Ecosystem Indicators
Project # 2005-UNR-578

Final Report 2005-UNR-578

Deliverable D27

June 2011

University of Nevada Reno

Recommended citation: Heaton, J. S., X. Miao, K. Von Seckendorff Hoff, D. Charlet, P. Cashman, J. Trexler, A. Grimmer, R. Patil. 2011. Final Report 2005-UNR-578. Report to Clark County MSHCP 2005-UNR-578:D27.

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1.0 Executive Summary

The objectives of this study were to 1) produce a geomorphology GIS dataset of Clark County, 2) update and refine the vegetation based ecosystem GIS dataset currently being used by the Multiple Species Habitat Conservation Program (MSHCP) and 3) produce a pilot vegetation model. In the course of developing the vegetation models we applied the geomorphology data and numerous texture algorithms generated from Quickbird imagery to the remote sensing classifier. This was done for the entire county (designated Pilot Area 3) and Ivanpah Valley (designated Pilot Area 1). We conducted additional field data collection in Piute Valley (designated Pilot Area 2) and Ivanpah Valley (Pilot Area 1) to further explore the relationship between *Yucca sp.*, topographic position, geomorphology and bedrock composition mapping. In addition, we developed a county wide model of *Yucca brevifolia*. Each of the above are detailed in a series of reports (Table 1). Refer to each of these reports for details on each deliverable. Beyond a general introduction to each major project deliverable this final report focuses on the assessment of the Final Vegetation GIS Data Delivery and Final Pilot Vegetation GIS Data Delivery (Pilot Area 3), the Ivanpah Valley GIS vegetation models (Pilot Area 1) and the impacts of geomorphology and texture on the models. We also summarize our findings regarding the county-wide Joshua Tree GIS model. In summary, we

1. believe both the Final Vegetation GIS Data Delivery and Final Pilot Vegetation GIS Data Delivery are better models than RECON (2000; Figure 1, Figure 2, Figure 3 respectively),
2. would use the Final Vegetation GIS Data Delivery over the Final Pilot Vegetation GIS Data Delivery as the county wide vegetation based ecosystem model,
3. would use the Joshua Tree Model (Figure 10) as necessary for management purposes,
4. do not recommend use of any of the six geographically restricted Ivanpah models.

For ease of reading, the following nomenclature is utilized throughout the report

- Final Geomorphology GIS Data Delivery (D16) is referred to as the Final Geomorphology Model.
- Final Vegetation GIS Data Delivery (D21) is referred to as the Final Vegetation Model.
- Final Pilot Vegetation GIS Data Delivery (D22) Pilot Area 3 is referred to as the Final Pilot Vegetation Model

Table 1. Summary of major deliverables.

Deliverable	Explanation of Deliverable
D-4 Processed Quickbird Imagery	• Assessed prior processing and registration • Mosaiced and re-sampled the imagery.
D16 Final Geomorphology GIS Data Delivery	• A robust GIS-based characterization of the geomorphology and surficial geology of Clark County. • Emphasis was on sediment rather than bedrock geology, however bedrock was compiled and classified by lithology.
D21 Final Vegetation GIS Data Delivery	• Ecosystem model of Clark County based upon spectral and topographic data
D22 Final Pilot Vegetation GIS Data Delivery	• Ecosystem model of Clark County based upon spectral, topographic, geomorphology, and texture (Pilot Area 3). • Evaluated two scales of geomorphology data on the remote sensing classifier model (Pilot Area 1). • Explored the relationship between *Yucca sp.*, topographic position, geomorphology and bedrock composition mapping. • *Yucca brevifolia* model of Clark County.

