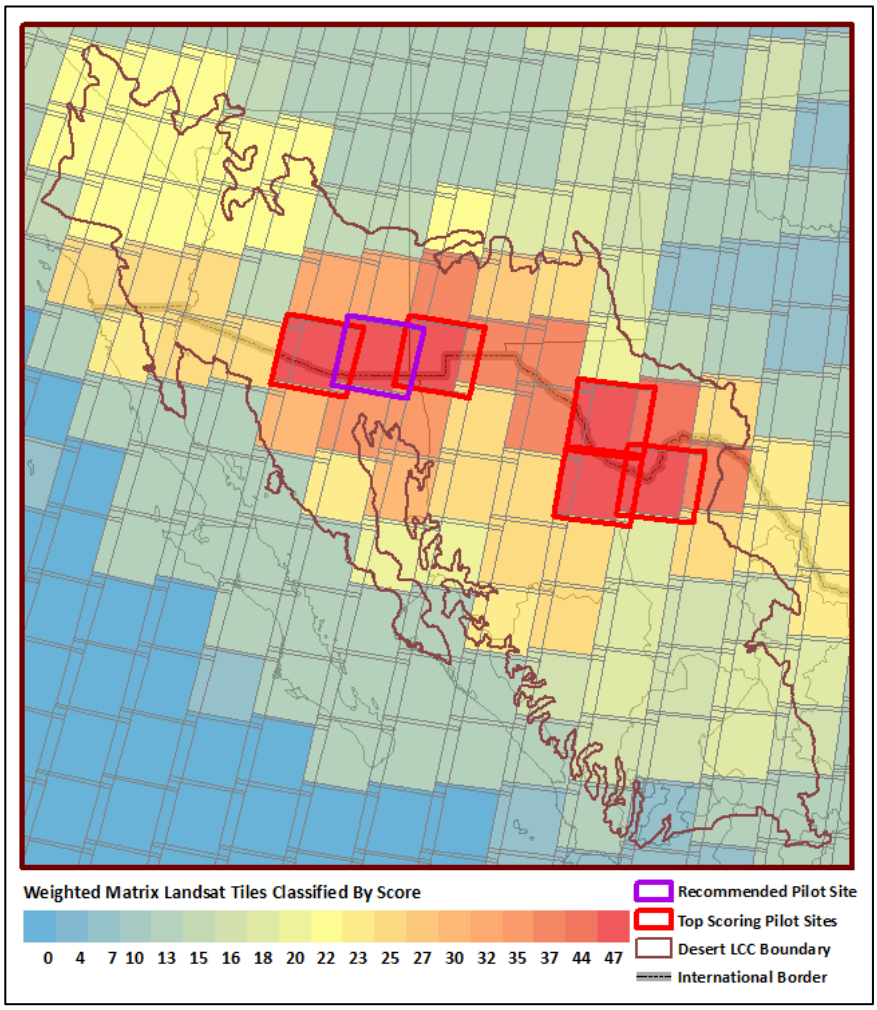

Figure 4 Final Pilot Site Selection[49]

2.3 Exploration Process

Before the object oriented classification, there were multiple previous attempts with supervised and unsupervised classifications. Worth mentioning is a combination of both techniques, a mixed approach, in which an unsupervised classification is used initially to create objects of pixels with similar spectral characteristics. The resulting polygons are used with context information (INEGI's Uso de Suelo y Vegetación Serie V) to assign a name into the user-defined area and create spectrally-similar, spatially contiguous training polygons. Using these sample polygons under this mixed approach, a supervised maximum likelihood classification was performed. The same process was used for both pilot areas with some promising results. After several iterations of using single granules, multitemporal imagery, multitemporal with elevation, slope, soils and geology added, the borderline effect where the soils and geology

with different schemas meet was visible and hard to ignore. We learned by experience that soils and geology didn't help improve the process (at least as used).

When using soils or geology, the mapping is not continuous across the border, the classification system for soils is very different and a borderline is also evident in the geology dataset. When creating these datasets, a number was used as a proxy for the different soils, same for geology. The effect in the classifications cannot be mitigated. However, using elevation and slopes as context information helps resolve different land cover classes since some plant communities prefer particular ranges of elevation and slopes. Through trial and error, the decision was made to remove soil and geology layers from the stack in preparation for the classification Soils and Geology data layers were dropped from the stack and multitemporal with only elevation and slope was used, it was evident that the latter combination was preferable. In most instances the border effect was transparent, except when different land management practices were evident in the imagery and the subsequent classification.

There were also attempts with segmentation options (Object-oriented) for image classification in ArcGIS and they did not work on multispectral, multitemporal imagery. ArcGIS uses several tools together in a geoprocessing model built in Model Builder which can be exported to python scripts. Initially, objects are produced via an image segmentation procedure where adjacent pixels having similar spectral characteristics are grouped together into a segment (similar to an unsupervised classification with proximity context information added). Each segment comes with a set of attributes that describe and define it, this information is used to produce training polygons. The training polygons are later used by classifier processes to create the classified image, similar to the previous mixed approach combining unsupervised and supervised classifications. Even when documentation claims that it can work with any ESRI supported raster, when attempting to run the geo-process with a 23 band image, it would invariably error-out with an "Unsupported raster" flag, even when the same image can be used in the viewer and is obviously supported. After several attempts and consultations with customer support and user forums, this option was abandoned. The suggested fix for object oriented classification on ArcGIS for stacks with more than three or four bands was to wait for next release (10.4).

Imagine Objective, an add-on to Erdas Imagine, was able to handle the multispectral, multitemporal images. A full description of the mechanics of Imagine Objective is included in the section 2.4 Classification Process and a step by step guide, with suggested parameters to use, is described in section 3.3 Imagery Classification Procedures.

Site A includes 2 Landsat 8 tiles and Site B includes 4 tiles with 3 seasons each. Granule selection was made aiming to identify images with less than 10 percent cloud cover before the summer, during the summer and after the heat of the summer. A year that was close to average was selected, not in drought, while not abnormally wet, 2014 was a recent, good candidate, and the dates for the scene were around February for the first, August for the second and October for the third temporal set. Standard Landsat 8 data products provided by

the USGS EROS Data Center consist of quantized and calibrated scaled Digital Numbers (DN). The products are delivered in 16-bit unsigned integer format

Initially, there was the intention to incorporate soils, geology, elevation and slope as context information. As described above the decision to drop soils and geology was made to minimize the border effect of these two datasets that are not homologated at the borderline. Only the first 7 bands of OLI were used. Band 8 (Panchromatic), band 9 (Cirrus), band 10 (TIR1) and 11 (TIR2) were not included. Processing was performed on a 23 band image-stack per pilot site:

- 7 bands from Landsat 8 mosaic for spring
- 7 bands from Landsat 8 mosaic for summer
- 7 bands from Landsat 8 mosaic for fall/winter
- 1 band elevation
- 1 band slope

A step-by-step methodology is included in *Appendix 5*, the following chapter is just an overview of the workflow and an explanation of the main steps in the Object Oriented Classification Process.

2.4 Classification Process

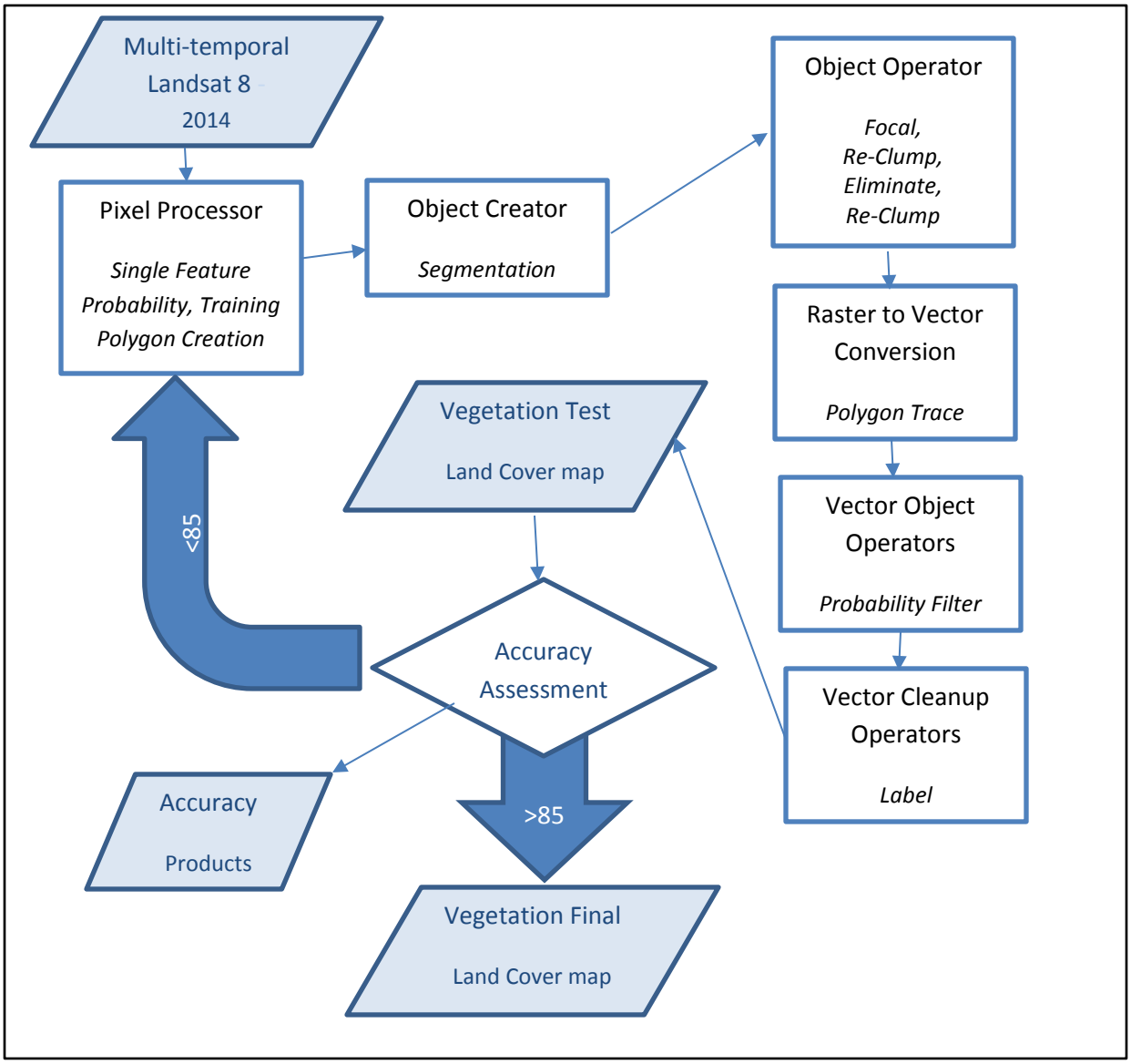

Figure 5 Object Oriented Classification process steps flow chart

The process starts by including the multispectral, multitemporal (three dates of Landsat 8 imagery plus elevation and slope) stack in the Raster Pixel Processor (RPP) that executes a pixel level supervised raster classification. This is typically the initial process node in an object oriented classification feature model. All the training polygons are defined individually in this step. Single Feature Probability (SFP) is a process at pixel level that calculates the probability number for each pixel of the input raster (a number between 0 and 1, where zero is not likely and 1 is full confidence) comparing its pixel value to the mean values of training polygons

(samples). In this way, pixels that are spectrally similar to the ones in the training sample have higher values of probability for belonging to the land cover class defined in the training polygons. A classification probability image is produced for each class. This step creates a stack of classification probability images, one per land cover class.

Raster Object Creation Operators produce sets of Raster Objects from the input image. This process is also called segmentation. During segmentation, the operators form groups of pixels from the input raster data called objects and identify each object by assignment of a unique output value which identifies it. The Raster Objects may be created directly from the input Pixel Probability Layer, a process similar to an unsupervised classification. Segmentation is a way of partitioning raster images into segments based on pixel values but also using the pixel location to create groups of contiguous pixels (different from unsupervised classification) . Pixels that are adjacent and have similar values are grouped in a single object. The result is a thematic raster where pixel values represent class IDs of contiguous objects. The Pixel Probability Layers input is used to calculate the pixel probability zonal mean of each object and that zonal mean is used as the value of the segments Pixel Probability attribute (similarly to the use of spectral metrics in a maximum likelihood supervised classification).

Next step is to use Raster Object Operators to work the raster objects produced in the previous step. The Raster Object Operator can accomplish several functions on the Raster Objects, for example:

- Work to grow or shrink the existing Raster Objects
- Erase raster objects that do not pass certain criteria
- Merge multiple input raster objects into a bigger single raster object
- Separate input raster objects into smaller new raster objects
- Sort the raster objects to remove missing places after a filtering or erase operation

The Focal Operator substitutes each pixel with the most frequently occurring pixel value inside a square vicinity around the pixel. The window used is a 3X3 and it works as a majority filter.

Re-clump executes a clump procedure on the input raster object layer. The input layer is typically a layer of raster objects which have been grown, contracted, split, joined or filtered by other raster object operators.

There may be a need to work with very small objects or to filter them, to clean the segments and eliminate the ones that are too small, eliminate some by defining a minimum clump or class size. Clumps of smaller size than the specified area or less than a certain number of pixels are eliminated.

The rest of the processing in the Imagine Objective workflow happens in the vector domain, so a conversion to vector is necessary. Raster to Vector Conversion Operators, like the name suggests, transforms raster objects to Vector Objects. The set of Vector Objects produced may be either Polygons or Polylines. Polygon trace draws the perimeters of raster objects and

transforms them into vector objects. For vegetation mapping, the use of polygons was preferred and is part of the process.

The rest of the processing in the Imagine Objective workflow happens in the vector domain, so a conversion to vector (shapefile) is necessary. Vector Object Operators is used to handle the vector objects produced by the "Raster To Vector Conversion". These processes may achieve an assortment of tasks on the vector objects, for example:

- Change the shape of Vector Objects
- Erase vector objects that do not pass certain criteria
- Merge multiple input vector objects into a bigger single vector object
- Separate input vector objects into smaller new vector objects
- Transform polygon objects into polylines, addicionally, polylines into polygon objects

The probability filter eliminates all vector objects when their zonal probability mean is smaller than a defined threshold.

The Vector Object Processor node completes classification on vector objects. The vector object classification process develops one or more indicators or cues to be used by an Object Classifier. The cues include metrics that measure characteristics of vector objects. The Object Classifier uses the cues to allocate a probability of belonging to a land cover class (a number between 0 and 1, where zero is not likely and one is full confidence) to each object in a group of vector objects. The bayesian network classifier takes as input any figure of discrete or binned uninterrupted pixel cue metrics. It may be taught empirically or have a distribution given to each input manually. The classifier produces a vector object layer where each object has a probability attribute in the range 0-1 representing the probability the object is part of the feature being detected. This probability is calculated for each land cover classes and stored as attributes in the shapefile table.

Vector Cleanup Operators allow the refining of Vector Objects after their production by the Vector Object Processor. Vector Cleanup Operators typically polish the set of vector objects to produce an improved final output. Some Vector Cleanup Operators will use the Probability attribute produced by the Vector Object Processor in the operation. Label operator allocates the most likely output class to each vector object. The label operator only writes the attribute table of the shapefile. The vector objects are unchanged.

2.5 Project Materials

2.5.1 Computer Software and Hardware

For computer software, several applications were used, they include:

- ArcMap 10.3
- Erdas Imagine 15.01 including Imagine Objective add-on for workstation.

Computer Hardware:

- Dell T7500 Workstation, 32 GB installed memory (RAM) and Intel Xeon ® CPU X5560 @ 2.80GHz with 8 cores and Windows 7, 64 bit operating system.

2.5.2 Imagery

USGS data downloaded from earthexplorer as surface reflectance data Level 1T (systematic radiometric and geometric accuracy). Pilot Zone A Granules and dates:

- LC80350382014046LGN00 2014-02-15 7 bands
- LC80350382014174LGN00 2014-06-23 7 bands
- LC80350382014286LGN00 2014-10-13 7 bands
- LC80360382014053LGN00 2014-02-22 7 bands
- LC80360382014181LGN00 2014-06-30 7 bands
- LC80360382014277LGN00 2014-10-04 7 bands

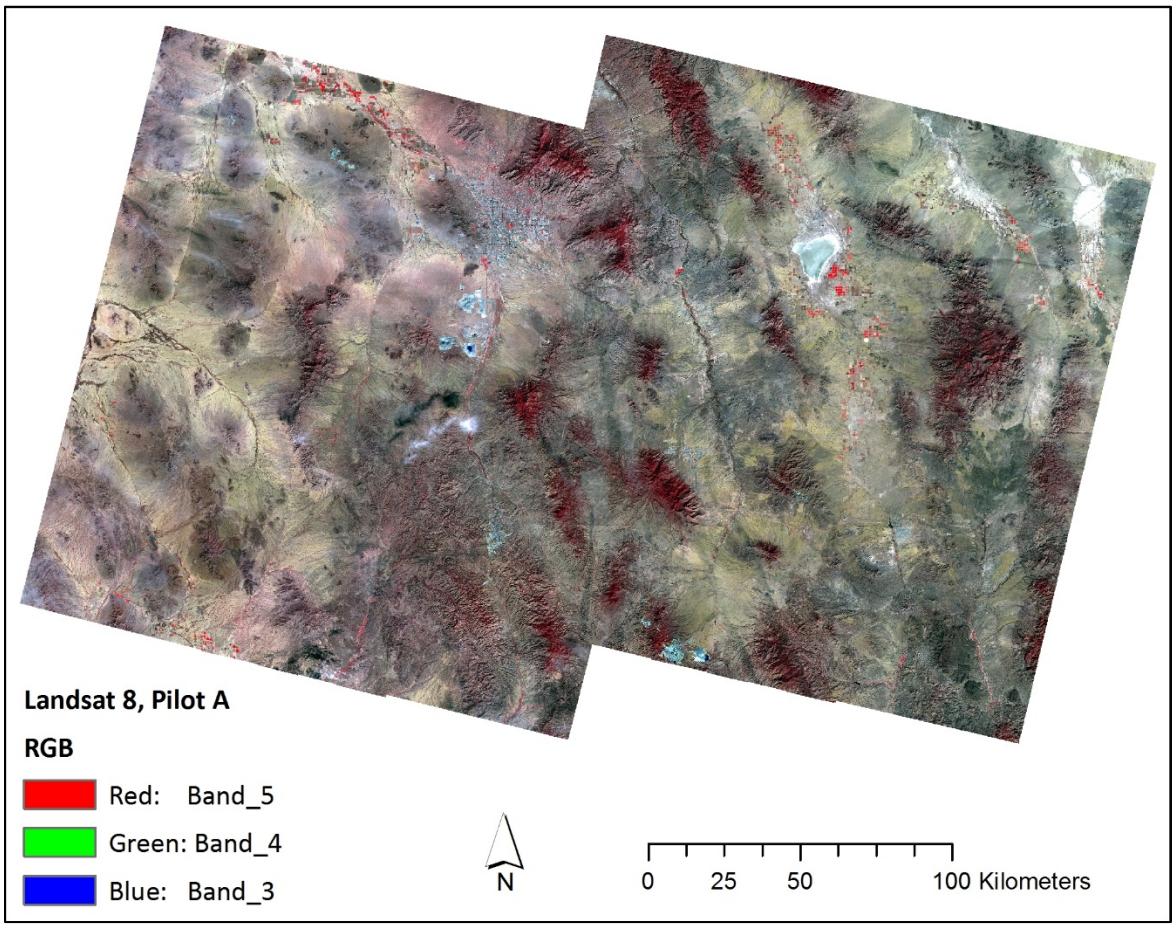

Figure 6. Zone A Granules mosaic and stack, multispectral and multitemporal, Feb 15 (left: 36,38) and Feb 22 (right: 35, 38) 2014 shown.

Because Landsat 8 data includes additional bands the combinations used to create RGB composited are different than in previous Landsat granules.

To create a Color Infrared (CIR) composite using Landsat 8 data, bands 5, 4, 3 are used (see *Figure 6.* and *Figure 7.*). There is a new Landsat 8 coastal/aerosol band (band one) and a new cirrus band (band nine), band nine can be used for detection and mitigation of cirrus cloud contamination in each granule. Band eight is a higher resolution panchromatic. The reflective bands and thermal bands are split into two instruments: the Operational Land Imager (OLI, 8 bands at 30 m. spatial resolution plus panchromatic band eight at 15 m.) for the reflective information and the Thermal Infrared Sensor (TIRS, 2 bands at 100 m., re-sampled and co-registered at 30 m.), for the thermal bands[11,16]. For this study, we will use the stacking: band 1 for shallow water; bands 2-4 for blue, green and red in the visible portion of the spectrum; band 5 for near infrared and bands 6 and 7 for middle infrared. Bands 8-11 are not used. A graphic of the bandpass wavelengths for Landsat 8 can be referenced in *Figure 1.*

USGS data downloaded from earthexplorer as surface reflectance data Level 1T. Pilot Zone B Granules and dates:

- LC80300392014043LGN00 2014-02-12 7 bands
- LC80300392014155LGN00 2014-06-04 7 bands
- LC80300392014331LGN00 2014-11-27 7 bands
- LC80300402014059LGN00 2014-02-28 7 bands
- LC80300402014155LGN00 2014-06-04 7 bands
- LC80300402014331LGN00 2014-11-27 7 bands
- LC80310392014018LGN00 2014-01-18 7 bands
- LC80310392014162LGN00 2014-06-11 7 bands
- LC80310392014322LGN00 2014-11-18 7 bands
- LC80310402014050LGN00 2014-02-19 7 bands
- LC80310402014162LGN00 2014-06-11 7 bands
- LC80310402014322LGN00 2014-11-18 7 bands

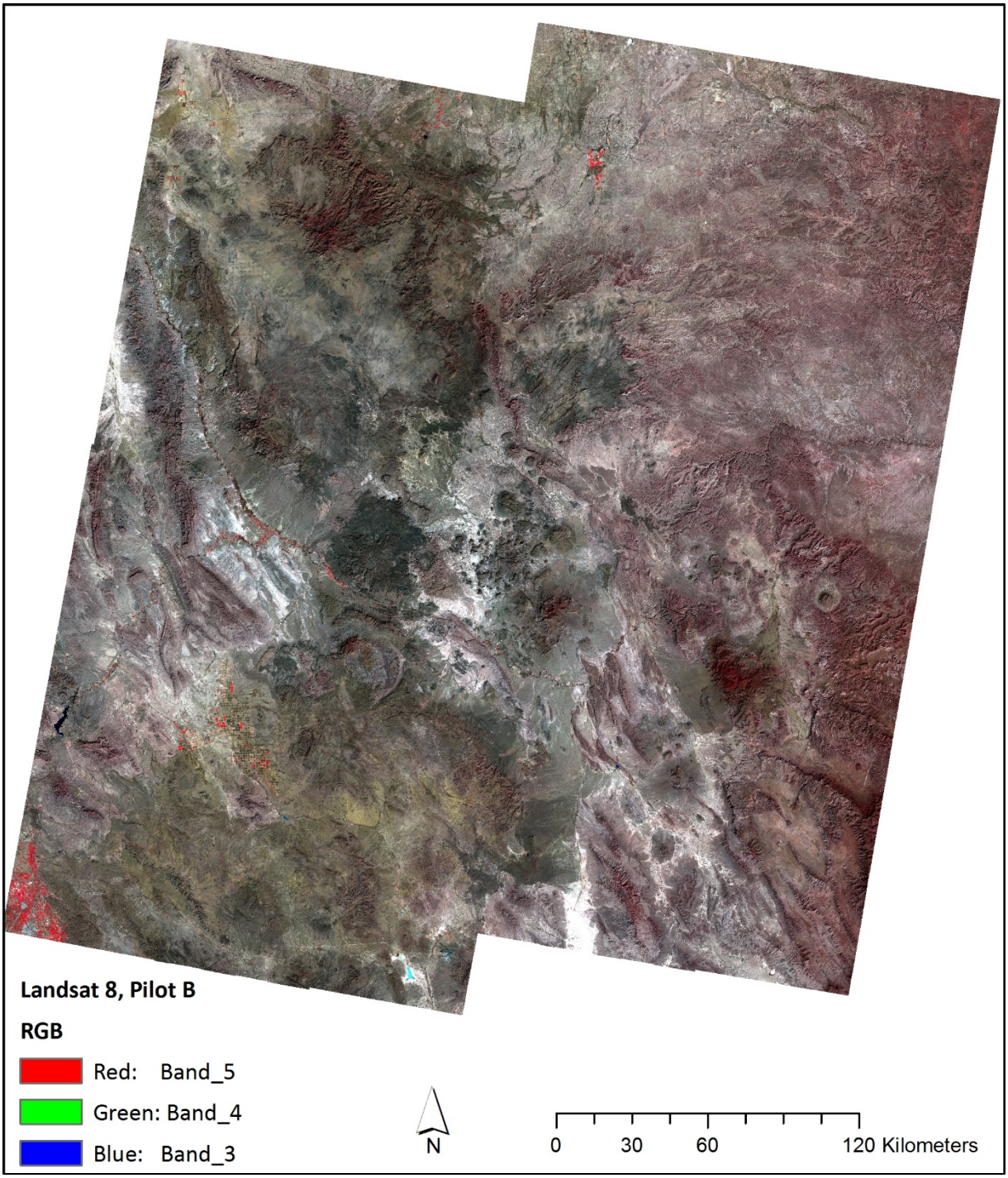

Figure 7. Zone B Granules mosaic and stack, multispectral and multitemporal, Jan 18 (upper left: 31, 39), Feb 12 (upper right: 30,39), Feb 19 (lower left: 31,40) and Feb 28 (lower right: 30, 40) 2014 shown.

For the band aggregation, a mosaic was created (with color balancing) using the first 7 bands of the before-summer granules for each pilot site then the first 7 bands of the summer images and then mosaic the first 7 bands of the fall images. The next step was to stack in a new image the mosaics for before, during and after the hot months, the DEM subset and its slope, using an unsigned 16-bit data type for the pixel depth. The output projection for the layer stack was set as DLCC Lambert Azimuthal Equal Area.

2.5.3 Ancillary Data

Data on America's elevation have naturally been represented as contour lines and digital elevation models (DEMs). Certain types of raster datasets allow you to achieve better understanding into the terrain that they represent. DEMs are particularly useful in this regard. A raster-based system lends easier to image processing. Digital elevation data was downloaded from USGS and INEGI and merged into a common coordinate system (DLCC Lambert Azimuthal Equal Area) and datum, original resolution was 30, 10 and 15 m, it was resampled to match the Landsat imagery at 30 m. To avoid mosaicking errors and artifacts a raster DEM was created to cover the extent of the DLCC with information from both countries, later a slope model was created from it, *Figure 8.* Once the mosaic was satisfactory, it was clipped to form Zone A and Zone B DEMs (*Figures 9 and 10*).

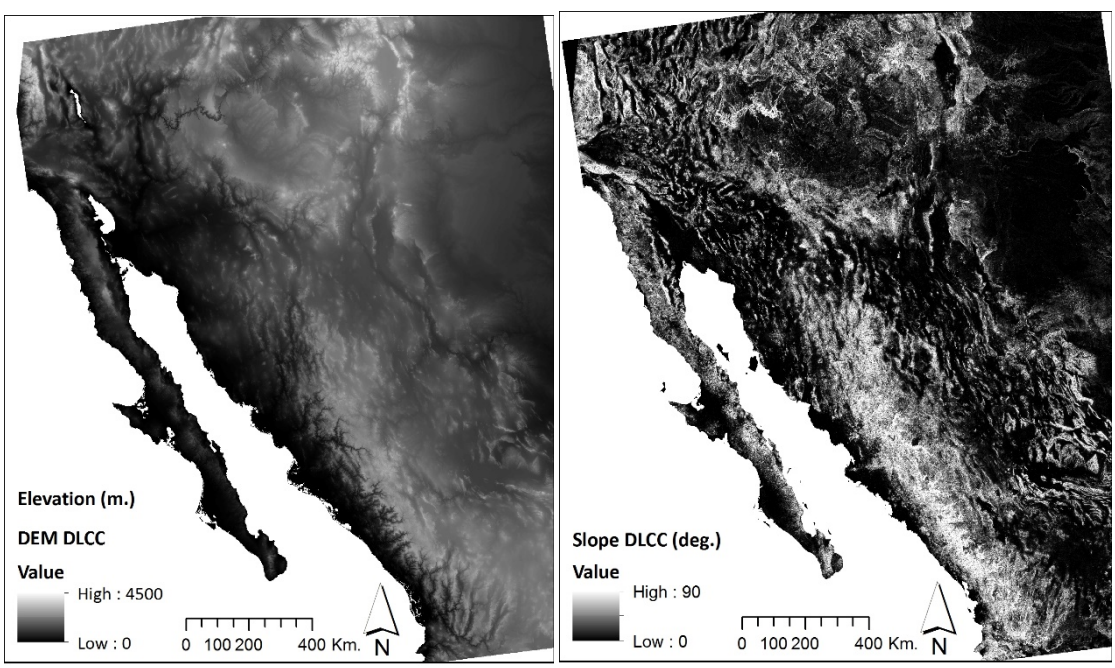

Figure 8. DLCC Digital Elevation Model and Slope datasets at 30 m.

The slope was created from the DEM using a degree measurement system as opposed to a percent rise or percent slope. The degree measurement system goes from 0 for flat to 90 degrees for completely vertical walls. Elevation and slope range determine the amount and kind of vegetation that is viable as described by many authors[52] and in the class descriptions.

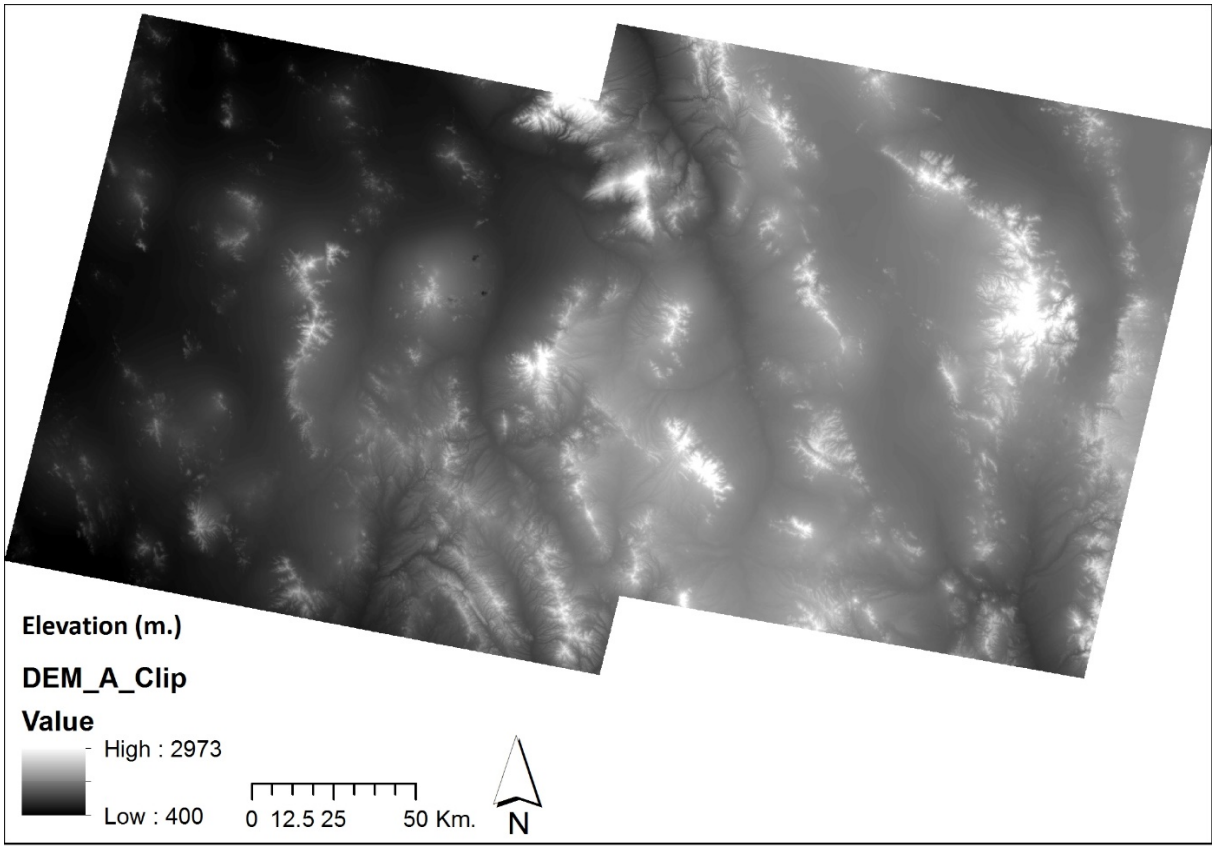

Figure 9. Zone A digital elevation model

It is not equivalent to perform classifications on flat topography than in areas of high topographic relief, in the later, problems arise with spectral variations in ground target illumination and radiance, owing to differences in instance radiation. *Figure 9,* shows the level of complex topography in Zone A and the challenge that mapping vegetation for illuminated and shadowed areas presents. To overcome this problem, training polygons were taking in pairs in areas of significant incident radiation changes, one for the illuminated area and another one for the darker portion of the vegetative community. This will allow assigning bright and shaded instances of objects to the same informational class.

A similar process with a collection of pairs of training polygons for illuminated and shadowed portions of a vegetative class took place also on Pilot Zone B due to the high topographic relief evident in *Figure 10.* Zone B offers a number of mountain ranges separated by valleys, includes features known for their topography, such as Big Bend Ranch State Park, Big Bend National Park in the U.S. and Area Natural Protegida Maderas del Carmen and Cañon Santa Elena in Mexico.

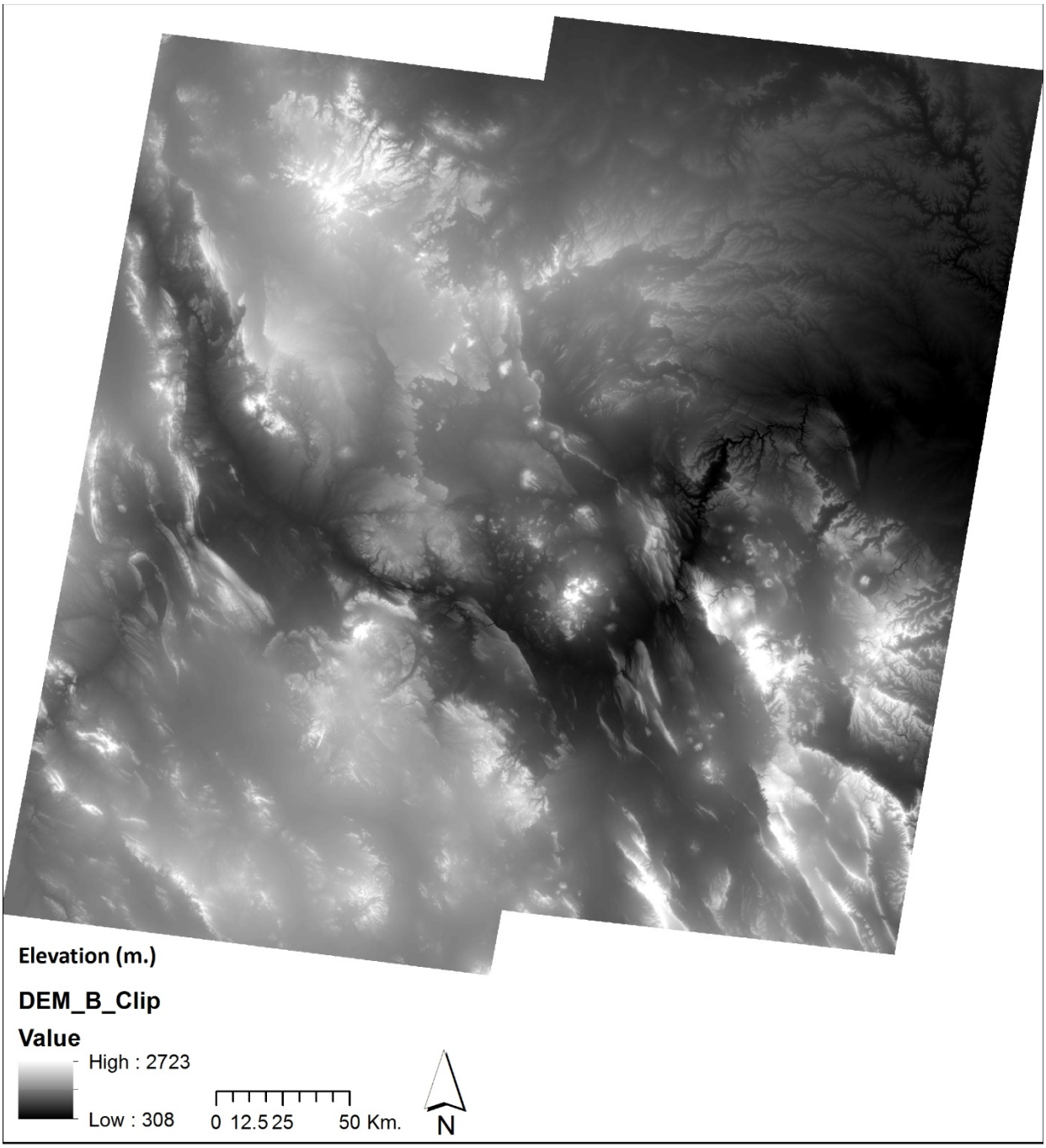

Figure 10. Zone B Digital elevation model

2.6 Mapping Classification

Object-Oriented Image Classification techniques are a convenient and encouraging method of classifying objects from remotely-sensed imagery[53]. The Kappa coefficients and overall accuracies are routinely greater for the segmentation/object-oriented classifications than for the counterpart pixel-based classifications and producer and user accuracies were also higher[25]. The use of multi-seasonal data results in a slight increase in overall accuracy over the single-season imagery[25].

For a vegetation map that is created using an Object-Oriented Image Classification approach, the pixels are congregated in a way that variances in one object are less than the variances among different objects and the thresholds for both smallest size and maximum variability of the segments are defined by the user creating the classified image or map. Following this process, the objects are generally of dissimilar size (within ranges) and are reliant on the characteristics of the image and context information. In order to validate classifications created using an Object-Oriented approach, the reference sample units should be the same as the segments (i.e. polygons), rather than pixels, so that the units are directly comparable to the map segments. Nevertheless, contrasting with more traditional mapping techniques that are based on individual pixels, each segment unit will have a unique size, which should be accounted for in the calculation process. Therefore, an error matrix that associates the reference unit area into each cell is needed for reporting the thematic accuracy of a map created using an Object-Oriented Image Classification approach[24].

Early in the project, when discussing its reach, objectives, and goals, it was decided to use INEGI's Uso de Suelo y Vegetación Classification Scheme[54]. Since two-thirds of the DLCC is in Mexico, it is most useful to have this classification system. The system comes with a rather high informational class resolution, a great number of classes described individually in the Map Unit Descriptions Chapter. The greater thematic resolution facilitates generation of crosswalks to other systems with a lesser informational class resolution, for example, the National Land Cover Database (NLCD) as seen in *Appendix 4.* Going in the opposite direction would be impossible, negating the advantages of a higher resolution classification system. The map units in INEGI's Uso de Suelo y Vegetación Serie V were manually drawn and assigned, photo-interpreted from aerial photography and performed between 2011 and 2013. The reference date for the whole data set is 2011. Class descriptions were adapted, translated and build into a crosswalk to NLCD from the interpretation guide[54] with the help of INEGI's biologist, and are later defined in *Appendix 1.*

An additional criterion in favor of this classification system is that we can use some of the larger map units, when identified and corroborated as present in the Landsat imagery, to create training polygons for the classification. The series scale and accuracy of INEGI's dataset used for training samples is 1:50,000, and this will drive the accuracy of the final vegetation map. This is not a limitant, since the main resolution of our imagery, Landsat 8 is 30 m.

Following Tobler's rule[55,56] "Divide the denominator of a map scale by 1,000 to the detectable size in meters, and the resolution is half of that amount". Working it backward, each Landsat imagery pixel is 30 meters raster resolution (not counting the panchromatic or thermal bands). Double that to get four pixels (two rows and two columns) with a resolution of 60 meters on a size (an area of 3600 square meters). Multiplying then that 60-meter resolution by 1000 to get a map scale of 60,000 as can be seen in *Table 2.*

Map Scale	**Detectable size (m.)**	**Raster resolution (m.)**
1:1,000	1	0.5
1;10,000	10	5
1:50,000	50	25
1:60,000	60	30
1:100,000	100	50
1:200,000	200	100
1:250,000	250	125
1:500,000	500	250
1:1,000,000	1,000	500

Table 2. Raster Resolutions and map scales

In INEGI's Uso de Suelo y Vegetación Serie V[54], through its various classes, the distribution of natural and induced vegetation is shown, includes specific information on representative botanical species of plant cover when looked under the class descriptions. It is useful to know the current state of the landscape due to the high-resolution different types vegetation, provides basic information for research on natural resources and evaluation of land management practices over time when the classification process is performed at different dates.

Choosing INEGI's Uso de Suelo y Vegetación classification scheme comes with several challenges given the great number of classes. Early attempts had a lot of confusion between classes, especially in this desert area, bare earth was mistaken with human settlements, low-density bushland and grasslands were also confused. The solution was to not include areas that are not represented in the pilots with the exception of a few small polygons. An additional enhancement was the creation of training polygons covering small areas of spectrally similar pixels. In areas with topography, several polygons have to be done on north and south slopes to account for sunny and shady areas, sometimes in the same informational class, in other instances, they were different vegetation communities.

In INEGI's classification system vegetation types are sorted for its ecological affinity and floristic composition, grouped into two hierarchical levels. The vegetation types are defined according to the classification system of vegetation types from INEGI and ordered by large groups of vegetation:

- Current status successional vegetation according to the degree of change or alteration of vegetation cover (secondary vegetation).
- Distribution of plant communities based on recognition of its variants defined by ecological elements, floristic and physiognomic distinctive.
- Types of farming water availability during the growing season and duration of the crop cycle.

Object-Oriented Image Classification methods are selected as superior for vegetation mapping based on the literature review and on the lessons learned during the exploration and classification process. Further discussion of the procedures, results, accuracy and its significance for the DLCC is developed in the results and conclusion sections.

Chapter 3: Results

3.1 Object Oriented Classification

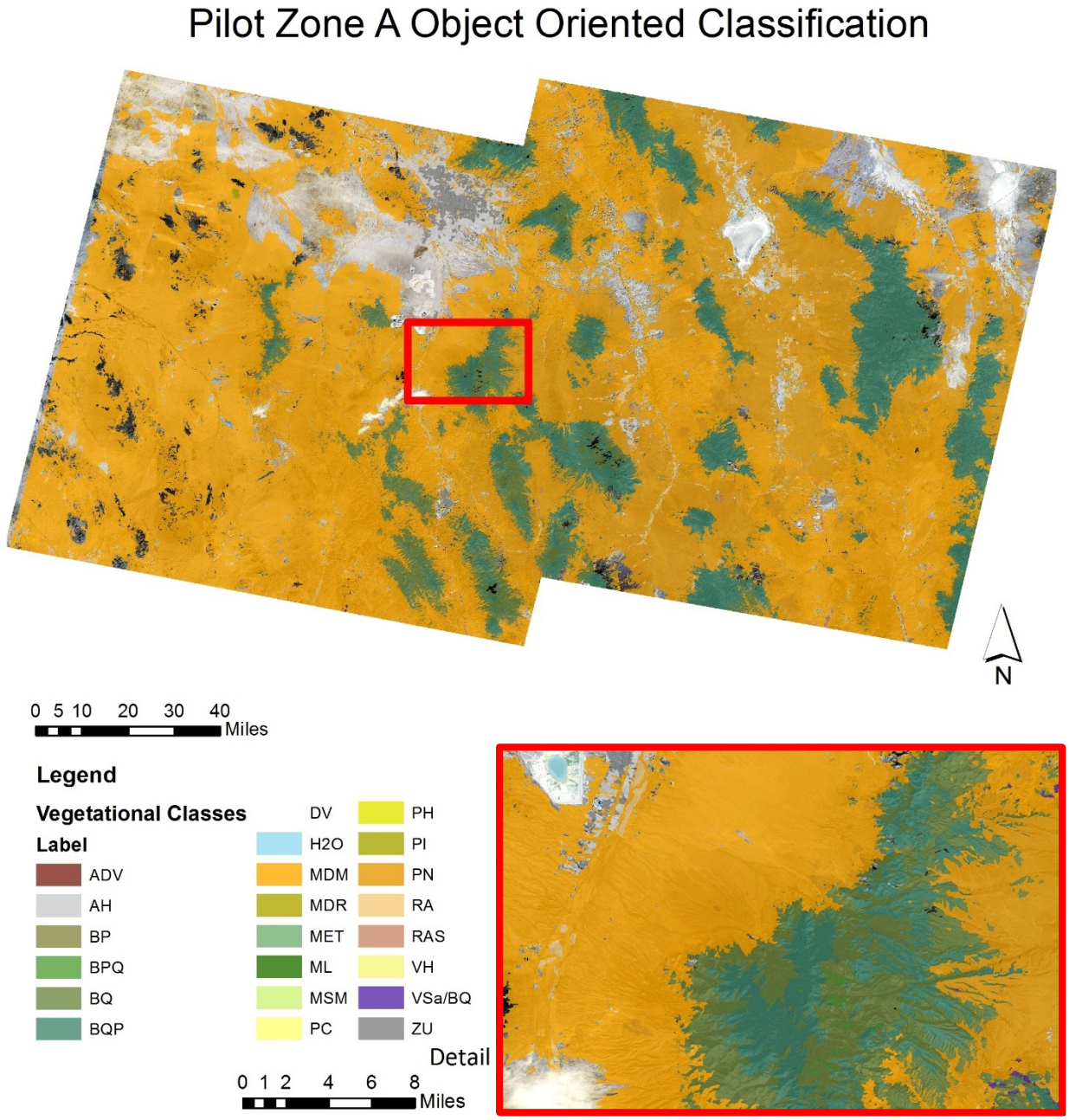

Figure 11. Overview of Pilot Zone A Object Oriented Classification and Detail

Having multitemporal image stacks helped identify different farming classes, and account for some of the phenological changes of vegetation over the seasons exploiting the temporal and spectral reflectance properties of land cover components.

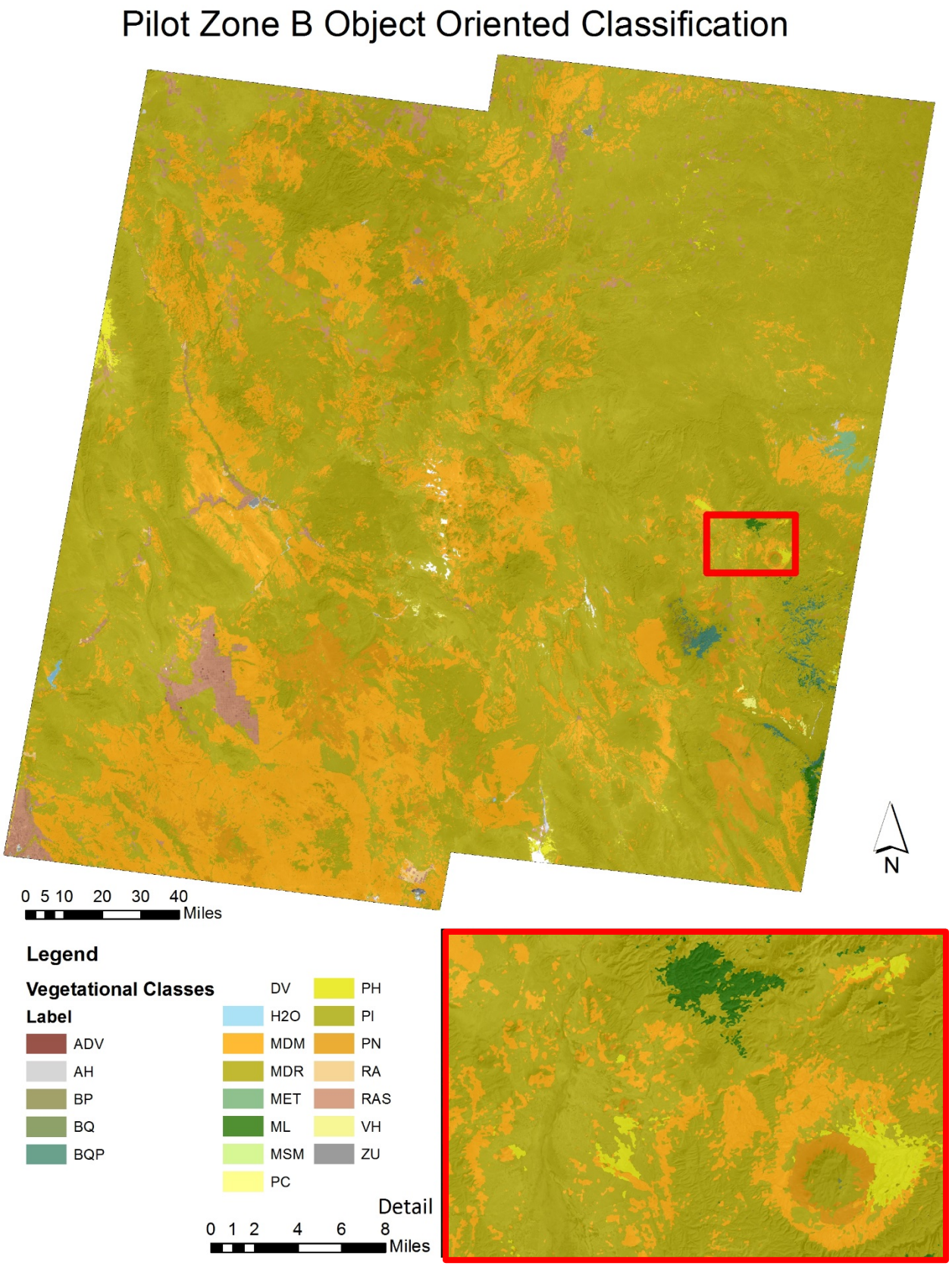

Figure 12. Overview of Pilot Zone B Object Oriented Classification and Detail

Inter-annual and seasonal land surface phenology data are important for understanding and predicting an ecosystem's response to variations caused by natural and anthropogenic drivers[57].

Having a methodology for object oriented classification allows us to map vegetation cover over the years. Vegetation cover is often viewed as the most evident response to climate and other stressors. On the bright side, it also responds to good land management and conservation practices. Having classifications for several years of the DLCC area will allow us in the future to see where those practices are bringing fruit and where additional efforts in conservation are needed. This aligns very well with DLCC vision statement[48]: "Through collaborative partnerships, the DLCC seeks to provide scientific and technical support, coordination, and communication to resource managers and the broader DLCC community to address climate change and other landscape-scale ecosystem stressors."

The vision for the DLCC is "Resilient landscapes capable of responding to environmental challenges and supporting natural and cultural values for current and future generations."

A copy of the classifications, with the layer files and all the attribution generated by Imagine Objective, are included as shapefiles, layer files and metadata in the project deliverables.

3.2 Ground Truth Data

Thanks to field work, we can take advantage of use field-verified data for our test samples, references that then can be identified in the imagery, similar to the training polygons. The test samples should be evenly distributed on the imagery and should cover all the classes. They should be distinct pixels from the training areas. The test pixels identified at each ground truth site should be ideally in the same coordinate system as the result of the object oriented classification.

For the ground truth points INEGI's "Uso de Suelo y Vegetación Series V" vegetation map was used as ground-truthing for the Mexico portion of the study areas. A simple standard approach was implemented in order to deliver an accuracy assessment. A simple comparison between INEGI's product and the object-oriented classification in the overlap areas is conducted using 100% random stratified sampling (RSS) only, with a target of 50 points per class with no user-imported or user-selected points or polygons.

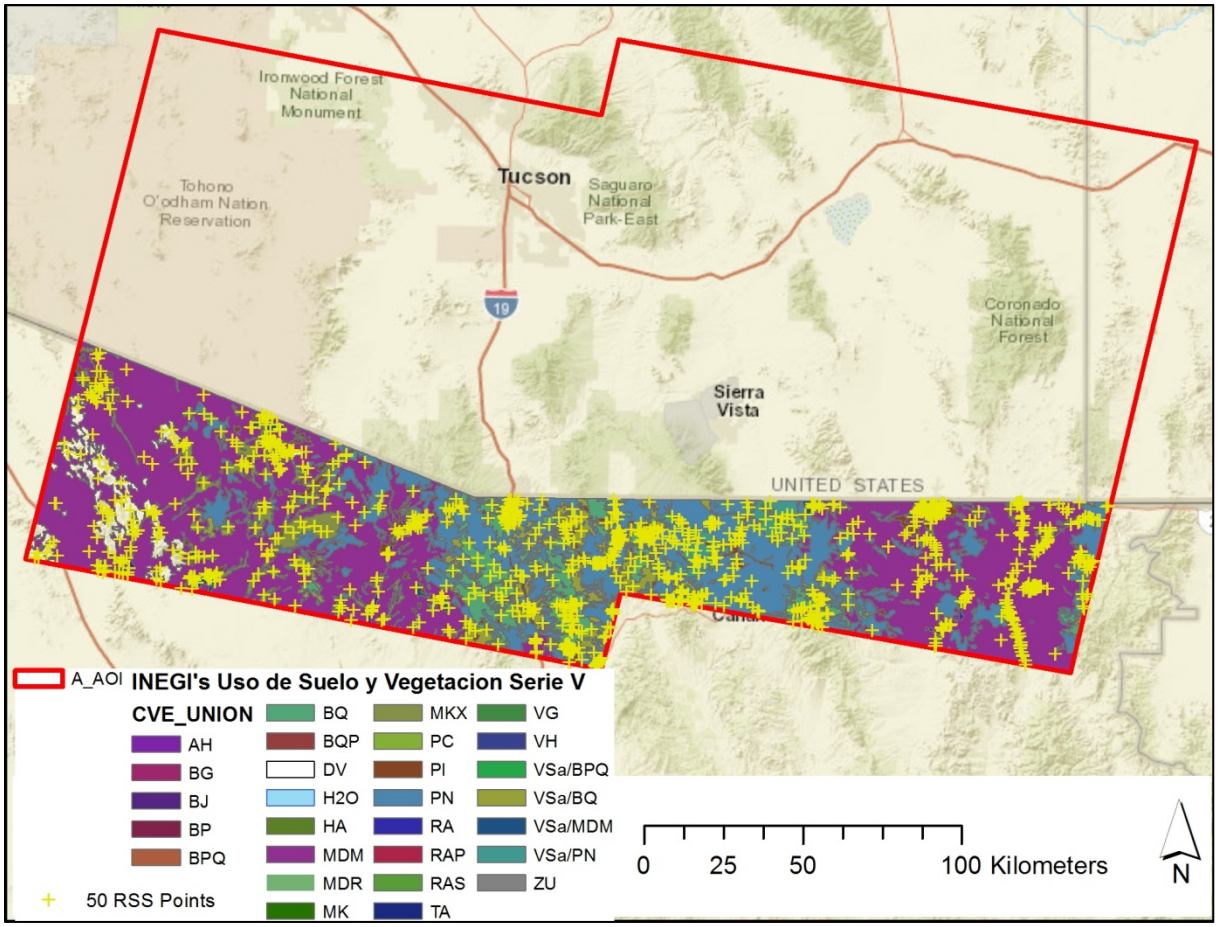

Figure 13. Ground truthing locations for Site A

The distribution of the 50 RSS points per class can be seen in *Figure 13 and 14* respectively for Site A and Site B. The target was to identify for the classes with 50 pixels or more (Landsat pixel considered as 30X30m.), 50 standard stratified random checking points. The sampling ranges from 100% sampling for 50 pixels to a minimum sample percentage for the largest classes, but still 50 random check points each class. A strategy was developed if classes had small areas in any area of interest. For classes with more than 20, but less than 50 pixels, the sampling would be 50 %, half as many stratified random check points as Landsat pixels, for the smallest class considered, with 20 pixels, the sampling would be 50%, 10 standard stratified random checking points. There was no need to go to such measures for small areas; the fewest used RSS points for any class was 49 for Annual-Irrigation Agriculture (RA).

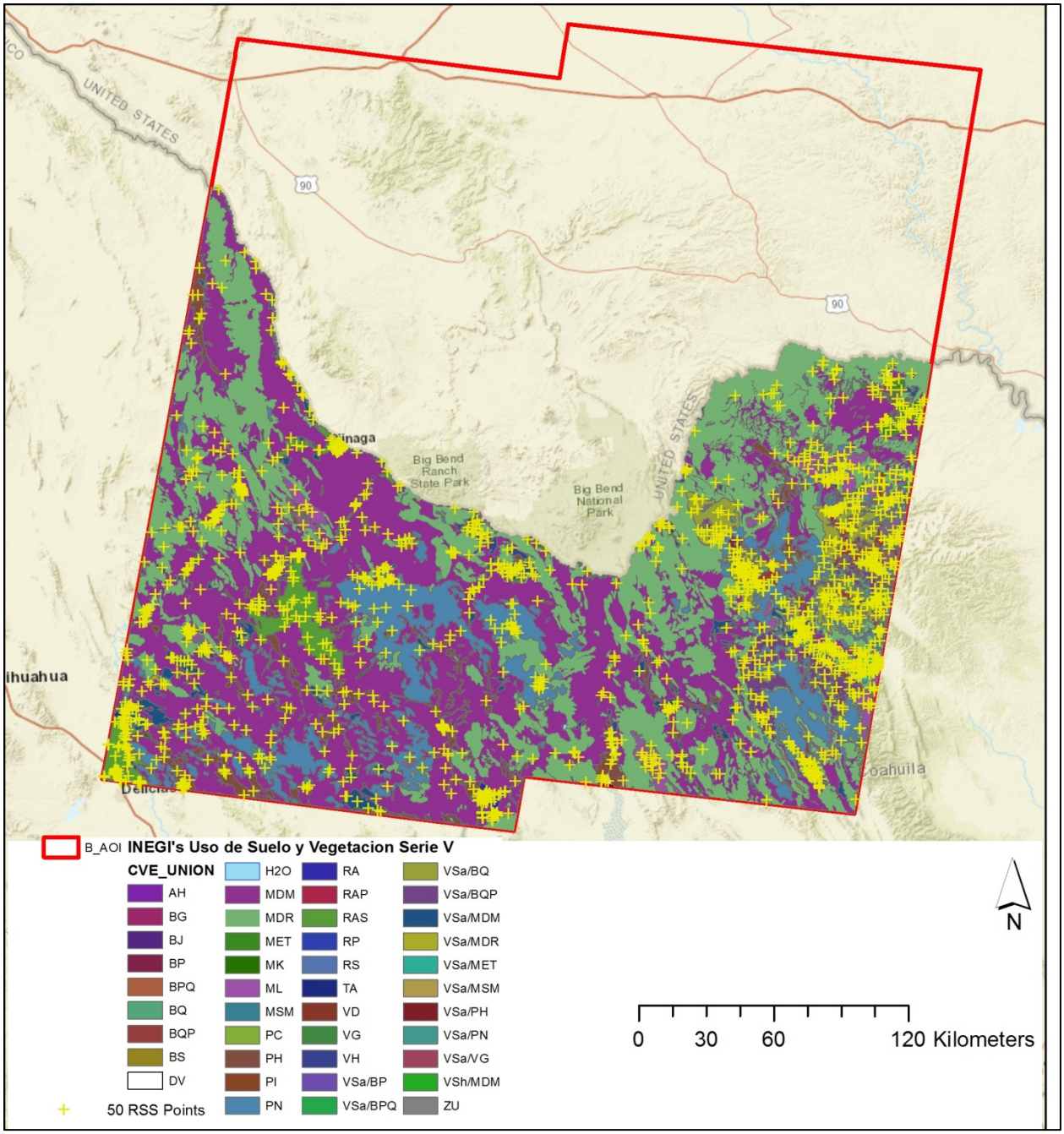

Figure 14. Ground truthing locations for Site B

3.3 Accuracy Assessment

Accuracy assessment of a classified image or stack is a significant step in remote sensing for evaluating classifications [38–41]. Most literature that compares pixel based vs object-based classifications reports that the object-oriented approach gave more accurate results than those

achieved with pixel-based algorithms over the same area[22,29,36,37]. The general classification accuracy based on the object-oriented technology of image classification is higher, in comparison with the results based on the traditional technology of image classification[42]. This is one of the reasons why the DLCC Science Group points out Object Oriented Classification as preferable to supervised or unsupervised alternatives. Object-oriented image classification has great potential to improve classification accuracies in landscape land cover[43], it is identified as an alternative leaning to change pixel-based methods[44]. Having only one metric of accuracy assessment and reporting can be associated with problems or deficiencies[45], more than one method is preferable for further reference. Several metric can is shown for both pilot sites on *Table 3* comparing INEGI's Uso de Suelo y Vegetación as a reference with the object-oriented classification.

Metric	Site A	Site B
Overall Accuracy	23.22%	16.98%
Kappa	.21416	.15334
User's Accuracy	57.06%	40.99%
Producer's Accuracy	23.19%	16.98%

Table 3. Accuracy Assessment metrics

Accuracy assessment is performed by comparing the map created by the Object Oriented Classification against the Ground-Truth resources available. The Kappa coefficient is a statistic that measures the degree of agreement among raters for qualitative (categorical) classes. It is generally thought to be a more robust measure than the overall accuracy. The accuracy of image classification is most often reported as a percentage correct or overall accuracy[24,41,58]. Classification error occurs when a pixel (or object) belonging to one category is assigned to another category. Errors of omission occur when a pixel is left out of the category being evaluated; errors of commission occur when a pixel is incorrectly included in the category being evaluated. An error of omission in one category will be counted as an error in commission in another category.

A 50 point per class random stratified sampling was created for the Mexican portions of site A and site B following USGS suggestions of a simple comparison method. NOAA's sampling tool was used to create 100% random stratified sampling, 50 points per class with no user imported/selected points or polygons based on INEGI's Uso de Suelo y Vegetacion classes. A point dataset is included in the deliverables. It includes Ref_CVE_U for INEGI's code as the reference in the Uso de Suelo y Vegetacion dataset from (2011) and spatially join also the label from the object oriented classification. A_Assesme includes the match with score of a 100 for perfect match and 50 for match of very similar classes or same NLCD codes (i.e. Oak forest with

Oak forest with secondary brush both are cross-walked into Deciduous Forest), and a score of zero for no matches.

As reported in the confusion matrix, there was some miss-classification, especially with mixed communities (BQP, BPQ,) and the ones with secondary vegetation (VSa/BPQ, VSa/BQ, VSa/MDM, VSa/MKX and VSa/PN). Areas with similar land-cover vegetation were also confused for example PI and PN, (Error Matrices, *Appendix 6*).

For Site A, MDM and PN were much more represented in the object oriented classification (2014) that in INEGI's "Uso de Suelo y Vegetación Series V" vegetation map (2010).

For Site B, MDM, MDR and RAS were much more represented in the object oriented classification (2014) that in INEGI's "Uso de Suelo y Vegetación Series V" vegetation map (2010).

See ***Appendix 7. Independent Quality Assurance Check.***

Chapter 4: Conclusion

Landsat 8 Operational Land Imager granules in USGS EROS archive (EarthExplorer) are a great resource. Especially useful is the availability of this resource over different dates to capture desert phenology develop over more than one season. Near infrared (Band 5) helps detect photosynthetically active plants, biomass content, and short wave infrared (Band 6) was useful to detect moisture content of soils and vegetation.

Landsat 8 Level 1T products are corrected for terrain effects geometrically, but not radiometrically. Shadow and light areas are evident in the topographically complex and challenging terrain that is present in both samples: Pilot A and B. Different solar location for the seasonal and hourly variation, in combination with terrain slope and aspect, result in different illumination of vegetation communities that can belong to the same informational class, while having very different radiance. Instead of collecting a double number of training samples (one in shadow and the second one in illuminated areas), pre-processing the data with topographic normalization of illumination (such as the Minnaert topographic correction) may prove time-effective in the future.

Context information initially comprised geology, soils, elevation and slope. After several tries, the non-homologated geology, and soil classification systems in Mexico and the U.S. were evident with a borderline (showing in the interim vegetation map products) in areas where is not visible in the imagery. After just keeping the continuum of elevation and slope, the border effect was no longer a problem and this solution was preferred, effectively dropping the number of bands from 25 to 23.

Previous attempts with supervised and unsupervised classifications were valuable to have a better understanding of the data.

The combined approach, where an unsupervised classification is used initially to create objects of pixels with similar spectral characteristics, in which we assign a name into the user-defined area and create spectrally-similar, spatially contiguous training polygons, is worth of further experimentation. These sample polygons are used to perform a supervised maximum likelihood classification with better results than supervised or unsupervised classifications when used alone. Several instances of open source software support these classification procedures, making it a technology-methodology combination usable by the majority of DLCC stakeholders.

INEGI's Vegetation Classification system is rich and well described, it includes definitions for elevations were vegetation communities develop best and dominant species. Some of the classes include also land use, which can be difficult to define without context information. Elevation and Slope were useful. The addition of training samples using field photography,

google street maps, panoramas and user-uploaded photographs in google earth are a tremendous help in validating land cover classes training polygons and ground truthing with more precision. Having 29 classes in pilot A and 41 in B makes the classification process more difficult than when working with fewer classes. An additional complication is when there is a primary community (i.e. brushland) mixed with a secondary one (i.e. oak forest). These are the result of a disruption, i.e. secondary oak-pine forest is a forest or woodland area which has re-grown, and the original forest may have been harvested, reduced by fire or an infestation of insects. The great number and diversity of classes mean that the careful selection of training polygons in the early steps is crucial for a successful object oriented classification. This requires several attempts.

Using Imagine Objective gives the user access to more precisely defined classes, pixel and object cues to intuitively go through the process, allowing partial processing of tasks with visual feedback of the improvement (or lack of it) when changing parameters in an object oriented classification. The final product in vector format (shapefile) is user-friendly and can be shared with the different stakeholders in the DLCC community. Map services, open source GIS, and free viewers are able to display and analyze shapefiles without complications.

Object oriented classification approaches reported better for higher accuracy assessment metrics in the literature review, and that is also the case for pilot A and B. After evaluating visually the results of the unsupervised, supervised and mixed approach classifications, visually image analysts have seen that there is a lot of mixture and confusion with some classes, i.e. bare earth (DV) with human settlements (AH), mixed communities (BQP, BPQ,) and the classes with secondary vegetation (VSa/BPQ, VSa/BQ, VSa/MDM, VSa/MKX and VSa/PN). Using the context information in the object oriented classification reduced the confusion and also prevented the salt and pepper effect of mixed pixels; the use of segment geometry and zonal functions in Objective produces a cleaner vegetation map. For Site A we have that 572 out of 1433 random stratifies sample points that didn't match (39%), the rest 61% have a perfect match or a partial match. That can be explained by the different methodology between INEGI and MAP, temporal difference and dissimilar weather patterns between 2010 and 2014. In the same way, Site B has 890 out of 2050 points that didn't match (43%), the rest 56% have a perfect match or a partial match. That can similarly be explained by the different methodology, temporal variance and different weather patterns between 2010 and 2014.

Beyond this pilot, the need for a complete, current, transboundary and adequate-resolution vegetation map for the DLCC region still persists.

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Appendix 1: Map Unit Descriptions

Classes in A.

CVE_UNION	Count	Description
AH	18	ASENTAMIENTOS HUMANOS (Human Settlements)
BG	4	BOSQUE DE GALERÍA (Tree Gallery Forest)
BJ	4	BOSQUE DE TASCATE (Tascate Forest)
BP	1	BOSQUE DE PINO (Pine forest)
BPQ	12	BOSQUE DE PINO-ENCINO (Pine-oak forest)
BQ	57	BOSQUE DE ENCINO (Oak forest)
BQP	10	BOSQUE DE ENCINO-PINO (Pine-Oak forest)
DV	8	SIN VEGETACIÓN APARENTE (Without apparent vegetation)
H2O	14	CUERPO DE AGUA (Waterbody)
MDM	43	MATORRAL DESÉRTICO MICROFILO (Microphyllous Desert Scrub)
MDR	1	MATORRAL DESÉRTICO ROSETOFILO (Rosetofilous desert shrubland)
MK	12	BOSQUE DE MEZQUITE (Mesquite Forest)
MKX	87	MEZQUITAL XEROFILO (Xerophytic Mesquite Forest)
MSC	46	MATORRAL SARCOCAULE (Sarcocaulon Brushland)
PC	16	PASTIZAL CULTIVADO (Cultivated Grassland)
PI	156	PASTIZAL INDUCIDO (Induced Grassland)
PN	237	PASTIZAL NATURAL (Natural Grassland)
RA	43	AGRICULTURA DE RIEGO ANUAL (Annual Irrigation Agriculture)
RAP	2	AGRICULTURA DE RIEGO ANUAL Y PERMANENTE (Annual and permanent irrigated agriculture)
RAS	13	AGRICULTURA DE RIEGO ANUAL Y SEMIPERMANENTE (Annual and semi-permanent irrigated agriculture)
TA	12	AGRICULTURA DE TEMPORAL ANUAL (Annual seasonal agriculture)
VG	17	VEGETACIÓN DE GALERÍA (Gallery Vegetation)
VH	1	VEGETACIÓN HALÓFILA XEROFILA (Halophyte Xeric Vegetation)
VSa/BPQ	1	VEGETACIÓN SECUNDARIA ARBUSTIVADE BOSQUE DE PINO-ENCINO (Pine-Oak Forest Secondary Shrub Vegetation)
VSa/BQ	53	VEGETACIÓN SECUNDARIA ARBUSTIVADE BOSQUE DE ENCINO (Oak Forest Secondary Shrub Vegetation)
VSa/MDM	18	VEGETACIÓN SECUNDARIA ARBUSTIVADE MATORRAL DESÉRTICO MICROFILO (Microphyllous Desert Scrub Secondary Shrub Vegetation)
VSa/MKX	2	VEGETACIÓN SECUNDARIA ARBUSTIVADE MEZQUITAL XEROFILO (Xerophytic Mesquite Forest Secondary Shrub Vegetation)
VSa/PN	31	VEGETACIÓN SECUNDARIA ARBUSTIVADE PASTIZAL NATURAL (Natural Grassland Secondary Shrub Vegetation)
ZU	13	ZONA URBANA (Urban Area)

Table 4.Vegetation classes in A and its frequency

Classes in B.

CVE_UNION	Count	Description
AH	8	ASENTAMIENTOS HUMANOS (Human Settlements)
BG	7	BOSQUE DE GALERÍA (Tree Gallery Forest)
BJ	10	BOSQUE DE TASCATE (Tascate Forest)
BP	50	BOSQUE DE PINO (Pine forest)
BPQ	20	BOSQUE DE PINO-ENCINO (Pine-oak forest)
BQ	50	BOSQUE DE ENCINO (Oak forest)
BQP	31	BOSQUE DE ENCINO-PINO (Pine-Oak forest)
BS	2	BOSQUE DE AYARİN (Spruce-fir forest)
DV	16	SIN VEGETACIÓN APARENTE (Without apparent vegetation)
H2O	75	CUERPO DE AGUA (Waterbody)
MDM	224	MATORRAL DESÉRTICO MICROFILO (Microphyllous Desert Scrub)
MDR	342	MATORRAL DESÉRTICO ROSETOFILO (Rosetofilous desert shrubland)
MET	15	MATORRAL ESPINOSO TAMAULIPECO (Tamaulipecan Thorny Scrub)
MK	38	BOSQUE DE MEZQUITE (Mesquite Forest)
ML	50	CHAPARRAL (Chaparral)
MSM	26	MATORRAL SUBMONTANO (Sub-montane Scrub
PC	4	PASTIZAL CULTIVADO (Cultivated Grassland)
PH	137	PASTIZAL HALÓFILO (Halophyte Grassland)
PI	51	PASTIZAL INDUCIDO (Induced Grassland)
PN	225	PASTIZAL NATURAL (Natural Grassland)
RA	34	AGRICULTURA DE RIEGO ANNUAL (Annual Irrigation Agriculture)
RAP	2	AGRICULTURA DE RIEGO ANUAL Y PERMANENTE (Annual and permanent irrigated agriculture)
RAS	18	AGRICULTURA DE RIEGO ANUAL Y SEMIPERMANENTE (Annual and semi-permanent irrigated agriculture)
RP	2	AGRICULTURA DE RIEGO PERMANENTE (Permanent irrigation agriculture)
RS	1	AGRICULTURA DE RIEGO SEMIPERMANENTE (Semi-permanent irrigated agriculture)
TA	39	AGRICULTURA DE TEMPORAL ANUAL Annual (Annual seasonal agriculture)
VG	65	VEGETACIÓN DE GALERÍA (Gallery Vegetation)
VH	10	VEGETACIÓN HALOFILA XEROFILA (Halophyte Xeric Vegetation)
VSa/BP	3	VEGETACIÓN SECUNDARIA ARBUSTIVA DE BOSQUE DE PINO (Pine Forest Secondary Shrub Vegetation)
VSa/BPQ	1	VEGETACIÓN SECUNDARIA ARBUSTIVA DE BOSQUE DE PINO-ENCINO (Pine-Oak Forest Secondary Shrub Vegetation)
VSa/BQ	28	VEGETACIÓN SECUNDARIA ARBUSTIVA DE BOSQUE DE ENCINO (Oak Forest Secondary Shrub Vegetation)
VSa/BQP	12	VEGETACIÓN SECUNDARIA ARBUSTIVA DE BOSQUE DE ENCINO-PINO (Oak-Pine Forest Secondary Shrub Vegetation)
VSa/MDM	97	VEGETACIÓN SECUNDARIA ARBUSTIVA DE MATORRAL DESÉRTICO MICROFILO (Microphyllous Desert Scrub Secondary Shrub Vegetation)
VSa/MDR	15	VEGETACIÓN SECUNDARIA ARBUSTIVA DE MATORRAL DESÉRTICO ROSETOFILO (Rosetofilous like Desert Scrub Secondary Shrub Vegetation)

VSa/MET	3	VEGETACIÓN SECUNDARIA ARBUSTIVA DE MATORRAL ESPINOSO TAMAULIPECO (Tamaulipecan Thorny Scrub Secondary Shrub Vegetation)
VSa/MSM	3	VEGETACIÓN SECUNDARIA ARBUSTIVA DE MATORRAL SUBMONTANO (Submontane Scrub Secondary Shrub Vegetation)
VSa/PH	5	VEGETACIÓN SECUNDARIA ARBUSTIVA DE PASTIZAL HALÓFILO (Halophyte Grassland Secondary Shrub Vegetation)
VSa/PN	15	VEGETACIÓN SECUNDARIA ARBUSTIVA DE PASTIZAL NATURAL (Natural Grassland Secondary Shrub Vegetation)
VSa/VG	1	VEGETACIÓN SECUNDARIA ARBUSTIVA DE VEGETACIÓN DE GALERÍA (Gallery Vegetation Secondary Shrub Vegetation)
VSh/MDM	1	VEGETACIÓN SECUNDARIA HERBÁCEA DE MATORRAL DESÉRTICO MICROFILO (Microphyllous Desert Scrub Secondary Herbaceous Vegetation)
ZU	13	ZONA URBANA (Urban Area)

Table 5. *Vegetation classes in B and its frequency*

Appendix 2: Vegetation Map and Class Descriptions

Classes found in pilot Areas A or B can be identified in alphabetical order by Code in the table below:

Class Proper Name	***CVE_UNION***
Asentamientos Humanos	AH
Bosque De Galería	BG
Bosque De Táscate	BJ
Bosque De Pino	BP
Bosque De Pino-Encino	BPQ
Bosque De Encino	BQ
Bosque De Encino-Pino	BQP
Bosque De Ayarín	BS
Sin Vegetación Aparente	DV
Cuerpo De Agua	H2O
Matorral Desértico Micrófilo	MDM
Matorral Desértico Rosetófilo	MDR
Matorral Espinoso Tamaulipeco	MET
Bosque De Mezquite	MK
Mezquital Xerófilo	MKX
Chaparral	ML
Matorral Submontano	MSM
Pastizal Cultivado	PC
Pastizal Halófilo	PH
Pastizal Inducido	PI
Pastizal Natural	PN
Agricultura De Riego Anual	RA

Agricultura De Riego Anual Y Permanente	RAP
Agricultura De Riego Anual Y Semipermanente	RAS
Agricultura De Riego Permanente	RP
Agricultura De Riego Semipermanente	RS
Agricultura De Temporal Anual	TA
Vegetación De Galería	VG
Vegetación Halófila Xerófila	VH
Vegetación Secundaria Arbustiva De Bosque De Pino	VSa/BP
Vegetación Secundaria Arbustiva De Bosque De Pino-Encino	VSa/BPQ
Vegetación Secundaria Arbustiva De Bosque De Encino	VSa/BQ
Vegetación Secundaria Arbustiva De Bosque De Encino-Pino	VSa/BQP
Vegetación Secundaria Arbustiva De Matorral Desértico Micrófilo	VSa/MDM
Vegetación Secundaria Arbustiva De Matorral Desértico Rosetófilo	VSa/MDR
Vegetación Secundaria Arbustiva De Matorral Espinoso Tamaulipeco	VSa/MET
Vegetación Secundaria Arbustiva De Mezquital Xerófilo	VSa/MKX
Vegetación Secundaria Arbustiva De Matorral Submontano	VSa/MSM
Vegetación Secundaria Arbustiva De Pastizal Halófilo	VSa/PH
Vegetación Secundaria Arbustiva De Pastizal Natural	VSa/PN
Vegetación Secundaria Arbustiva De Vegetación De Galería	VSa/VG
Vegetación Secundaria Herbácea De Matorral Desértico Micrófilo	VSh/MDM
Zona Urbana	ZU

Table 6. Vegetation class description for pilot zone A and B

Appendix 3: Class descriptions

Class descriptions are modified and translated from INEGI's interpretation guide[54]. This guide is used extensively in Mexico and North America, it is a basic input for performing institutional programs such as generation National Forest and Soil Inventory, conducted by the National Forestry Commission (CONAFOR), the map of Ecologic Regions of North America, prepared by the Commission for Environmental Cooperation of North America (CCA) and the Monitoring Map of Land Cover in North America that for the portion corresponding to Mexico was drawn up between the INEGI, CONABIO and CONAFOR. A crosswalk can be referenced later in this report as *Table 7.* in Appendix 4.

Asentamientos Humanos (Human Settlements)

Figure 15. Human Settlements

These are small settlements, such as hamlets and villages, with low populations and/or low population densities as compared with urban areas. They may have restricted access to some services. For example, a village may have only one or two general stores, while a large metropolis may have many specialized stores and chain stores. Larger settlements also have a sphere of influence affecting surrounding settlements.

Settlements may also be identified by the site chosen. The functions of human settlements also differ, as settlements may be established as ports, market towns, and resorts. Types of rural settlements may also be classified by function, such as proximity to farming, fishing, and mining.

Bosque de Galería (Tree Gallery Forest)

Figure 16. Tree Gallery Forest

Arboreal community forming narrow strips of vegetation on the banks of the rivers or streams in much of the country, it can be found usually in places with climates temperate to dry along water features, so the values of altitude, temperature, and precipitation in these sites are highly variable. It develops in areas with favorable conditions of soil moisture and its species can withstand temporary flooding and even invade quickly exposed riverine areas.

The dominant arboreal layer of these Woods presents varying heights, from 4 up to more than 30 meters, with species Evergreen, semi-deciduous or deciduous. The gallery forests formed by sabino are characterized for Ahuehuete (*Taxodium mucronatum*) in the North of Mexico, as well as other species such as willow (*Salix spp*.), ash (*Fraxinus spp*.), poplars (*Populus spp.*), Sycamore Alder or poplar (*Platanus spp*.) and *Astianthus viminalis*.

Bosque de Táscate (Tascate Forest)

Figure 17. Tascate Forest

Plant community, diffused from Baja California to Chiapas focusing mainly on the Neo-volcanic axis, in the States of Hidalgo, Tlaxcala, and Puebla, and to a lesser extent in the provinces Peninsula of Baja California, Sierra Madre Oriental, Sierra Madre Occidental, and the Sierra Madre del Sur. Climates in which this community develops range from the cold of the high mountains to the sub-humid temperate and the dry arid, is located at altitudes between 1 000 and 2 600 m., with an annual average temperature ranging from 12 to 22° C, and precipitation that fluctuates from 200 to 1 200 mm. in terms of the substrate takes place mainly in tuffs and basalts igneous, sedimentary rocks such as limestone and Shales, and to a lesser extent the metamorphic rocks such as gneiss and schists among others, in terms of soils the most common and representative are regosols luvisols, leptosols, vertisols and to a lesser extent the chernozem, phaeozem, among others. They are formed by squamous-folios (Flake-shaped leaves) trees of the genus *Juniperus*; those who are known as Táscate, Juniper or Cedar, with an average height of 8 to 15 m., always in contact with forests of oak, pine-oak, tropical deciduous forest and arid scrub. The species most common and greater distribution in these forests are *Juniperus flaccida, j. deppeana, j. monosperm.*

Bosque de Pino (Pine forest)

Figure 8. Pine Forest

These are plant communities that are located in the mountain ranges from California to Chiapas. The areas of greatest importance are located in the Sierra Madre Occidental and the Neo-volcanic axis. Climates, where it develops, are warm and temperate sub-humid with rains in summer, with an average annual temperature that varies from the 6 to 28 °C and annual rainfall ranging from 350 to 1 200 mm. It is located from 150 m. of

altitude up to 4 200 m. in the altitudinal Timberline limit. With a slope ranging from 10 to 75%, they can be found in various exhibitions, but prefer which are oriented towards the North. The pine forests are set on igneous rocks, gneiss, schists, and shales, sandstones, and limestones, although on the latter with much less frequency.

They are located on cambisols, leptosols, luvisols, phaeozems, regosols, and umbrisols soils, among others.

These forests are dominated by different species of pine with average heights of 15 to 30 m., pine forests have a lower stratum relatively poor in bushes, but with abundant grasses, this condition is associated with frequent fires and immoderate felling.

The pine trees have evergreen leaves, with a time of flowering and fruiting heterogeneous, due to different weather conditions presented. The most common species are Chinese pine (*Pinus leiophylla*), pine (p. hartwegii), white pine (*p. montezumae*), straight pine (*p. pseudostrobus*), pine (*p. rudis*), pine escobeton (*p. devoniana (p. michoacana*)), Chinese pine (*p. teocote*), ocote trompillo (*p. oocarpa*), pine ayacahuite (*p. ayacahuite*), pine (*p. pringlei*), *p. duranguensis, p. chihuahuana, p. engelmannii, p. lawsoni, p. Oaxacan,* among the 46 species cited for Mexico.

Bosque de Pino-Encino (Pine-oak forest)

Figure 9. Pine-Oak Forest

These are plant communities characteristic of the mountainous areas of Mexico. They are distributed in neo-volcanic axis, the Sierra Madre Oriental, Sierra Madre Occidental and the Sierra Madre del Sur.

In temperate, semi-cold, semi-warm and warm climates humid and sub-humid with rains in summer, with temperatures ranging between 10 and 28° C and a rainfall ranging from 600 to 2 500 mm. per year. Its largest distribution is located between 1 200 to 3 200 m., although you can find them at a lower altitude. Exposure can occur from flat to those that are oriented towards the North, South, East, and West. They settled in the substrate of igneous and sedimentary and metamorphic, less frequently seen on soils shallow, deep and Rocky as cambisols, luvisols, leptosols, regosols, among others.

They reach heights of 8 to 35 m., communities are made up of different species of pine (I and oak (*Quercus spp*.); but with the dominance of the first. The transition from Oak to the pine forest is determined (in natural conditions) by the altitudinal gradient. They are trees Evergreen and deciduous, flowering and fruiting is variable throughout the year. These mixtures are common and occupy many

conditions of distribution. Some of the most common species are Chinese pine (*Pinus leiophylla*), pine (*p. hartwegii*), white pine (*p. montezumae*), straight pine (*p. pseudostrobus*), pine (*p. rudis*), pine escobeton (*p. devoniana (p. michoacana)*), Chinese pine (*p. teocote*), ocote trompillo (*p. oocarpa*), pine ayacahuite (*p. ayacahuite*), pine (*p. pringlei*), *p. duranguensis, p. chihuahuana, p. engelmannii, p. lawsoni, p. Oaxacan, Oak laurelillo (Quercus laurina),* oak *(Q. magnoliifolia) ,* white oak *(q. candicans),* oak *(Q. crassifolia),* quebracho oak *(rough Q.),* tesmolillo oak *(Q. crassipes),* spoon oak *(Q. urbanii), charrasquillo (Q. microphylla),* red oak *(Q. castanea), encino prieto (Q. laeta), laurelillo (Mexican Q.), q. glaucoides* and *Q. scytophylla.*

Bosque de Encino (Oak forest)

Plant communities in the mountain massifs of Mexico, in the Sierra Madre Oriental, Sierra Madre Occidental and Sierra Madre del Sur, Neo-volcanic axis, Sierra Norte de Oaxaca in the States of Baja California, Baja California, Nuevo Leon, Veracruz, Oaxaca, Michoacan Mexico, Jalisco, Guerrero, among others, with the exception of the Yucatan península.

Figure 20. Oak Forest

Weather warm, temperate sub-humid, humid to dry, with annual temperatures that go from the 10 to 26 ° c and a rainfall annual average varies from 350 to 2 000 mm. It develops in very different ecological conditions from sea level up to 3000 m.of altitude.

Preferably located in Northern and Western exposure, but can be found elsewhere. This type of vegetation has been observed in different kinds of bedrock, igneous, sedimentary and metamorphic rocks, in deep or shallow soils as regosols, leptosols, cambisols, andosols, and luvisols, among others.

These communities are formed by different species of Oaks or Oaks of the genus Quercus (more than 200 species in Mexico); These forests are usually found as a transition between the coniferous forests and jungles, the size varies from 4 to 30 m.in height from open to very dense. In general, this type of community is closely related to the pine, forming a series of complex mosaics. The most common species of these communities are oak laurelillo *(Quercus laurina),* Oak nopis *(Q. magnoliifolia),* white oak *(Q. candicans),* oak *(Q. crassifolia),* encino quebracho *(rough Q.),* Oak tesmolillo *(Q. crassipes),* Oak cúcharo *(Q. urbanii),* charrasquillo *(Q. microphylla),* red oak *(Q. castanea),* encino prieto *(Q. laeta),* laurelillo (Mexican Q.), *q. glaucoides, Q. scytophylla* in tropical area *Quercus oleoides.* They are evergreen trees or deciduous trees with a period of flowering and fruiting variable, usually, blooming occurs in the dry season from December to March, and the fruits mature between the months of June and August.

Bosque de Encino-Pino (Pine-Oak forest)

Community mainly distributed in the mountain systems of the country, concentrating most on Sierra Madre Occidental, Neo-volcanic axis, and Sierra Madre South and to a lesser extent Sierra Madre Oriental, Central American Cordillera, mountains of Chiapas and Guatemala, the coastal plain of the north Gulf, and Baja California Peninsula.

Develops in climates temperate, semi-warm, warm, humid and sub-humid with rains in summer, with temperatures ranging between 10 and 28° C and an annual total rainfall that varies from 600 to 2 500 mm, in terms of altitude ranges from 300 to 800 m.2. Exposure can occur from flat to those that are oriented towards the North, South, East, and West. The substrate where this community develops is of igneous origin rhyolites and tuffs and sedimentary limestones as mainly the durisoles and umbrisoles are set in soils as luvisols, leptosols, regosols, and phaeozem to a lesser extent.

Figure 21. Pine-Oak Forest

These communities are shaped by Oaks (*Quercus spp*.) and in a smaller proportion of pine (*Pinus spp*.). It develops mainly in areas of forestry major, in the pine-oak forests lower altitudinal limits. These communities are smaller and height than those where dominates the pine on Oak with a height of 8 to 35 m. They are trees Evergreen and deciduous, flowering and fruiting is variable throughout the year. The most representative species in these communities are oak laurelillo (*Quercus laurina*), Oak nopis (*Q. magnoliifolia*), white oak (*Q. candicans*), oak (*Q. crassifolia*), encino quebracho (rough Q.), Oak tesmolillo (*Q. crassipes*), Oak cúcharo (*Q. urbanii*), charrasquillo (*Q. microphylla*), red oak (*Q. castanea*), encino prieto (*Q. laeta*), laurelillo (Mexican Q.), *q. glaucoides, q. scytophylla*, chinese pine (*Pinus leiophylla*), pine (*p. hartwegii*), white pine (*p. montezumae*) , straight pine (*p. pseudostrobus*), pine (*p. rudis*), pine escobeton (*p. devoniana (p. michoacana*)), chinese pine (*p. teocote*), ocote trompillo (*p. oocarpa*), pine ayacahuite (*p. ayacahuite*), pine (*p. pringlei*), *p. duranguensis, p. chihuahuana, p. Engleman, p. lawsoni,* and *p. oaxacana.*

Bosque de Ayarín (Spruce-fir forest)

Community located in very localized areas and in small patches of the Sierra Madre Occidental in the States of Sonora, Chihuahua, Durango and Coahuila, and in the Sierra Madre Oriental in the States of Nuevo Leon and Tamaulipas; southbound on the Neo-volcanic axis in the State of Puebla and Hidalgo, recently reported to Oaxaca, preferably in slopes and ravines along water currents or very protected valleys. Climates, where it develops, are cool and temperate sub-humid with rains in summer, a temperature that varies from 5 to 22 °C and annual rainfall ranging from 600 to 1 600 mm. It is located between 1 500 and 3 400 meters of altitude.

With a slope ranging from 20 to 65%, the exhibition is preferably north-northeast and northwest. The type of rock lying is igneous and sedimentary, develops on with a sandy texture, deep well-drained soils like cambisols, leptosols, luvisols, among others.

The physiognomy of these forests is characteristic of its high species, with heights ranging from 15 to 40 m. trees Evergreen with a period of bloom from April to May, the maturation of the cones arises from August to October. The dominance of these trees occurs at heights of 30 to 35 m. The most representative of this forest genera are *Pseudotsuga spp*. or *Picea spp*., both known as ayarin or Guatemalan FIR; developing ecological conditions similar to the ones of the oyamel (*Abies spp*.) and times it is mixed with white cedar (*Cupressus sp.).*

Figure 22. Without Apparent Vegetation

Sin Vegetación Aparente (Without apparent vegetation)

Areas void of vegetation, which are composed of bedrock, pebbles, sands, salt, or any geologic outcropping or soil combination. Its main trade is that this class presents with no apparent vegetation in it. The lack of vegetation can be because of the substrate materials or climate (or combination of them) that does not allow vegetation to take hold significantly or permanently in this area.

Additional criteria for the lack of vegetation may be elevation or slope conditions. These may combine with high erosion rates preventing vegetation communities to take hold, or in some cases just delaying the colonization process.

Cuerpo de Agua (Waterbody)

Figure 23. Waterbody

A body of water or waterbody (often spelled water body) is any significant accumulation of water, generally on a planet's surface. The term most often refers to oceans, seas, and lakes, but it includes smaller pools of water such as ponds, wetlands, or more rarely, puddles. A body of water does not have to be still or contained; Rivers, streams, canals, and other geographical features where water moves from one place to another are also considered bodies of water. Waterbodies are naturally occurring geographical features, but some are artificial. There are types that can be

either. For example, most reservoirs are created by engineering dams, but some natural lakes are used as reservoirs.

Matorral Desértico Micrófilo (Microphyllous Desert Scrub)

The distribution of this scrub extends to the drier areas of Mexico, and in areas where precipitation is less than 100 mm. per year, the vegetation comes to cover only 3% of the surface, whereas in places with less unfavorable climates coverage can reach 20%; the height varies from 0.5 to 1.5 m. *Larrea* and *Ambrosia* are 90 to 100 percent of the vegetation in areas of low-relief, but along drainage pathways or in places with pronounced slopes are shrubs with species of *Prosopis, Cercidium, Olneya, Condalia, Lycium, Opuntia, Fouquieria, Hymenoclea, Acacia, Chilopsis* and so on.

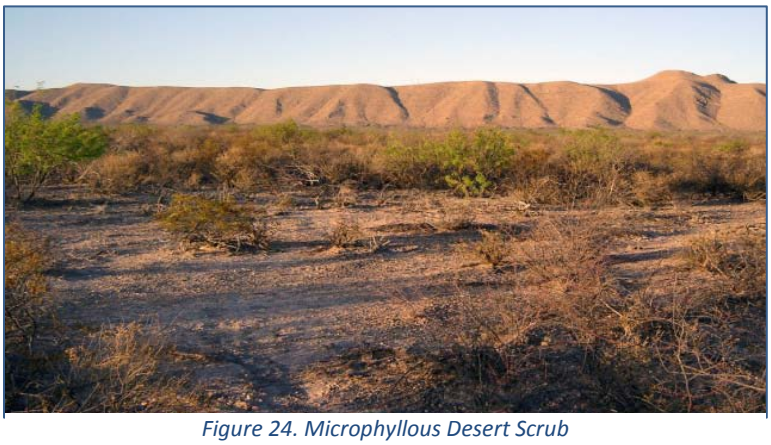


Figure 24. Microphyllous Desert Scrub

In the Sonoran Desert, Larrea extends to the town of Guaymas, where it becomes form patches of pure or almost pure thicket. Community that could deserve the label of border-limiting with respect to the previous is occupied most of the Chihuahuan arid zone, located on the plateau surface and extending from Chihuahua and Coahuila to Hidalgo in elevations that are commonly not less than 1 000 m., it is the thicket of *Larrea tridentata* and *Flourensia cernua* which also develops preferably on Plains and lowlands of alluvial fans, although in even more arid conditions also thrives on hillsides. Anywhere in its area of distribution seems less than 150 mm. in annual average rain and in some warmer areas the upper limit of the precipitation is approaching the 500 mm.

Larrea is often the only dominant, sometimes together with *Flourensia*, account for 80 to 100% of the vegetation; *Flourensia* thickets are less frequent and the observed close to Actopan, Hidalgo, apparently marks the southern end of the distribution of the community.

Matorral Desértico Rosetófilo (Rosetofilous desert shrubland)

Figure 25. Rosetofilous desert shrubland

Scrub dominated by species with rosette leaves, with or without thorns, Stemless apparent either developed. It is usually found on soils type xerosols hillsides of sedimentary origin, in the upper parts of the alluvial fans or conglomerates in almost all the arid and semi-arid areas of the Centre, North, and Northwest of the country. Here are some of the species of greatest economic importance in these arid regions developed as: *Agave* (lechuguilla)

lechuguilla, Agave spp., Hechtia spp. (guapilla*), Dasylirion spp*. (sotol), *Euphorbia antisyphilitica* (candelilla*), Parthenium argentatum* (guayule), *Yucca carnerosana* (samandoca Palm), it is remarkable the presence of cacti companions.

Matorral Espinoso Tamaulipeco (Tamaulipecan Thorny Scrub)

Figure 26. Tamaulipecan Thorny Scrub

Typical of the northern Mexican state of Tamaulipas, this shrub or sub-arboreal community is formed by the dominance of thorny species (therefore its name), deciduous a large part of the year or without leaves.

Its distribution is located in the northern portion of the Northern Gulf coastal plain and the end South of the Great Plains of North America, where some saw tended slopes are presented and mostly plain with low hills, at altitudes from the Northeast State of Tamaulipas that are 100 to 200 m., following this strip to the northeast of the State of Nuevo Leon is continuing in this same parameter and in the Northeast the State of Coahuila de Zaragoza we come to develop at altitudes ranging from 200 to 600 m.

This type of vegetation is established in BS1(h') climates hx' and BS0(h') hx' which correspond to those of semidry type warm and very warm with rains in summer and scarce throughout the year where the maximum temperature is 40 ° C and the minimum is - 2 ° C. The average annual rainfall varies between 500 and 700 mm.

Mostly this type of vegetation is developed in the fluvial soils, a small portion in the State of Coahuila in sedimentary limestone rock and some associations of limestone-shale, in areas northeast of the States of Tamaulipas and Nuevo Leon it presents in sedimentary rock of the shale-sandstone type.

This scrub is composed of shrub species of 1.5 to 2 m.in height, as main species are: *Acacia spp*. (Gavia, Huizache) *Cercidium spp*. (Palo verde), *Leucophyllum spp*. (ASH), *Prosopis spp*. (Mesquite), *tortuous Castela* (Amargoso), *Condalia spp*. (Thorns), and so on. In sites with an accumulation of moisture, they can form a high shrub with individuals up to 4 or 6 m.tall, with leaves or small leaflets and the presence of lateral spines.

Bosque de Mezquite (Mesquite Forest)

Community tree species of Prosopis which develops in alluvial soils in bottom of Valley and depressions in the Plains, where water table is shallow, is also common along streams and intermittent rivers in the semi-arid regions, as in the plain of Rio Verde, SLP and in the Valley of Aguascalientes Ags., or parts of the Bajio, Gto.

Figure 27. Mesquite Forest

In Baja California these mesquite forests occur along streams intermittent, emphasizing on the surrounding vegetation.

They often form tree communities of between 5 and 20 m.in height.

The distribution of this type of community is very wide in the the southern United States and all of Mexico but highly fragmented by their ecological requirements.

Mezquital Xerófilo (Xerophytic Mesquite Forest)

It occurs in northwest of the country, discontinuously enters also in Tamaulipas, and part of the States of Chihuahua, Zacatecas, and San Luis Potosí, predominant weather types are very dry BW, dry BS is 45.8 ° C the maximum temperature and the minimum temperature of - 3 ° C, the precipitation average annual 100 to 700 mm.

Figure 28 Xerophytic Mesquite Forest

This type of community is developed from 100 up to 2300 m.of altitude. It occurs mainly in Plains, and to a lesser extent on mountains and hills. The main elements are associated with other types of xerophytes bushes as the microphyll desert scrub-shrub.

The species present are *Prosopis juliflora, Acacia spp., Opuntia SP., Jatropha sp. Bouteloua spp.*

Chaparral (Chaparral)

Chaparral is an Association of shrubs or sclerophyllous trees from 1-4 m.high, usually fire-resistant. It is located in the Plains, valleys and hills occasionally interspersed with other kinds of vegetation.

Figure 29. Chaparral

It develops in semi-hot and semi-cold with low humidity climates and sub-humid temperate, very characteristic of the northern region of the Baja California peninsula. The average annual rainfall varies between 350 and 600 mm, more than 75% of the precipitation occurs during the months of October to April. The period of the six dry months (May to October) coincides with high temperatures; as the rains disappear between April and May, the chaparral begins to dry out, and in the months of July and August, the community is highly susceptible to fire.

Chaparral is well adapted to the dry season and the fire; after the fires, many of the species are quickly regenerated by scarification seeds suffer during the fire.

The most common species of this Chaparral in Baja California is *Adenostoma fasciculatum*; other common components include: *Arctostaphylos spp., Ceanothus spp., Quercus spp., Eriogonum fasciculatum, Cercocarpus spp., Mimulus spp., Rhamnus spp., Heteromeles arbutifolia* and *Yucca whipplei*. While the largest of chaparral extensions are in California and Baja California, where it is developed under a Mediterranean climate, there are some similar communities that require further study in many mountain ranges of the country, under other climatic regimes.

Figure 30. Sub-montane Scrub

Matorral Submontano (Sub-montane Scrub)

Sub-montane scrub occurs at altitudes of 1 500 to 1 700 m., developed mainly in the low slopes of both slopes of the Sierra Madre Oriental, is a sometimes very dense shrub community, made up of unarmed or sometimes thorny, deciduous species for a brief period of the year, it develops mainly in dry climates steppe, desert and temperate its average annual temperature varies from 12 to 26 °C reaching up to 40 °C in summer the mean annual rainfall ranges between 300 to 900 mm. per year of precipitation.

Its range extends in the States of Nuevo León, Nuevo León and Tamaulipas, San Luis Potosí, Querétaro, and Hidalgo. This type of vegetation is located on slopes, Glens and Highlands, are flat or sloping of the

plateaus and hills, the terrain is stony surface and texture fine and it is common to find plants growing on rocks.

They are very thin soils, its thickness is less than 10 cm, rests on a layer of hard and continuous, and in soils little developed, consisting of loose rock-like material.

It grows on shallow soils that sometimes are a surface layer of leaf litter and commonly presented to outcroppings of bedrock, corresponding to the types of soils Leptosols and Regosols.

Its main components include the following: *Helieta parvifolia (*Jimmy*), Neopringlea integrifolia* (hen hamstrings)*, Cordia boissieri* (*anacahuita*), *Pithecellobium pallens (*pliers*), Acacia rigidula (*gavia)*, Gochnatia hypoleuca (*ocotillo, olive*) Karwinskia spp. (*Lemongrass*), Capparis incana (*Croton*), Rhus virens* (lantrisco), *Flourensia laurifolia, Mimosa leucaeneoides, Mortonia greggi (*tuner)*, Zanthoxylum fagara,* etc.

Sub-montane scrub provides the physiognomy of this community the upper shrub layer, whose height varies between 2.5 to 5.0 m.and reaches up to 70% coverage. Helietta characterizes it parvifolia, rutacea unarmed that gives the vegetation a structure relatively uniform, as it is normally the only dominant, although occasionally *Acacia berlandieri* (Huajillo) is equally important. Prevailing medium shrub (0.5 to 2 m.high) species are *Leucophyllum frutescens* and *Acacia rigidula*. Coverage varies from 50 to 80%. The bottom tier, less than 0.5 m.in height, is diverse both in species and coverage; It is remarkable in the clear of vegetation, where Agave lechuguilla, *Euphorbia antysiphilitica* (Candelilla) and grasses of the genus *Bouteloua, Tridens,* and *Aristida amacolladas* are the most important elements.

Pastizal Cultivado (Cultivated Grassland)

Figure 31. Cultivated Grassland

The grasslands or pastures are those ecosystems dominated by herbaceous vegetation. These ecosystems can be of natural origin constituting extensive biomes, or result from a human intervention for the purpose of breeding livestock or recreation, that is the case of the cultivated grassland.

Grasslands occur in places where it does not fall enough rain water so that a forest develops, but where there is much like there is a desert. Grasslands are just full of pasture (grasses). Wheat pastures can be considered cultivated grassland, while they are almost always grown and tendered by humans. During cold weather, grass remains dormant until it greens again.

Pastizal Halófilo (Halophyte Grassland)

Figure 32 Halophyte Grassland

The community of grasses and straw that develops on saline soils, so its presence is independent of the climate; it is common in the bottom of the closed basins in arid and semi-arid areas and in some areas close to coastlines affected by the sea or coastal lagoons.

Its distribution ranges throughout the Highlands, from Chihuahua and Coahuila to Jalisco, Michoacan, Mexico Valley, Puebla, and Tlaxcala, as well as portions of coastal plains of the northern part of the country.

When the chlorides and sulfates are dominant salts, the pH of the soil where these pastures are developed is usually kept between 7 and 8.5, on the other hand, if the carbonates are the most abundant, the reaction is strongly alkaline.

Usually, the average annual rainfall that facilitates the development of this class ranges from 200 mm. to 600 mm. on average. These soils, typically, are clayey texture and poor drainage and often are subject to more or less extended flooding. Soil moisture, as well as the content of salts and its alkalinity, may have a variation pointed throughout the year and often also from year to year.

Between biological forms of communities, Halophytes dominate the rhizomatous grasses and herbaceous succulent plants.

Halophyte grasslands of the Highlands vary usually from low to medium-sized (up to 80 cm high) and are generally dense. With the objective of stimulating the emergence of tender young shoots these pastures are periodically burned. In Chihuahua and Coahuila, mainly, occupies large tracts of *Hilaria mutica* (Toboso) grassland, 40 to 70 cm in height.

Of the most outstanding coastal halophilous grasslands include those of *Distichlis spicata, Sporobolus virginicus* and *Monantochloe littoralis*, forming a low folder, and *Spartina* and *Uniola*, measuring about 1 m.high.

In general, the dominant grasses are rather rigid and only tender parts constitute an attractive fodder for livestock. Since then the grasses are not the only plants that grow in such conditions, but often they are dominant and which define the appearance of the plant communities that live there.

Pastizal Inducido (Induced Grassland)

This community is dominated by grasses or straw and appears as a result of the dismantling of any type of vegetation; it can also settle in abandoned agricultural areas or product areas that are often set on fire.

Figure 33. Induced Grassland

Induced grassland sometimes corresponds to a phase of the normal succession of plant communities, whose climax is usually a forest or a thicket. As a result of intense grazing or periodic fires, or both factors together, often stops the process of succession and induced grassland remains as such while endures the human activity that keeps it. Other times induced grassland is not part of any normal series of succession of communities, but is established and endures as a result of an intense and prolonged disturbance, exercised through logging, fire, grazing, and many with the help of some factor of the natural environment, as, for example, the tendency to produce changes in soil favoring the maintenance of grassland. In this way, it has the status of induced grasslands that thrive once forests of pine and oak, typical of the mountainous areas of Mexico are destroyed.

At altitudes of over 2 800 m.secondary communities are often similar to the high mountain meadow, formed by tall grasses growing in extensive tillers. *Muhlenbergia, Festuca, Stipa* and *Calamagrostis* genres are the most typical of these grasslands that, in addition to its livestock interest, they are also used through the extraction of the root of rough grass as raw material for the manufacture of brooms that provide underground parts of *Muhlenbergia macroura*.

Below 3 000 m.altitude, induced grassland-derived from forests of oak and pine, are much more varied and generally do not present the appearance of very large tillers. They are often similar in appearance to grassland climax of semi-arid, may vary from low to very high, often regions according to the climate. The genera to which they belong the dominant grasses include *Andropogon, Aristida, Bouteloua, Bromus, Deschampsia, Hilaria, Muhlenbergia, Stipa, Trachypogon* and *Trisetum*.

Less frequent or perhaps less easy to identify are grasslands originated at the expense of xerophytes bushes and even of other grasslands.

Of the Valley of Mexico described communities of this type, which are generally low and often open, include a large number of grasses per year. The genera *Buchloe, Erioneuron, Aristida, Lycurus* and *Bouteloua* frequently contain the dominant species.

Another group of induced grassland that stands out much, are those seen in the middle of the low deciduous forest, especially on the Pacific slope, where apparently they thrive as a result of a very pronounced disturbance. They are almost always in the vicinity of settlements and are so intensely grazed that during most part of the year the indoor vegetable herbaceous happens from an average height of 5 cm.

They are subjected to frequent fires and trampling action seems to be one of the main factors of its existence. The long period of drought makes having a straw yellow color for more than 6 months.

The most common dominant species here belong to the genera: *Bouteloua, Cathestecum, Hilaria, Trachypogon* and *Aristida*. Some legumes are abundant. Another community is the one that thrives mainly on the side of the Gulf of Mexico in wetlands, the climax vegetation, corresponding to the forest mesophyll of the mountain, almost always on very steep slopes of the mountains. Unlike the previous grasslands, it remains green year-round but likewise remains quite low. In general, it covers thick soil but usually gives the impression of being over-grassed.

The most common grasses here belong to the genera Axonopus, Digitaria, *and* Paspalum.

Some other species of grasses that form induced grassland communities, are: *Aristida adscensionis* (three grass beards), *Erioneuron pulchellum* (Zacate borreguero), *Bouteloua simplex, Paspalum notatum* (Zacate donkey), *Cenchrus spp*. (Grass cadillo or rosette), *Lycurus phleoides, Enneapogon desvauxii* and others. The occasional presence of different herbs, shrubs, and trees is not uncommon.

Pastizal Natural (Natural Grassland)

Figure 34. Natural Grassland

Natural grassland is a community dominated by species of grasses and straw, sometimes accompanied by herbs and bushes of different families, such as: composed, legumes, etc. Their main area of distribution is located in the transition zone between the xerophytes bushes and different types of forests. The extensive area of natural grassland enters Mexican territory in the form of a narrow wedge that runs on the plateau along the base of the Sierra Madre Occidental from Chihuahua's northwest to Jalisco's Northeast and neighboring areas of Guanajuato, and also includes the far northeast of Sonora. This continuous strip consists of plant communities dominated by grasses which constitute climatic climax and it represents the largest area of natural grassland in Mexico. Like the majority of grasslands in the world, this strip occupies a portion of transition between forest on one side and on the other xerophytes thickets.

Natural Grassland develops preferably in moderately deep soils of plateaus, funds of valleys and slopes little inclined, almost always of a fiery nature, at altitudes between 1 and 100 and 2 500 m., although in Sonora can descend to 450 m. The annual average temperatures vary in the greater part of its extension from 12 to 20 ° C. Seasonal and diurnal fluctuations are relatively pronounced, every year presents Frost and in the Highlands of Chihuahua and Sonora occur snowfall with some frequency, registering extreme minimum temperatures from - 20 up to 45 ° C maximum in the hottest months.

The average annual rainfall is of the order of 300 to 600 mm, with 6 to 9 months dry and humidity remains low during most of the year. Own these grassland soils are generally neutral (pH 6 to 8), with a texture varying from granular clay to Sandy-granular and reddish color to Brown, often with a horizon of gypsum concentration or ferruginous layers that continues more or less. Usually they are fertile and

fairly rich in organic matter, although these soils erode easily when they are in decline and with lack of sufficient protection provided by vegetation.

Grasslands in question are usually high in average, 20 to 70 cm, although because of the intense grazing they are almost always below those values. Pale yellowish coloration is characteristic for most of the year and the community creates only green in the more humid times. Coverage varies significantly from one place to another and has to do with the use of the grassland, but rarely exceeds 80% and is often less than 50%.

Its structure is simple, because, in addition to a stratum flush, formed mainly by plants creeping, sometimes including algae, there is a single herbaceous stratum, which tends to dominate widely grasses, although many species from other families may appear in the Pro era. Woody plants are often completely absent when they exist, only to play a supporting role by the disturbance, and sometimes it forms one or two strata. The climbers plants are scarce and Xeric type epiphytes occur only occasionally on the branches of shrubs and isolated trees.

In this community, plants that are frequently dominant or codominant is the association of species of the *Bouteloua* genus and is the most common of all *Bouteloua gracilis*, which prevails in expanses of grassland, especially on sites that overgrazing not been disturbed too original conditions and preferably something deep soils. Outstanding slopes, with shallow, stony soil, are often more abundant *Bouteloua curtipendula* and *Bouteloua hirsuta*. They are less frequent in general, *Bouteloua rothrockii, Bouteloua radicosa, Bouteloua repens, Bouteloua eriopoda* and *Bouteloua chondrosioides*, but in some areas, it can also function as dominant or co-dominant: *Bouteloua eriopoda* and *Bouteloua scorpioides*; they are apparently favored by an intense grazing, displacing *Bouteloua* gracilis in certain areas.

Agricultura de Riego Annual (Annual irrigation agriculture)

These agricultural systems use supplemental water for the development of crops during the crop cycle, so its definition is based mainly on the way how is the implementation of the water, such as sprinkling, drip, or any other technique, is the case of rolling water (distribution of water through furrows either pipe from a main channel and distributed directly to the plant) , by pumping from the power supply (a well, for example) or by gravity when it goes directly to the main channel from upstream of a dam or a natural water body. Examples of these types of agricultural systems are presented in much of the country, mainly in some areas of the coastal plain of Sinaloa State and in the Bajio region.

Agricultura de Riego Anual y Permanente (Annual and permanent irrigated agriculture)

These agricultural systems use supplemental water for the development of crops during the crop cycle, same as above but can be supported seasonally or supported all year.

Agricultura de Riego Anual y Semipermanente (Annual and semi-permanent irrigated agriculture)

These agricultural systems use supplemental water for the development of crops during the crop cycle, same as above but can be supported seasonally or supported almost all year.

Agricultura de Riego Permanente (Permanent irrigation agriculture)

Figure 35. Permanent irrigation agriculture

These agricultural systems use supplemental water for the development of crops during the crop cycle year round, so its definition is based mainly on the way how is the implementation of the water, such as sprinkling, drip, or any other technique, is the case of rolled water (distribution of water through furrows either pipe from a main channel and distributed directly to the plant) , by pumping from the power supply (a well, for example) or by gravity when it goes directly to the main channel from upstream of a dam or a natural water body.

Agricultura de Riego Semipermanente (Semi-permanent irrigated agriculture)

Type of agriculture which is mainly practiced in the marginalized areas and in the Highlands, is mainly limited by natural rainfall (rain season) supplemented with some irrigation, is not competent in the market due to low yields of rained agriculture is not anything other than agricultural production that depends on conditions of rain to produce with little help from irrigation systems where water is scarce. Any crop that is sown in this way is known as temporary, even if it is cereal, fruit or vegetable. This type of agriculture is typical of low-tech systems of production, only in some regions achieve good yields, although this depends on good planning culture and above all of the good presence of rain. It is not meant for only a fruit of season or only cereals, is that production depends on rain.

Agricultura de Temporal Annual (Annual seasonal agriculture)

Figure 36. Annual seasonal agriculture

It is classified as a type of farming where the growing season of crops which are planted depends on rain water, so its success depends on rainfall and the ability of the soil to retain water, their classification is independent of time lasting cultivation on soil, which can reach more than ten years, in the case of fruit trees, or are for periods within one year as summer crops. It includes those who receive winter garbanzo crops dependent on water from natural precipitation.

These areas, to be classified as temporary should be planted at least

80% of the agricultural cycle. They may be areas of monoculture or polyculture and can combine with grassland either be mixed with areas of irrigation, which forms a mosaic complex, difficult to separate, but that usually has dominance of crops whose growth depends on rain water.

In very particular cases, as it is the cultivation of coffee, cocoa, and vanilla, which are developed in the shadow of natural or cultivated trees, his cartographic boundary is very difficult using low-resolution remote sensing by what his characterization is carried out with the support of field observation.

It is also common to find areas abandoned among the mentioned crops and where natural species have restored their natural succession to disappear the influence of man; under these conditions, the areas are classified as natural according to its successional stage vegetation or as primary vegetation if original arboreal components predominate. As an example we have it in conditions of high forest - Evergreen and semi-evergreen medium or mesophyll mountain forests.

Vegetación de Galería (Gallery Vegetation)

Figure 37. Gallery Vegetation

Composed by shrubby communities, occasionally with sub-arboreal elements, it is developed on the banks of rivers and streams, always under wet conditions. In general are located in areas of temperate climates to dry, with broad ranges of temperature, humidity, and altitude, above land surface moisture or shallow phreatic mantle into the usually dry river bed.

This type of vegetation is dominated by generally a single shrub, which can quite present as dense or also spaced, with between 1 and 2 m.height and scrubland constituted by elements usually Evergreen.

Other genres that can be integrated to the gallery vegetation include *Baccharis, Chilopsis, Senecio, Acacia, Mimosa,* and *Salix*, and the presence of mesquite is not rare (*Prosopis SP*.) in the Northwest and North of the country.

Vegetación Halófila Xerófila (Halophyte Xeric Vegetation)

Constituted by herbaceous or shrubby plant communities that are characterized by developing on soils with a high content of salts in any part of the country, it is common in the lower parts of closed basins in arid and semi-arid areas.

This community characterized by low height species, by the dominance of pastures rizomatosos and rigid stems, as well as a poor coverage of shrub species. This vegetation develops in areas where

geological and climatic factors gave rise to saline areas. The most abundant species correspond strictly to Halophyte as saltbush (*Atriplex spp.),* romerito (*Suaeda spp*.), herb rheuma (*Frankenia spp*.) and Lavender (*Limonium spp*.). Other species able to withstand these conditions are purslane (*Sesuvium spp.*), toboso grass (*Hilaria spp*.), grass (*Eragrostis obtusiflora*), among several others. They are common associations of *Atriplex spp., Suaeda spp., Frankenia spp.,* with other species.

This type of vegetation, characteristic of soils with high content of soluble salts, can assume various phenotypes and ecological forms because they can dominate as herbaceous plants, shrubs and even trees. Such fact is due, at least in part, in saline soils are presented in varied climatic conditions and in addition, also the edaphic characteristics vary in regards to the amount and types of salts, as a reaction pH, texture, permeability, amount of water available, etc.

Figure 38. Halophyte Xeric Vegetation

Soils with excess salts are common in the lower parts of the endorheic basins.

With very rare exceptions, it is formed by deep soils, alluvial, and clay, as it is the case of most of the bottoms of ancient lakes.

With respect to the floristic composition of the Halophyte communities, it is interesting to note that at the same time including genera and species very vastly distributed, some almost cosmopolitan, or are rare in their distribution. The best-represented families are *Gramineae* and *Chenopodiaceae*, deserving special mention the *Frankeniaceae*, whose members become very important in the Northwest of Mexico. Succulence is a feature frequently in the Halophyte of different families, as well as the vegetative reproduction and high osmotic pressure.

Vegetación Secundaria Arbustiva de Bosque de Pino (Pine Forest Secondary Shrub Vegetation)

A secondary pine forest is a forest or woodland area which has re-grown after a major disturbance such as fire, insect infestation, timber harvest or windthrow until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth forest (primary or primeval forest), which has not undergone such disruptions, as well as third-growth forests that result from severe disruptions in second growth forests.

Vegetación Secundaria Arbustiva de Bosque de Pino-Encino (Pine-Oak Forest Secondary Shrub Vegetation)

A secondary pine-oak forest is a forest or woodland area which has re-grown after a major disturbance such as fire, insect infestation, timber harvest or windthrow until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth forest

(primary or primeval forest), which has not undergone such disruptions, as well as third-growth forests that result from severe disruptions in second growth forests.

Vegetación Secundaria Arbustiva de Bosque de Encino (Oak Forest Secondary Shrub Vegetation)

A secondary oak forest is a forest or woodland area which has re-grown after a major disturbance such as fire, insect infestation, timber harvest or windthrow until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth forest (primary or primeval forest), which has not undergone such disruptions, as well as third-growth forests that result from severe disruptions in second growth forests.

Vegetación Secundaria Arbustiva de Bosque de Encino-Pino (Oak-Pine Forest Secondary Shrub Vegetation)

A secondary oak-pine forest is a forest or woodland area which has re-grown after a major disturbance such as fire, insect infestation, timber harvest or windthrow until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth forest (primary or primeval forest), which has not undergone such disruptions, as well as third-growth forests that result from severe disruptions in second growth forests.

Vegetación Secundaria Arbustiva de Matorral Desértico Micrófilo (Microphyllous Desert Scrub Secondary Shrub Vegetation)

A secondary microphyllous desert scrub is a scrub which has re-grown after a major disturbance such as fire, insect infestation or until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth microphyllous desert scrub, which has not undergone such disruptions, as well as third-growth microphyllous desert scrub that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Matorral Desértico Rosetófilo (Rosetofilous like Desert Scrub Secondary Shrub Vegetation)

A secondary rosetofilous desert scrub is a scrub which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth rosetofilous desert scrub, which has not undergone such disruptions, as well as third-growth rosetofilous desert scrub that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Matorral Espinoso Tamaulipeco (Tamaulipecan Thorny Scrub Secondary Shrub Vegetation)

A secondary tamaulipecan thorny scrub is a scrub which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth tamaulipecan thorny scrub, which has not undergone such disruptions, as well as third-growth tamaulipecan thorny scrub that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Mezquital Xerófilo (Xerophytic Mesquite Forest Secondary Shrub Vegetation)

A secondary xerophytic mesquite forest is a community which has re-grown after a major disturbance such as fire, insect infestation, until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth xerophytic mesquite forest, which has not undergone such disruptions, as well as third-growth xerophytic mesquite forest that result from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Matorral Submontano (Submontane Scrub Secondary Shrub Vegetation)

A secondary sub-montane scrub is a scrub which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth sub-montane scrub, which has not undergone such disruptions, as well as third-growth sub-montane scrub that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Pastizal Halófilo (Halophyte Grassland Secondary Shrub Vegetation)

A secondary halophyte grassland is a community which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth halophyte grassland, which has not undergone such disruptions, as well as third-growth halophyte grassland that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Pastizal Natural (Natural Grassland Secondary Shrub Vegetation)

A secondary natural grassland is a community which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth natural grassland, which has not undergone such disruptions, as well as third-growth natural grassland that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Arbustiva de Vegetación de Galería (Gallery Vegetation Secondary Shrub Vegetation)

A secondary gallery vegetation is a community which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth gallery vegetation, which has not undergone such disruptions, as well as third-growth gallery vegetation that results from severe disruptions in second growth scrubs.

Vegetación Secundaria Herbácea de Matorral Desértico Micrófilo (Microphyllous Desert Scrub Secondary Herbaceous Vegetation)

A secondary microphyllous desert scrub is a scrub which has re-grown after a major disturbance such as fire, insect infestation until a long enough period has passed so that the effects of the disturbance are no longer evident. It is distinguished from an old-growth microphyllous desert scrub, which has not undergone such disruptions, as well as third-growth microphyllous desert scrub that results from severe disruptions in second growth scrubs.

Figure 39. Urban Area

Zona Urbana (Urban Area)

An urban area is a location characterized by high human population density and vast human-built features in comparison to the areas surrounding it. Urban areas may be cities, towns or conurbations, but the term is not commonly extended to rural areas such as villages and hamlets that normally carry less population density. Larger types of urban areas, such as cities, have higher populations, higher densities and greater access to services.

Appendix 4. Crosswalk from INEGI's Uso de Suelo y Vegetación to NLCD classes

INEGI CODE	INEGI Uso de Suelo y Vegetación Description	NLCD Code	NLCD Description
ACUI	Acuícola	11	Open Water
ADV	Desprovisto De Vegetación	31	Barren Land
AH	Asentamientos Humanos	22	Developed-Low Density
BA	Bosque De Oyamel	42	Evergreen Forest
BC	Bosque Cultivado	43	Mixed Forest
BG	Bosque De Galería	43	Mixed Forest
BI	Bosque Inducido	43	Mixed Forest
BJ	Bosque De Táscate	42	Evergreen Forest
BM	Bosque Mesófilo De Montaña	43	Mixed Forest
BP	Bosque De Pino	43	Mixed Forest
BPQ	Bosque De Pino-Encino	41	Deciduous Forest
BQ	Bosque De Encino	43	Mixed Forest
BQP	Bosque De Encino-Pino	42	Evergreen Forest
BS	Bosque De Ayarín	42	Evergreen Forest
DV	Sin Vegetación Aparente	31	Barren Land
H2O	Cuerpo De Agua	11	Open Water
HA	Agricultura De Humedad Anual	82	Cultivated Cropland
MC	Matorral Crasicaule	52	Shrub/Scrub
MDM	Matorral Desértico Micrófilo	52	Shrub/Scrub
MDR	Matorral Desértico Rosetófilo	52	Shrub/Scrub
MET	Matorral Espinoso Tamaulipeco	52	Shrub/Scrub
MK	Bosque De Mezquite	52	Shrub/Scrub
MKE	Mezquital Tropical	52	Shrub/Scrub
MKX	Mezquital Xerófilo	52	Shrub/Scrub
ML	Chaparral	52	Shrub/Scrub
MSC	Matorral Sarcocaule	52	Shrub/Scrub
MSCC	Matorral Sarco-Crasicaule	52	Shrub/Scrub
MSM	Matorral Submontano	52	Shrub/Scrub
MSN	Matorral Sarco-Crasicaule De Neblina	52	Shrub/Scrub
MST	Matorral Subtropical	52	Shrub/Scrub
PC	Pastizal Cultivado	81	Pasture/Hay
PH	Pastizal Halófilo	71	Grasslands/Herbaceous

PI	Pastizal Inducido	71	Grasslands/Herbaceous
PN	Pastizal Natural	71	Grasslands/Herbaceous
PY	Pastizal Gipsófilo	71	Grasslands/Herbaceous
RA	Agricultura De Riego Anual	82	Cultivated Cropland
RAP	Agricultura De Riego Anual Y Permanente	82	Cultivated Cropland
RAS	Agricultura De Riego Anual Y Semipermanente	82	Cultivated Cropland
RP	Agricultura De Riego Permanente	82	Cultivated Cropland
RS	Agricultura De Riego Semipermanente	82	Cultivated Cropland
RSP	Agricultura De Riego Semipermanente Y Permanente	82	Cultivated Cropland
SBC	Selva Baja Caducifolia	41	Deciduous Forest
SBK	Selva Baja Espinosa Caducifolia	41	Deciduous Forest
SMQ	Selva Mediana Subperennifolia	41	Deciduous Forest
SMS	Selva Mediana Subcaducifolia	41	Deciduous Forest
TA	Agricultura De Temporal Anual	82	Cultivated Cropland
TAP	Agricultura De Temporal Anual Y Permanente	82	Cultivated Cropland
TAS	Agricultura De Temporal Anual Y Semipermanente	82	Cultivated Cropland
TP	Agricultura De Temporal Permanente	82	Cultivated Cropland
VD	Vegetación De Desiertos Arenosos	71	Grasslands/Herbaceous
VG	Vegetación De Galería	52	Shrub/Scrub
VH	Vegetación Halófila Xerófila	71	Grasslands/Herbaceous
VHH	Vegetación Halófila Hidrófila	95	Emergent Herbaceous Wetlands
VM	Manglar	90	Woody Wetlands
VPI	Palmar Inducido	41	Deciduous Forest
VPN	Palmar Natural	41	Deciduous Forest
VSa/BB	Vegetación Secundaria Arbustiva De Bosque De Cedro	52	Shrub/Scrub
VSA/BG	Vegetación Secundaria Arbórea De Bosque De Galería	43	Mixed Forest
VSa/BG	Vegetación Secundaria Arbustiva De Bosque De Galería	52	Shrub/Scrub
VSA/BJ	Vegetación Secundaria Arbórea De Bosque De Táscate	43	Mixed Forest
VSa/BJ	Vegetación Secundaria Arbustiva De Bosque De Táscate	52	Shrub/Scrub
VSA/BM	Vegetación Secundaria Arbórea De Bosque Mesófilo De Montaña	43	Mixed Forest
VSa/BM	Vegetación Secundaria Arbustiva De Bosque Mesófilo De Montaña	52	Shrub/Scrub
VSA/BP	Vegetación Secundaria Arbórea De Bosque De Pino	43	Mixed Forest
VSa/BP	Vegetación Secundaria Arbustiva De Bosque De Pino	52	Shrub/Scrub

VSA/BPQ	Vegetación Secundaria Arbórea De Bosque De Pino-Encino	43	Mixed Forest
VSa/BPQ	Vegetación Secundaria Arbustiva De Bosque De Pino-Encino	52	Shrub/Scrub
VSA/BQ	Vegetación Secundaria Arbórea De Bosque De Encino	43	Mixed Forest
VSa/BQ	Vegetación Secundaria Arbustiva De Bosque De Encino	52	Shrub/Scrub
VSA/BQP	Vegetación Secundaria Arbórea De Bosque De Encino-Pino	43	Mixed Forest
VSa/BQP	Vegetación Secundaria Arbustiva De Bosque De Encino-Pino	52	Shrub/Scrub
VSA/BS	Vegetación Secundaria Arbórea De Bosque De Ayarín	43	Mixed Forest
VSa/BS	Vegetación Secundaria Arbustiva De Bosque De Ayarín	52	Shrub/Scrub
VSa/MC	Vegetación Secundaria Arbustiva De Matorral Crasicaule	52	Shrub/Scrub
VSa/MDM	Vegetación Secundaria Arbustiva De Matorral Desértico Micrófilo	52	Shrub/Scrub
VSa/MDR	Vegetación Secundaria Arbustiva De Matorral Desértico Rosetófilo	52	Shrub/Scrub
VSa/MET	Vegetación Secundaria Arbustiva De Matorral Espinoso Tamaulipeco	52	Shrub/Scrub
VSA/MK	Vegetación Secundaria Arbórea De Bosque De Mezquite	43	Mixed Forest
VSa/MK	Vegetación Secundaria Arbustiva De Bosque De Mezquite	52	Shrub/Scrub
VSa/MKE	Vegetación Secundaria Arbustiva De Mezquital Tropical	52	Shrub/Scrub
VSa/MKX	Vegetación Secundaria Arbustiva De Mezquital Xerófilo	52	Shrub/Scrub
VSa/ML	Vegetación Secundaria Arbustiva De Chaparral	52	Shrub/Scrub
VSa/MSC	Vegetación Secundaria Arbustiva De Matorral Sarcocaule	52	Shrub/Scrub
VSa/MSCC	Vegetación Secundaria Arbustiva De Matorral Sarco-Crasicaule	52	Shrub/Scrub
VSa/MSM	Vegetación Secundaria Arbustiva De Matorral Submontano	52	Shrub/Scrub
VSa/MST	Vegetación Secundaria Arbustiva De Matorral Subtropical	52	Shrub/Scrub
VSa/PH	Vegetación Secundaria Arbustiva De Pastizal Halófilo	52	Shrub/Scrub
VSa/PN	Vegetación Secundaria Arbustiva De Pastizal Natural	52	Shrub/Scrub
VSa/PY	Vegetación Secundaria Arbustiva De Pastizal Gipsófilo	52	Shrub/Scrub
VSA/SBC	Vegetación Secundaria Arbórea De Selva Baja Caducifolia	43	Mixed Forest
VSa/SBC	Vegetación Secundaria Arbustiva De Selva Baja Caducifolia	52	Shrub/Scrub

VSA/SBK	Vegetación Secundaria Arbórea De Selva Baja Espinosa Caducifolia	43	Mixed Forest
VSa/SBK	Vegetación Secundaria Arbustiva De Selva Baja Espinosa Caducifolia	52	Shrub/Scrub
VSa/SBS	Vegetación Secundaria Arbustiva De Selva Baja Subcaducifolia	52	Shrub/Scrub
VSA/SMQ	Vegetación Secundaria Arbórea De Selva Mediana Subperennifolia	43	Mixed Forest
VSa/SMQ	Vegetación Secundaria Arbustiva De Selva Mediana Subperennifolia	52	Shrub/Scrub
VSA/SMS	Vegetación Secundaria Arbórea De Selva Mediana Subcaducifolia	43	Mixed Forest
VSa/SMS	Vegetación Secundaria Arbustiva De Selva Mediana Subcaducifolia	52	Shrub/Scrub
VSa/VD	Vegetación Secundaria Arbustiva De Vegetación De Desiertos Arenosos	52	Shrub/Scrub
VSa/VG	Vegetación Secundaria Arbustiva De Vegetación De Galería	52	Shrub/Scrub
VSa/VH	Vegetación Secundaria Arbustiva De Vegetación Halófila Xerófila	52	Shrub/Scrub
VSh/BP	Vegetación Secundaria Herbácea De Bosque De Pino	43	Mixed Forest
VSh/BPQ	Vegetación Secundaria Herbácea De Bosque De Pino-Encino	43	Mixed Forest
VSh/BQ	Vegetación Secundaria Herbácea De Bosque De Encino	43	Mixed Forest
VSh/BQP	Vegetación Secundaria Herbácea De Bosque De Encino-Pino	43	Mixed Forest
VSh/MDM	Vegetación Secundaria Herbácea De Matorral Desértico Micrófilo	71	Grassland/Herbaceous
VSh/MDR	Vegetación Secundaria Herbácea De Matorral Desértico Rosetófilo	71	Grassland/Herbaceous
VSh/MET	Vegetación Secundaria Herbácea De Matorral Espinoso Tamaulipeco	71	Grassland/Herbaceous
VSh/MSCC	Vegetación Secundaria Herbácea De Matorral Sarco-Crasicaule	71	Grassland/Herbaceous
VSh/PN	Vegetación Secundaria Herbácea De Pastizal Natural	71	Grassland/Herbaceous
VSh/SBC	Vegetación Secundaria Herbácea De Selva Baja Caducifolia	71	Grassland/Herbaceous
VSh/SMS	Vegetación Secundaria Herbácea De Selva Mediana Subcaducifolia	71	Grassland/Herbaceous
VSh/VH	Vegetación Secundaria Herbácea De Vegetación Halófila Xerófila	71	Grassland/Herbaceous
VT	Tular	41	Deciduous Forest
VU	Vegetación De Dunas Costeras	71	Grassland/Herbaceous
VY	Vegetación Gipsófila	71	Grassland/Herbaceous
ZU	Zona Urbana	24	Developed-High Density

Table 7. Crosswalk from INEGI's Uso de Suelo y Vegetación to NLCD classes.

Appendix 5. Imagery Classification Procedures

The imagery classification procedures objective is to develop and test methodology that can be used to create a vegetation land cover map for the full geography of the DLCC . Instructions modified from Hexagon Geospatial (https://hexagongeospatial.fluidtopics.net/). Prerequisite is a multitemporal image mosaic of tree Landsat 8 scenes, with elevation and slope added as context variables.

Image Creation.

1. Collect binational digital elevation models (DEM) with a resolution of 30 m. or better; merge them into a common elevation units, coordinate system and datum for the DLCC geography. Possible sources include: http://earthexplorer.usgs.gov/ , http://nationalmap.gov/3DEP/, and http://www.inegi.org.mx/geo/contenidos/datosrelieve/continental/descarga.aspx
2. Derive slopes from the DEM.
3. For a typical weather year (not too dry or too wet, we picked 2014), go to http://earthexplorer.usgs.gov/ , login and search for Landsat 8 images (Level 1T surface reflectance data), have less than 1% clouds and cover the proposed pilot site A. Do the same for siteB.
4. For each tile identified in the pilot sites download three images: one from before-the-hot months (Feb.-Apr.), one during the hot months (Jun.-Aug.) and one for after (Oct.-Dec). This will try to capture vegetation at different phenological stages.
5. In ArcMap mosaic the first 7 bands of the before images for pilot site A tiles.
6. Mosaic the first 7 bands of the hot month images for pilot site A tiles.
7. Mosaic the first 7 bands of the after images for pilot site A tiles.
8. Stack in a new image the mosaics for before, during and after the hot months, the DEM and slope, use an **unsigned 16-bit** data type for the pixel depth and call it a meaningful name e.g. **A23.img**).
9. Repeat steps 5 – 8 for additional sites.
10. With the 23 band composites, check how many classes you can expect by comparing the pilot's extent with INEGI's "Uso de Suelo y vegetación 1:250,000 serie V" available at: http://www.inegi.org.mx/geo/contenidos/recnat/usosuelo/
11. **Clip** INEGI's "Uso de Suelo y vegetación 1:250,000 serie V" to your AOI.
12. Create a table **summarizin**g by **CVE_UNION** attribute to count how many features, additionally you can include the **Average and the Sum of the Area** to know how prevalent each class is in your AOI, call this table summary something meaningful, i.e. **Classes_in_A.txt**.

Object Oriented Classification methodology for pilot sites A and B:

Imagine Objective Multiple Class Feature Model

Open Erdas Imagine 2015, click on the raster tab, within the new ribbon under classification you will see Imagine Objective as an option. Click on it to start this process by opening an Objective Workstation.

Define the parameters for the Feature Model Open the tree view menu, choose the **Feature#** module.

1. Once on the Feature Model Properties tab, edit the model name to **OOC** or any name of your preference..
2. Click the **Multiple Class** checkbox to turn on this feature.
3. Press the **Classes** tab to define the classification scheme.
4. Click the **Add** button **several** times to add a total of classes found in the INEGI vegetation shapefile (usv250s5_union.shp) that intersects your tile or mosaic. Rename the classes in the classification scheme to those found in the intersect, i.e: **AH**, **BG**, **BJ**, **H2O**, **MDM**, **DV**, **ZU,** etc.
5. Click the **Color** tab to select a color for each class.
6. On the Properties tab, click the **Variable Properties** button.
7. On the Properties tab, click the Add button. Click the **Add New Variable** button.
8. Enter a name as the variable name (i.e. multispectral image).
9. Select an image file with your Landsat 8 tile or mosaic (i.e. **A23.img**) and then press **Enter**.
10. Click **OK** in the Variable Properties dialog.

The input file is added to the viewer.

Set the **Raster Pixel Processor** Properties

1. From the tree view menu, select **Raster Pixel Processor**.
2. Select **True Color Image** as the input variable.
3. Select **SFP** as the Available Pixel Cue, then click the Add button.
4. From the tree view menu, select the Raster Pixel Processor node, then click the **Training** tab. The AOI tool palette is displayed.
5. Click on the **Training** tab, make sure **Viewer** is selected to use for the sample collection.
6. Make sure **New Type** is **Pixel** and **Class** is your first class, i.e. **AH**.
7. Click the **Create Polygon AOI** button on the AOI Tool Palette.
8. You can use the Trans-Pecos Field photographs, Big Bend field photographs, Google maps street-view images (taken from locations along roads), Google map user-uploaded photographs and also INEGI's vegetation shapefile (usv250s5_union.shp) polygons as guidance, additionally, you can use an unsupervised classification with

about double the number of expected classes to help you identify training polygons that are spectrally similar to a particular training class.

9. In the IMAGINE Objective Workstation Viewer, click the mouse button and digitize a polygon AOI that represents the boundary of a single area (for AH, read the description on the shapefile table or in Appendix 3. It is defined briefly as Human Settlements (Asentamientos Humanos, human settlements), low density urban).
10. Click on the Training menu to add the training samples to the training sample list.
11. Digitize and add several more roof polygons or human settlements instances, but try to represent the most different variations in colors within the class.
12. From the Class list, select your second class, i.e. **BG**.
13. Digitize and add **three** polygons of the areas with Gallery Vegetation (**B**osque de **G**alería or gallery forest).
14. Repeat the previous steps to digitize and add **three** to **four** polygon samples for all major classes represented in the study area. Add fewer polygons land cover classes covering small areas, add more polygons for classes that represent more coverage (bigger area) of your tile or mosaic.
15. Click on the Training tab.
16. Click on the tree view, right-click on the Raster Pixel Processor node and select **Stop Here**.

When Stop Here is selected, the model will only run this process node and display the result of the Raster Pixel Process.

16. Click the **Run the Feature Model** button on the Objective Workstation toolbar menu.

The model will run and then display the results in the Objective Viewer.

17. Select the **Layers** tab from the tree view panel to show the layers in the Viewer.
18. Right-click on the **RPP.img** layer and select **Band Combinations**.
19. Change the band number for each band in the RPP.img to visualize the results. Each band is a probability layer which corresponds to each of the land cover classes which you set up earlier.

The RPP.img layer's pixels should be bright for the class that corresponds to that layer. If this is not the case then you may need to redo the training by deleting your old samples and returning to step 6.

20. Click on the Project tree view tab to return to the Project tree view.

Set the **Raster Object Creators Properties**

1. From the tree view menu, select **Raster Object Creators**.
2. Click on the Properties tab, select **Segmentation** from ROC list.

3. In the tree view menu, expand the Raster Object Creators node, and then click on the Segmentation node.

The Segmentation Properties tab is displayed.

4. In Segmentation Properties, make sure **your Landsat Image** is the input variable, **Use** is set to **All Layers**, **Euclidean distance** is **checked**, **Min Value Difference** is **100.00**, and **Variation Factor** is **3.5**.

The **Advanced Settings Dialog**

1. Click the **Advanced Settings** button to display that dialog.
2. Click on the Advanced Settings dialog and make sure **Apply Edge Detection** is **checked**, **Pre Smoothing** is **0**, **Threshold** is **100.00**, **Minimal Length** is **3 pixels**, and **Output Edge Layer** is **unchecked**.

These are close to the default settings for 16-bit data with the exception of the Min Value Difference which was raised from 15 to 100 and the Edge Threshold was raised from 18 to100. These changes create more segments based on spectral characteristics.

3. In the Segment Geometry Setting tab, **Minimum Size** is **checked** and set to **20 pixels**.

Setting a Minimum Size will reduce the number of segments based on their size. This will simplify the result and improve efficiency in the subsequent processing.

4. The Find Narrow Strips parameter is **unchecked**.
5. Click **OK**.

Set the **Raster Object Operators** Properties

1. From the tree view menu, select **Raster Object Operators**.
2. Click on the **Properties** tab, select **Focal** from ROO list and then click the button.
3. Click on **Focal Properties** tab, **Window Size** is set to **3** and both parameter boxes are **checked**.

The Focal Raster Object Operator will smooth the raster objects edges and make the results simpler and more appealing in some cases.

4. Click on the Properties tab to return to the ROC Properties.
5. Click on the Properties tab, select **ReClump** from ROO list and then click the Add button.

Re-clump is necessary after other Raster Object Operators which may cause new raster objects to be created which is the case with the Focal operator.

6. Click on the Properties tab, select **Eliminate** and then click the Add button.
7. Click on **Eliminate Properties** tab, set the **Minimum Size** to **10**. This will eliminate all segments smaller than 10 pixels.
8. Click on the Properties tab, select **ReClump** and then click the Add button.

Set the **Raster To Vector Conversion** Properties

1. In the tree view menu, expand the Raster To Vector Conversion node. Make sure **Polygon Trace** is selected.

To specify a color for the Contour Trace output shapefile symbology, go to the I/O tab and click on the color chooser button and select the color.

As this point, it is beneficial to run the section of the feature model that was just specified.

2. Right-click on the Raster Object Creator or Segmentation tree view node and check **Start Here**.
3. Right-click on the Raster Vector Converter or Contour Trace tree view node and check **Stop Here**.
4. Click the execute button, and the model will run from the Segmentation operation and finish with the Contour Trace operation.

The Focal and Eliminate Operators actually run separate **Spatial Modeler** processes and will display their own meter. Click OK when this meter finishes if necessary.

5. Now click on any tree view node that has been executed and has produced an output and the Viewer will show the results of that tree view node's process in the Viewer.

Set the **Vector Object Operator** Properties

1. In the tree view menu, add probability filter, under the properties click **.6**

Set the **Vector Cleanup Operators** Properties

1. From the tree view menu, select **Vector Cleanup Operators**.
2. Click on the Properties tab, select **Label** from VCO list and then click the button.
3. Click on the Label Properties tab, **Retain Old Vector Attributes** is **checked** and **Fuzzy** is **checked**. For Center Weight, enter **1.0**; and for Threshold, enter **0.60**.
4. Click on the Properties tab to return to VCO Properties.
5. Select **Dissolve** from VCO list and then click the button.
6. Make sure Dissolve type is set to **Raster**, and **Pixel Size** for both **X** and **Y** is **1.25** pixels.
7. Click the **Run the Feature Model** button on the Objective Workstation toolbar menu.

8. Save the AOI for training polygons (i.e. aoi_Site A.shp) and the result from the vector cleanup operators (i.e. VCO_Label1_A.shp or similar classification file) in a directory where you store the output of your object oriented classification

The model will run and then display the results in the Objective Viewer.

Assessing accuracy of the classification with a confusion matrix.

Thematic maps created from imagery will have some classification errors, the accuracy assessment will let the user know what those errors are and which classes may need to be revised. Depending on the acceptable error, the user may define if the image is usable or if the classification process needs to be re-run with improved parameters or additional training samples for classes that need more discerning and separation. Some classes may not be reliably mapped from the Landsat, DEM and slope data.

For the accuracy assessment a reference is needed in the form of ground-truthing, field-verified data for test samples. INEGI's vegetation shapefile (usv250s5_union.shp) polygons from 2010 were used as guidance, additionally. A simple comparison (i.e. accuracy assessment) between the object oriented classification and INEGI's Uso de Suelo y Vegeteacion Series V was performed for Mexico portion of the study areas where INEGI data overlaps with the pilot areas. 100% random stratifies sampling was used with a target of 50 points per class using NOAA's sampling tool with no user imported/selected points or polygons.

1. In ArcMap **open** the Object oriented classification and a clipped version of usv250s5_union.shp to the AOI.
2. Download NOAA Sampling Tool manual as well as the application from: http://www.arcgis.com/home/item.html?id=ecbe1fc44f35465f9dea42ef9b63e785
3. **Customize** your ArcMAP toolbar to add NOAA Sampling Tool following the Sampling Design Tool Manual pdf.
4. Use NOAA's sampling tool to **create** 100% random stratified sampling dataset, 50 points per class with no user imported/selected points or polygons based on INEGI's Uso de Suelo y Vegetacion classes as a reference.
5. **Spatially join** the random stratified points dataset created in step 3 with the result of the object oriented classification.
6. **Create** a new field (Ref_Label) in which the attribute from the reference is concatenated with the attribute from the class in the classification.
7. **Summarize** the field Ref_Label counting the instances of each combination of reference class and classified class.
8. In Excel **create** a confusion matrix, using the data from the summary table were the Classified image classes names are in the first column and the Reference class names are in the first row (See appendix 6 for an example).
9. **Calculate the total number of points for each class** at the bottom of each column. In this example it should be 50 points by sampling design.

10. **Calculate the ground truth total number of points** by adding each row horizontally, it will vary.
11. Let's call this first calculation the **confusion matrix.**
12. Optionally**, calculate ground truth accuracy** copying and pasting your contents into a new group of cells, for each cell in the diagonal of the confusion matrix divide the number of correctly classified points by the total number of points in that column.
13. **Calculate the Commission error**, how many test points were incorrectly classified as a class. Divide the incorrectly classified number of points in a row divided by the total number of points in the row.
14. **Calculate the Omission error**, how many points were incorrectly classified as a class in a reference polygon. Divide the incorrectly classified number of points in a column divided by the total number of points in the column.
15. **Calculate the User's Accuracy** dividing the number of correctly classified points (number in the diagonal for the given class) by the number of points in the row classified as such class.
16. **Calculate the Producer's Accuracy** dividing the number of correctly classified points (number in the diagonal for the given class) by the number of points in the column used as reference for such class.
17. **Calculate the Overall Accuracy of the classification.** In the confusion matrix add cells in the diagonal, which is the sum of all the correctly classified cells then divide it by the total number of cells.
18. **Calculate kappa coefficient** as *k* = ((Total * Sum of Correct points) – Sum of all the (Row total * Column total)) / (Total squared – Sum of all the (Row total * Column total))

$$k = \frac{N \sum_{i=l}^{r} Xii - \sum_{i=l}^{r} (X_{i+} * X_{+i})}{N^{2-} \sum_{i=l}^{r} (X_{i+} * X_{+i})}$$

24. **Check your results**. Some classes tend to be hard to distinguish (e.g. Pine-Oak Forest (BPQ) vs Oak-Pine forest (BQP)).

Appendix 6. Error Matrices

Site A Error Matrix

```
      CLASSIFICATION ACCURACY ASSESSMENT ERROR MATRIX AOI A
      -----------------------------------------------------
OOC File : W:\USGS\99_post_claim\Pilot_Area_A\OOC_Site_A.shp
Comparison file: W:\USGS\99_post_claim\Pilot_Area_A\SerieV_A_Clip.shp
RSS Points File: W:\USGS\99_post_claim\Pilot_Area_A\aa-50_RSSPointsA.shp
User Name  : mpavon
Date       : Sun Feb 12 10:05:01 2017


ERROR MATRIX
-------------
(see next page)
```

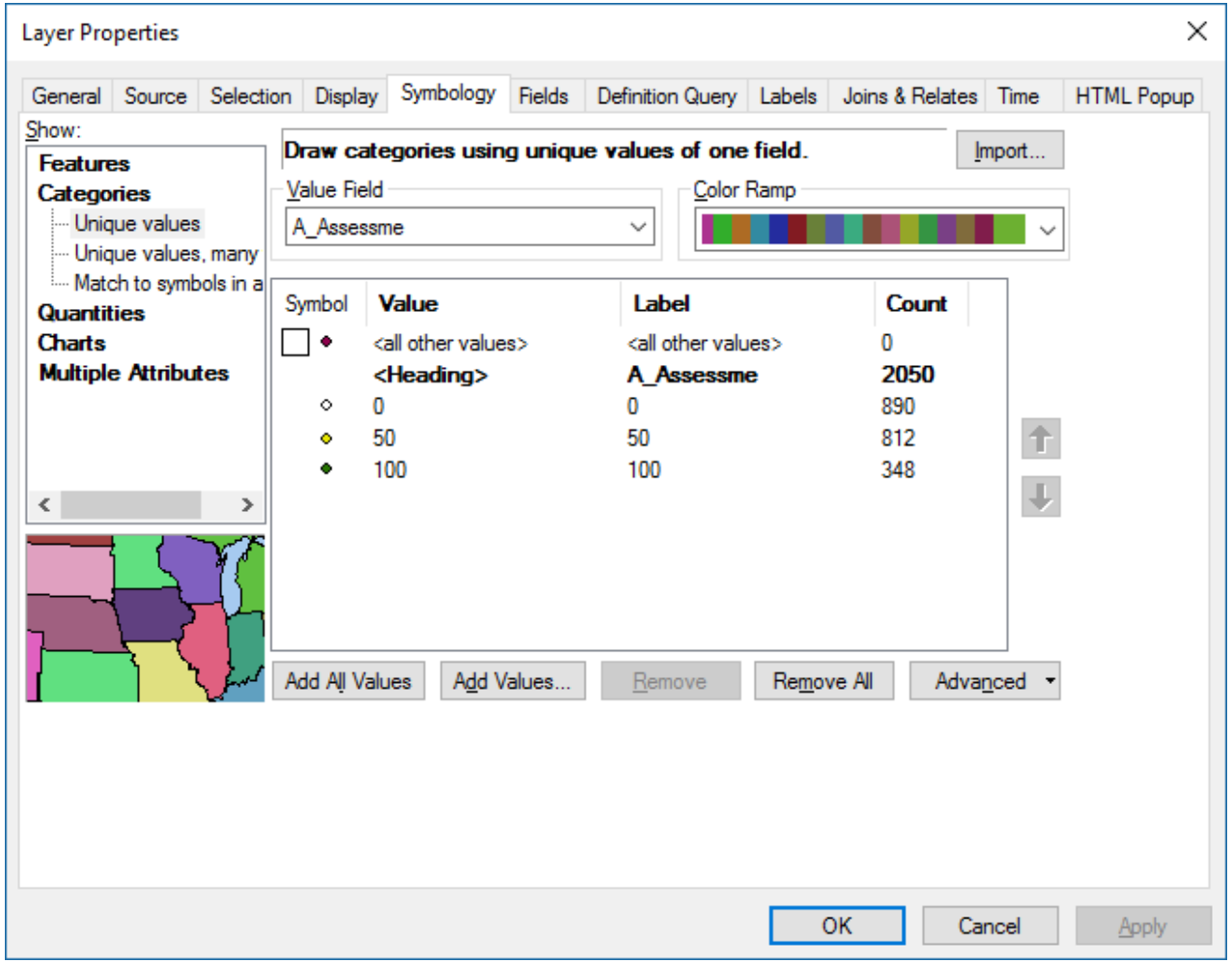
	Reference Data																													
Classified Data	1, BG	2, BJ	3, BP	4, BPQ	5, BQ	6, BQP	7, DV	8, H2O	9, MDM	10, MDR	11, MK	12, MKX	13, MSC	14, PC	15, PI	16, PN	17, RA	18, RAP	19, RAS	20, TA	21, VG	22, VH	VSa/BQP	VSa/BQ	VSa/MDM	VSa/MKX	VSa/PN	28, ZU	29, AH	Row Total
1, BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2, BJ	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	18
3, BP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4, BPQ	0	0	0	5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	11
5, BQ	0	9	37	17	25	4	0	0	0	0	0	0	0	0	3	3	0	0	0	0	1	0	1	12	0	0	0	0	0	112
6, BQP	0	12	13	28	13	44	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	49	4	0	0	0	0	0	168
7, DV	0	2	0	0	2	0	20	12	2		0	3	1	0	3	3	4	1	3	20	4	1	0	2	4	1	6	5	0	99
8, H2O	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
9, MDM	21	2	0	0	8	2	16	13	44	45	35	43	31	49	23	21	24	2	7	23	28	9	0	20	40	49	8	1	0	564
10, MDR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11, MK	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
12, MKX	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5
13, MSC	0	0	0	0	0	0	0	0	1	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
14, PC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15, PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16, PN	7	3	0	0	2	0	11	12	3	0	2	0	0	0	14	21	6	21	7	3	9	0	0	10	3	0	26	3	1	164
17, RA	22	1	0	0	0	0	1	4	0	5	11	1	0	1	2	0	15	25	10	4	8	40	0	0	0	0	4	0	0	154
18, RAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19, RAS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	23
20, TA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21, VG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22, VH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23, VSa/BQP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24, VSa/BQ	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	1	0	0	8
25, VSa/MDM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26, VSa/MKX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27, VSa/PN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28, ZU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	0	39
29, AH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	49	52
Column Total	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	49	50	50	50	50	50	50	50	48	50	50	50	50	1447

----- End of Error Matrix for Site A-----

Errors:	Comission			Omission			User's Accuracy		Producer's Accuracy	
	OOC_Site	Fraction	Percentage	OOC_Site	Fraction	Percentage	OOC_SiteA_Label		OOC_SiteA_Label	
	1, BG	---	---	1, BG	1.00	100.00%	1, BG	---	1, BG	0.00%
	2, BJ	0.06	5.56%	2, BJ	0.66	66.00%	2, BJ	94.44%	2, BJ	34.00%
	3, BP	---	---	3, BP	1.00	100.00%	3, BP	---	3, BP	0.00%
	4, BPQ	0.55	54.55%	4, BPQ	0.90	90.00%	4, BPQ	45.45%	4, BPQ	10.00%
	5, BQ	0.78	77.68%	5, BQ	0.50	50.00%	5, BQ	22.32%	5, BQ	50.00%
	6, BQP	0.74	73.81%	6, BQP	0.12	12.00%	6, BQP	26.19%	6, BQP	88.00%
	7, DV	0.80	79.80%	7, DV	0.60	60.00%	7, DV	20.20%	7, DV	40.00%
	8, H2O	0.00	0.00%	8, H2O	0.82	82.00%	8, H2O	100.00%	8, H2O	18.00%
	9, MDM	0.92	92.20%	9, MDM	0.12	12.00%	9, MDM	7.80%	9, MDM	88.00%
	10, MDR	---	---	10, MDR	1.00	100.00%	10, MDR	---	10, MDR	0.00%
	11, MK	0.00	0.00%	11, MK	0.96	96.00%	11, MK	100.00%	11, MK	4.00%
	12, MKX	0.40	40.00%	12, MKX	0.94	94.00%	12, MKX	60.00%	12, MKX	6.00%
	13, MSC	0.05	5.26%	13, MSC	0.64	64.00%	13, MSC	94.74%	13, MSC	36.00%
	14, PC	---	---	14, PC	1.00	100.00%	14, PC	---	14, PC	0.00%
	15, PI	---	---	15, PI	1.00	100.00%	15, PI	---	15, PI	0.00%
	16, PN	0.87	87.20%	16, PN	0.58	58.00%	16, PN	12.80%	16, PN	42.00%
	17, RA	0.90	90.26%	17, RA	0.69	69.39%	17, RA	9.74%	17, RA	30.61%
	18, RAP	---	---	18, RAP	1.00	100.00%	18, RAP	---	18, RAP	0.00%
	19, RAS	0.00	0.00%	19, RAS	0.54	54.00%	19, RAS	100.00%	19, RAS	46.00%
	20, TA	---	---	20, TA	1.00	100.00%	20, TA	---	20, TA	0.00%
	21, VG	---	---	21, VG	1.00	100.00%	21, VG	---	21, VG	0.00%
	22, VH	---	---	22, VH	1.00	100.00%	22, VH	---	22, VH	0.00%
	23, VSa/BQP	---	---	23, VSa/BQP	1.00	100.00%	23, VSa/BQP	---	23, VSa/BQP	0.00%
	24, VSa/BQ	0.75	75.00%	24, VSa/BQ	0.96	96.00%	24, VSa/BQ	25.00%	24, VSa/BQ	4.00%
	25, VSa/MDM	---	---	25, VSa/MDM	1.00	100.00%	25, VSa/MDM	---	25, VSa/MDM	0.00%
	26, VSa/MKX	---	---	26, VSa/MKX	1.00	100.00%	26, VSa/MKX	---	26, VSa/MKX	0.00%
	27, VSa/PN	---	---	27, VSa/PN	1.00	100.00%	27, VSa/PN	---	27, VSa/PN	0.00%
	28, ZU	0.00	0.00%	28, ZU	0.22	22.00%	28, ZU	100.00%	28, ZU	78.00%
	29, AH	0.06	5.77%	29, AH	0.02	2.00%	29, AH	94.23%	29, AH	98.00%
	Average	0.43	42.94%	**Average**	0.77	76.81%	**Average**	57.06%	**Average**	23.19%

Simple comparison between INEGI’s Uso de Suelo y Vegetacion V and object oriented Classification

In this comparison with 50 random stratified sample points per class for Site A, a value of a 100 means perfect match, 50 means partial match (very similar classes or same NLCD codes, i.e. Oak forest and Oak forest with secondary brush are both cross-walked into Deciduous Forest), and a score of zero for no matches.



Site B Error Matrix

```
      CLASSIFICATION ACCURACY ASSESSMENT ERROR MATRIX AOI B
      -----------------------------------------------------
OOC File : W:\USGS\99_post_claim\Pilot_Area_B\OOC_Site_B.shp
Comparison file: W:\USGS\99_post_claim\Pilot_Area_B\SerieV_B_Clip.shp
RSS Points File: W:\USGS\99_post_claim\Pilot_Area_B\aa-50_RSSPointsB.shp
User Name  : mpavon
Date       : Sun Feb 12 12:45:57 2017


ERROR MATRIX   (see next page)
-------------
```

lassified Data	1, BG	2, BJ	3, BP	4, BPQ	5, BQ	6, BQP	7, BS	8, DV	9, H2O	10, MDM	11, MDR	12, MET	13, MK	14, ML	15, MSM	16, PC	17, PH	18, PI	19, PN	20, RA	21, RAP	22, RAS	23, RP	24, RS	26, VG	27, VH	VSa/BP
1, BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2, BJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3, BP	0	0	6	0	2	1	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4, BPQ	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5, BQ	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6, BQP	0	0	0	8	5	9	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
7, BS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8, DV	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
9, H2O	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10, MDM	1	6	0	2	0	1	0	3	2	22	3	12	10	0	2	8	18	11	9	6	0	3	0	0	3	7	0
11, MDR	36	44	42	39	41	39	17	3	21	28	47	27	39	48	46	28	28	34	24	0	22	4	35	10	42	39	50
12, MET	0	0	0	0	0	0	0	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13, MK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14, ML	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		0	0	0
15, MSM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16, PC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0
17, PH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0
18, PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19, PN	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	17	0	0	0	0	0	0	0	0
20, RA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	0	0	0	0	1	0	0
21, RAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22, RAS	13	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	1	3	0	6	28	43	15	40	4	3	0
23, RP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24, RS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25, TA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26, VG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27, VH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28, VSa/BP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29, VSa/BPQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30, VSa/BQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31, VSa/BQP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32, VSa/MDM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33, VSa/MDR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34, VSa/MET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35, VSa/MSM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36, VSa/PH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37, VSa/PN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38, VSa/VG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39, VSh/MDM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40, ZU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41, AH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Column Total	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

ERROR MATRIX (Cont.)

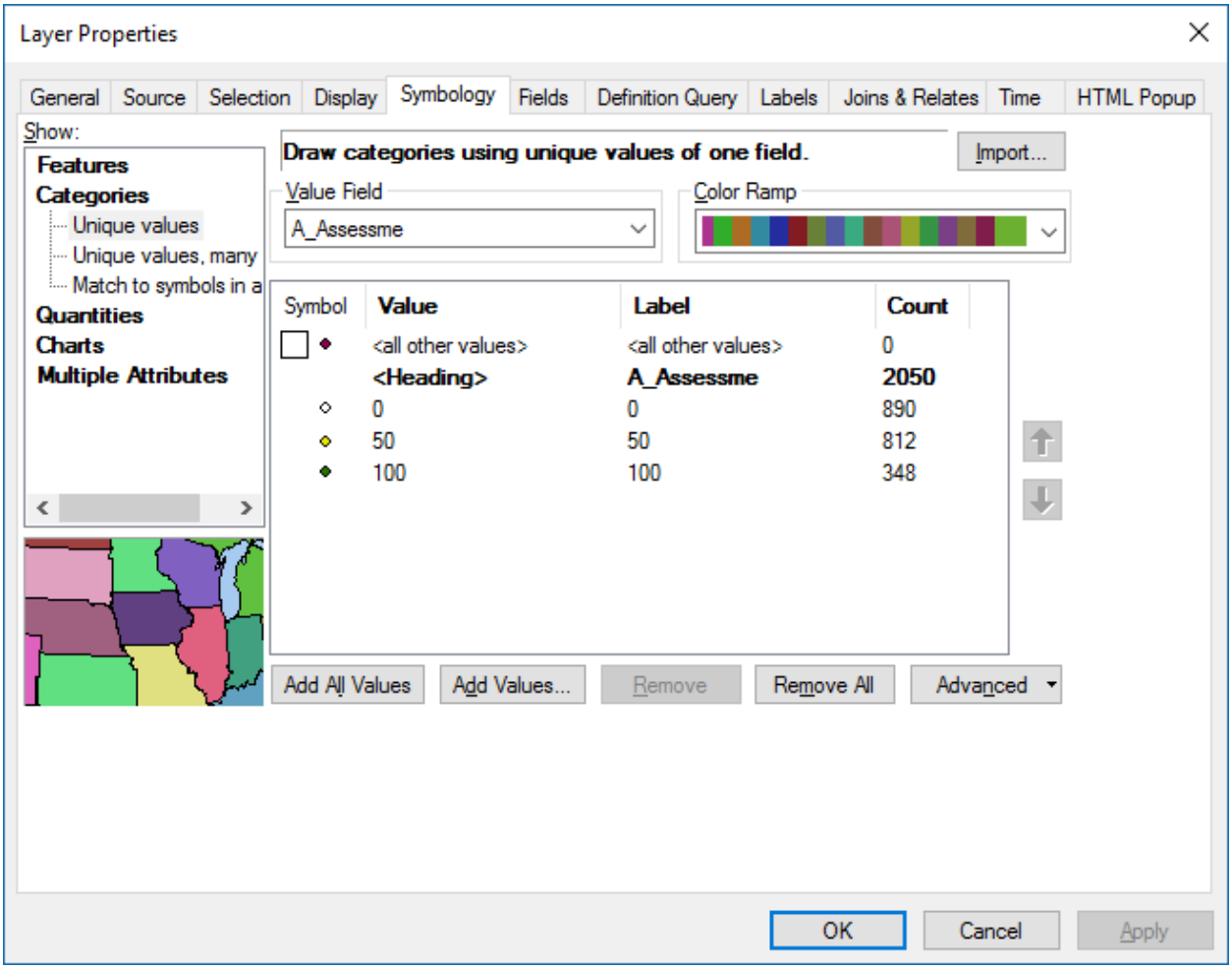
	Reference Data													
Classified Data	VSa/BPQ	VSa/BQ	VSa/BQP	VSa/MDM	VSa/MDR	VSa/MET	VSa/MSM	VSa/PH	VSa/PN	VSa/VG	VSh/MDM	40, ZU	41, AH	w Total
1, BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2, BJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3, BP	0	0	0	0	0	0	0	0	0	0	0	0	0	40
4, BPQ	0	0	0	0	0	0	0	0	0	0	0	0	0	2
5, BQ	0	0	0	0	0	0	0	0	0	0	0	0	0	2
6, BQP	13	2	0	0	0	0	0	0	0	0	0	0	0	40
7, BS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8, DV	0	0	0	0	0	0	0	0	0	0	0	0	0	44
9, H2O	0	0	0	0	0	0	0	0	0	0	0	0	0	12
10, MDM	0	1	0	14	8	1	0	15	4	0	48	0	0	223
11, MDR	37	44	50	33	41	49	50	23	43	47	2	1	2	1297
12, MET	0	0	0	0	0	0	0	0	0	0	0	0	0	11
13, MK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14, ML	0	2	0	0	1	0	0	0	0	0	0	0	0	6
15, MSM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16, PC	0	0	0	0	0	0	0	4	0	0	0	0	0	18
17, PH	0	0	0	1	0	0	0	0	0	0	0	0	0	5
18, PI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19, PN	0	1	0	0	0	0	0	0	3	0	0	0	0	25
20, RA	0	0	0	0	0	0	0	0	0	0	0	0	0	39
21, RAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22, RAS	0	0	0	2	0	0	0	8	0	3	0	1	2	192
23, RP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24, RS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25, TA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26, VG	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27, VH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28, VSa/BP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29, VSa/BPQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30, VSa/BQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31, VSa/BQP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32, VSa/MDM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33, VSa/MDR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34, VSa/MET	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35, VSa/MSM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36, VSa/PH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37, VSa/PN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38, VSa/VG	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39, VSh/MDM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40, ZU	0	0	0	0	0	0	0	0	0	0	0	36	0	36
41, AH	0	0	0	0	0	0	0	0	0	0	0	12	46	58
Column Total	50	50	50	50	50	50	50	50	50	50	50	50	50	2050

----- End of Error Matrix for Site B-----

Errors:	Comission			Omission			User's Accuracy		Producer's Accuracy	
	OOC_Site	Fraction	Percentage	OOC_Site	Fraction	Percentage	OOC_Site	B_Label	OOC_Site	B_Label
	1, BG	---	---	1, BG	1.00	100.00%	1, BG	---	1, BG	0.00%
	2, BJ	---	---	2, BJ	1.00	100.00%	2, BJ	---	2, BJ	0.00%
	3, BP	0.85	85.00%	3, BP	0.88	88.00%	3, BP	15.00%	3, BP	12.00%
	4, BPQ	1.00	100.00%	4, BPQ	1.00	100.00%	4, BPQ	0.00%	4, BPQ	0.00%
	5, BQ	0.50	50.00%	5, BQ	0.98	98.00%	5, BQ	50.00%	5, BQ	2.00%
	6, BQP	0.78	77.50%	6, BQP	0.82	82.00%	6, BQP	22.50%	6, BQP	18.00%
	7, BS	---	---	7, BS	1.00	100.00%	7, BS	---	7, BS	0.00%
	8, DV	0.02	2.27%	8, DV	0.14	14.00%	8, DV	0.00%	8, DV	86.00%
	9, H2O	0.00	0.00%	9, H2O	0.76	76.00%	9, H2O	0.00%	9, H2O	24.00%
	10, MDM	---	---	10, MDM	0.56	56.00%	10, MDM	9.87%	10, MDM	44.00%
	11, MDR	0.96	96.38%	11, MDR	0.06	6.00%	11, MDR	3.62%	11, MDR	94.00%
	12, MET	0.09	9.09%	12, MET	0.80	80.00%	12, MET	90.91%	12, MET	20.00%
	13, MK	---	---	13, MK	1.00	100.00%	13, MK	---	13, MK	0.00%
	14, ML	0.83	83.33%	14, ML	0.98	98.00%	14, ML	0.00%	14, ML	2.00%
	15, MSM	---	---	15, MSM	0.08	8.00%	15, MSM	---	15, MSM	0.00%
	16, PC	0.22	22.22%	16, PC	0.72	72.00%	16, PC	77.78%	16, PC	28.00%
	17, PH	0.40	40.00%	17, PH	0.94	94.00%	17, PH	60.00%	17, PH	6.00%
	18, PI	---	---	18, PI	1.00	100.00%	18, PI	---	18, PI	0.00%
	19, PN	0.32	32.00%	19, PN	0.66	66.00%	19, PN	68.00%	19, PN	34.00%
	20, RA	0.03	2.56%	20, RA	0.24	24.00%	20, RA	97.44%	20, RA	76.00%
	21, RAP	---	---	21, RAP	1.00	100.00%	21, RAP	---	21, RAP	0.00%
	22, RAS	0.78	77.60%	22, RAS	0.14	14.00%	22, RAS	22.40%	22, RAS	86.00%
	23, RP	---	---	23, RP	1.00	100.00%	23, RP	---	23, RP	0.00%
	24, RS	---	---	24, RS	1.00	100.00%	24, RS	---	24, RS	0.00%
	25, TA	---	---	25, TA	1.00	100.00%	25, TA	---	25, TA	0.00%
	26, VG	---	---	26, VG	1.00	100.00%	26, VG	---	26, VG	0.00%
	27, VH	---	---	27, VH	1.00	100.00%	27, VH	---	27, VH	0.00%
28,	VSa/BP	---	---	28, VSa/BP	1.00	100.00%	28, VSa/BP	---	28, VSa/BP	0.00%
29,	VSa/BPQ	---	---	29, VSa/BPQ	1.00	100.00%	29, VSa/BPQ	---	29, VSa/BPQ	0.00%
30,	VSa/BQ	---	---	30, VSa/BQ	1.00	100.00%	30, VSa/BQ	---	30, VSa/BQ	0.00%
31,	VSa/BQP	---	---	31, VSa/BQP	1.00	100.00%	31, VSa/BQP	---	31, VSa/BQP	0.00%
32,	VSa/MDM	---	---	32, VSa/MDM	1.00	100.00%	32, VSa/MDM	---	32, VSa/MDM	0.00%
33,	VSa/MDR	---	---	33, VSa/MDR	1.00	100.00%	33, VSa/MDR	---	33, VSa/MDR	0.00%
34,	VSa/MET	---	---	34, VSa/MET	1.00	100.00%	34, VSa/MET	---	34, VSa/MET	0.00%
35,	VSa/MSM	---	---	35, VSa/MSM	1.00	100.00%	35, VSa/MSM	---	35, VSa/MSM	0.00%
36,	VSa/PH	---	---	36, VSa/PH	1.00	100.00%	36, VSa/PH	---	36, VSa/PH	0.00%
37,	VSa/PN	---	---	37, VSa/PN	1.00	100.00%	37, VSa/PN	---	37, VSa/PN	0.00%
38,	VSa/VG	---	---	38, VSa/VG	1.00	100.00%	38, VSa/VG	---	38, VSa/VG	0.00%
39,	VSh/MDM	---	---	39, VSh/MDM	1.00	100.00%	39, VSh/MDM	---	39, VSh/MDM	0.00%
	40, ZU	0.00	0.00%	40, ZU	0.28	28.00%	40, ZU	100.00%	40, ZU	72.00%
	41, AH	0.21	20.69%	41, AH	0.08	8.00%	41, AH	79.31%	41, AH	92.00%
	Average	0.44	43.67%	**Average**	0.81	80.78%	**Average**	40.99%	**Average**	16.98%

Simple comparison between INEGI’s Uso de Suelo y vegetacion V and object oriented Classification

In this comparison with 50 random stratified sample points per class for Site B, a value of a 100 means perfect match, 50 means partial match (very similar classes or same NLCD codes, i.e. Oak forest and Oak forest with secondary brush are both cross-walked into Deciduous Forest), and a score of zero for no matches



Appendix 6. Independent Quality Assurance Check

An independent quality assurance check was conducted with on the delivered Desert Landscape Conservation Cooperative (DLCC) object-oriented classification (OOC) data sets for Pilot A and Pilot B with Instituto Nacional de Estadística y Geografía (INEGI) Uso de Suelo y Vegetación and the US Geological Survey (USGS) 2011 National Land Cover Data (NLCD). Reference data were chosen based on quality assurance information provided in the *Desert Landscape Conservation Cooperative Vegetation Map Pilot Report* (Pavon, in press) and cross-walked dataset information provided as part of the readme documentation with the object-oriented classification data delivery. The quality assurance check was completed both to independently verify results reported as part of the confusion matrix with the delivered data and to extend the geospatial extent of the quality assurance to the north by using the USGS NLCD data as reference data for areas in the United States not classified in the INEGI Uso de Suelo y Vegetación data and not analyzed as part of the original data delivery. Due to methodology differences, comparing the object-oriented classification data to Uso de Suelo y Vegetación and NLCD data is not a completely accurate assessment of class types at a specific geographic location. However, due to the lack of field verification data, the Uso de Suelo y Vegetación and NLCD data are the best available data to assess how well the object-oriented data classification types match existing data that have documented, ground verified accuracy assessments. This comparison does not account for differences in classification methodologies or temporal changes between data %sets. For the purpose of this analysis, reference data is assumed to be "truth." However, both the Uso de Suelo y Vegetación and the NLCD have error that may affect this analysis to an unknown degree.

Quality assurance for checks against both the INEGI Uso de Suelo y Vegetación and the USGS NLCD followed the same methodology for both Pilot Area A and Pilot Area B. The INEGI Uso de Suelo y Vegetación and the USGS NLCD, hereafter referenced together as "reference data," were clipped to only include areas that overlapped the object-oriented classification data in Pilot Area A and Pilot Area B. Using a stratified random method, 50 verification points were created in each defined class in the reference data. The distribution of verification points are presented in figure 1 for OCC Pilot Area A and figure 2 for OCC Pilot Area B. Verification points were intersected with object-oriented classification data and attributes from both data sets were stored in the verification point data set. Verification point data attribute tables were then exported to create a confusion matrix for each comparison and calculate total accuracy, kappa statistics, producer's accuracy, and user's accuracy. Total accuracy, or overall accuracy, is a direct measure of the how well the data matches the verification data as the number of matching points divided by the total number of samples expressed as a percentage, the Kappa statistics is a measure of the actual agreement and the agreement expected by chance, producer's accuracy is a measure of the error of omission or exclusion, and the user's accuracy is a measurement of the error of commission or inclusion.

OCC Pilot Area A has a total accuracies of 18.07% and 29.07% for checks against INEGI Uso de Suelo y Vegetación and the USGS NLCD, respectively. OCC Pilot Area B has a total accuracies of 6.34% and 15.60% for checks against INEGI Uso de Suelo y Vegetación and the USGS NLCD, respectively. Full

quality assurance statistics can be found in table 1 and table 2 for checks against INEGI Uso de Suelo y Vegetación and the USGS NLCD, respectively. Since the object-oriented classification pilot data sets were done created using an object based image analysis (OBIA) method, a single point verification may not be completely appropriate. However, due to the lack of independent verification data, and the time required to collect these data, an area-based Quality assurance method was not conducted. This quality assurance method may lead to more acceptable total accuracy, kappa statistics, and user and producer accuracies.

Object-oriented classification Pilot Area A						
All Reference						
Class	Reference Match	User Total	Commission	Omission	Producers Accuracy	Users Accuracy
AH	0	0		100.00%	0.00%	
BG	0	0		100.00%	0.00%	
BJ	14	15	6.67%	72.00%	28.00%	93.33%
BP	0	0		100.00%	0.00%	
BPQ	2	6	66.67%	96.00%	4.00%	33.33%
BQ	21	108	80.56%	58.00%	42.00%	19.44%
BQP	42	192	78.13%	16.00%	84.00%	21.88%
DV	24	156	84.62%	52.00%	48.00%	15.38%
H2O	6	6	0.00%	88.00%	12.00%	100.00%
MDM	47	595	92.10%	6.00%	94.00%	7.90%
MDR	0	0		100.00%	0.00%	

MK	2	2	0.00%	96.00%	4.00%	100.00%
MKX	0	0		100%	0.00%	
MSC	16	17	6%	68%	32.00%	94.12%
P/E	0	0		100%	0.00%	
PC	1	1	0%	98%	2.00%	100.00%
PI	0	0		100%	0.00%	
PN	17	190	91%	66%	34.00%	8.95%
RA	14	145	90%	72%	28.00%	9.66%
RAP	0	0		100%	0.00%	
RAS	26	26	0%	48%	52.00%	100.00%
TA	0	0		100%	0.00%	
VG	0	0		100%	0.00%	
VH	0	0		100%	0.00%	
VSa/BPQ	0	0		100%	0.00%	
VSa/BQ	2	4	50%	96%	4.00%	50.00%
VSa/MDM	0	0		100%	0.00%	
VSa/MKX	0	0		100%	0.00%	
VSa/PN	0	0		100%	0.00%	

ZU	37	37	0%	26%	74.00%	100.00%
Kappa Coefficient	15.24%					
Total Accuracy	18.07%					

Table 8. Pilot Area A quality assurance check results for comparisons against the Instituto Nacional de Estadística y Geografía Uso de Suelo y Vegetación

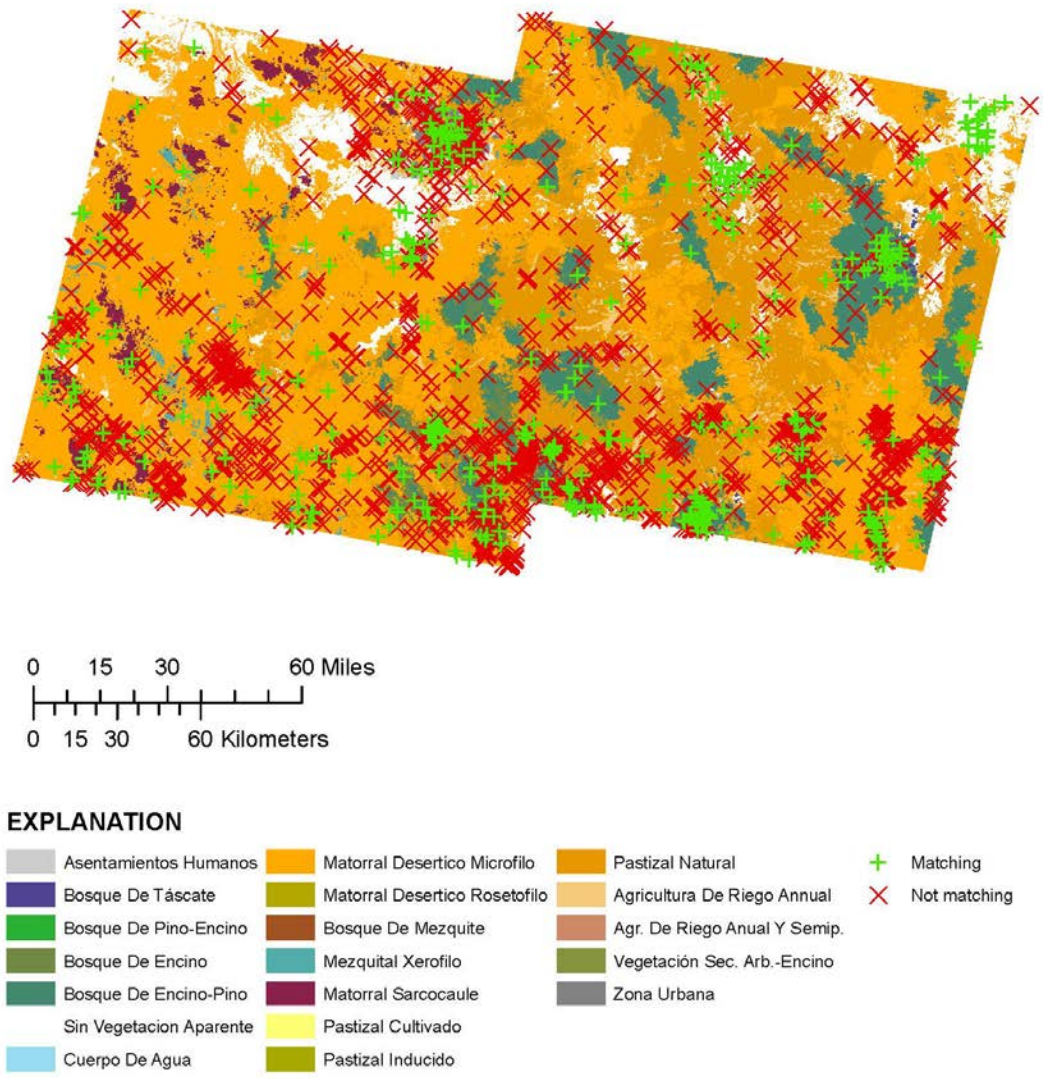


Figure 40. Object-oreinted classification Pilot Area A classes and quality assurance checks for Instituto Nacional de Estadística y Geografía (INEGI) Uso de Suelo y Vegetación and the US Geological Survey (USGS) 2011 National Land Cover Data (NLCD).

Object-oriented classification Pilot Area B						
All Reference						
Class	Reference Match	User Total	Commission	Omission	Producers Accuracy	Users Accuracy

AH	39	53	26.42%	22.00%	78.00%	73.58%
-BG	0	0		100.00%	0.00%	
BJ	0	0		100.00%	0.00%	
BP	2	29	93.10%	96.00%	4.00%	6.90%
BPQ	0	0		100.00%	0.00%	
BQ	0	1	100.00%	100.00%	0.00%	0.00%
BQP	13	49	73.47%	74.00%	26.00%	26.53%
BS	0	0		100.00%	0.00%	
DV	46	47	2.13%	8.00%	92.00%	97.87%
H2O	11	11	0.00%	78.00%	22.00%	100.00%
MDM	23	277	91.70%	54.00%	46.00%	8.30%
MDR	45	1263	96.44%	10.00%	90.00%	3.56%
MET	12	14	14.29%	76.00%	24.00%	85.71%
MK	0	0		100.00%	0.00%	
ML	3	12	75.00%	94.00%	6.00%	25.00%
MSM	2	2	0.00%	96.00%	4.00%	100.00%
PC	11	15	26.67%	78.00%	22.00%	73.33%
PH	6	9	33.33%	88.00%	12.00%	66.67%

PI	0	0		100.00%	0.00%	
PN	12	18	33.33%	76.00%	24.00%	66.67%
RA	33	33	0.00%	34.00%	66.00%	100.00%
RAP	0	0		100.00%	0.00%	
RAS	42	182	76.92%	16.00%	84.00%	23.08%
RP	0	0		100.00%	0.00%	
RS	0	0		100.00%	0.00%	
TA	0	0		100.00%	0.00%	
VG	0	0		100.00%	0.00%	
VH	0	0		100.00%	0.00%	
VSa/BP	0	0		100.00%	0.00%	
VSa/BPQ	0	0		100.00%	0.00%	
VSa/BQ	0	0		100.00%	0.00%	
VSa/BQP	0	0		100.00%	0.00%	
VSa/MDM	0	0		100.00%	0.00%	
VSa/MDR	0	0		100.00%	0.00%	
VSa/MET	0	0		100.00%	0.00%	
VSa/MSM	0	0		100.00%	0.00%	

VSa/PH	0	0		100.00%	0.00%	
VSa/PN	0	0		100.00%	0.00%	
VSa/VG	0	0		100.00%	0.00%	
VSh/MDM	0	0		100.00%	0.00%	
ZU	35	35	0.00%	30.00%	70.00%	100.00%
Kappa Coefficient	14.25%					
Total Accuracy	16.34%					

Table 9. Pilot Area B quality assurance check results for comparisons against the Instituto Nacional de Estadística y Geografía Uso de Suelo y Vegetación

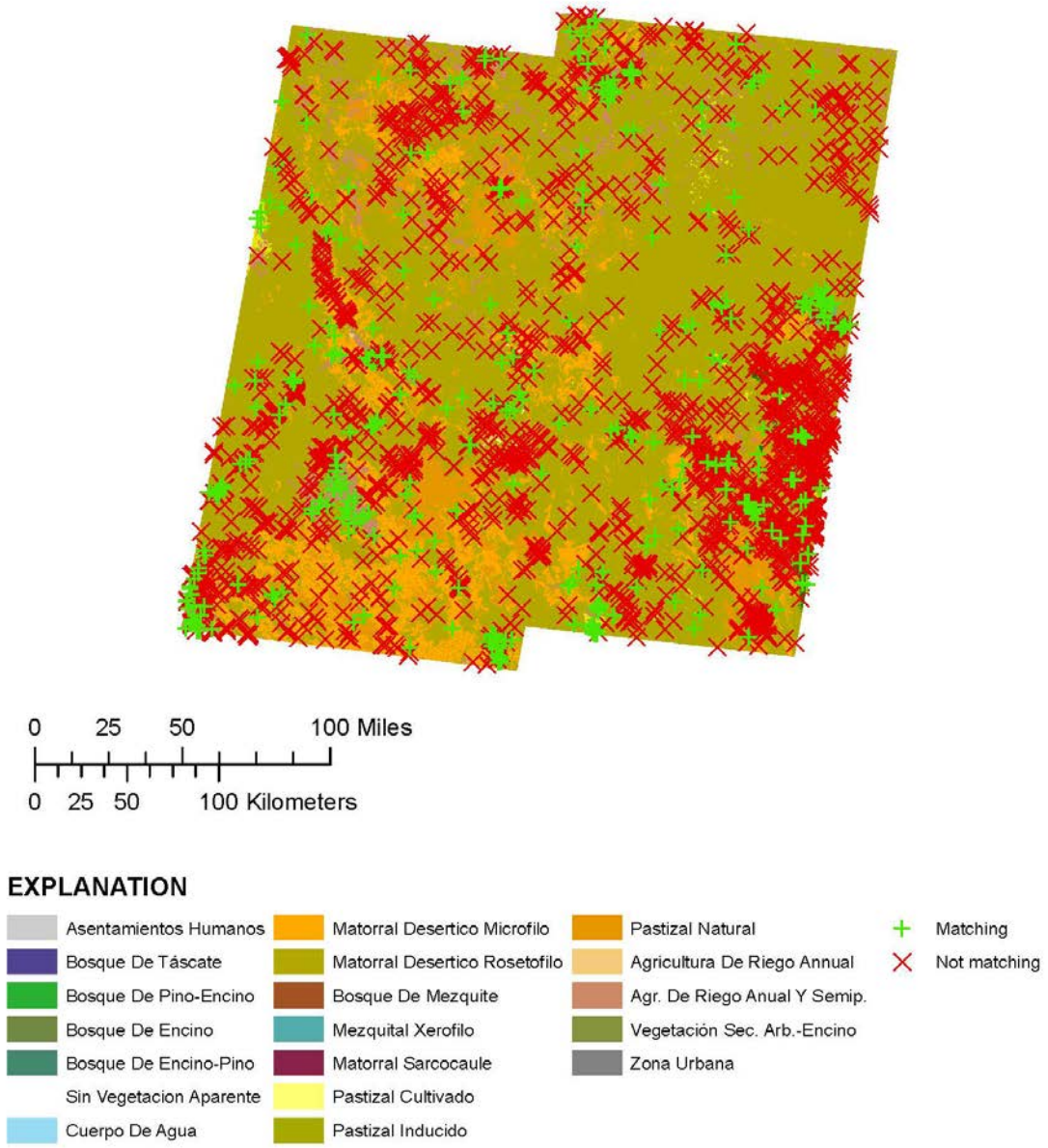


Figure 41. Object-oreinted classification Pilot Area B classes and quality assurance checks for Instituto Nacional de Estadística y Geografía (INEGI) Uso de Suelo y Vegetación and the US Geological Survey (USGS) 2011 National Land Cover Data (NLCD).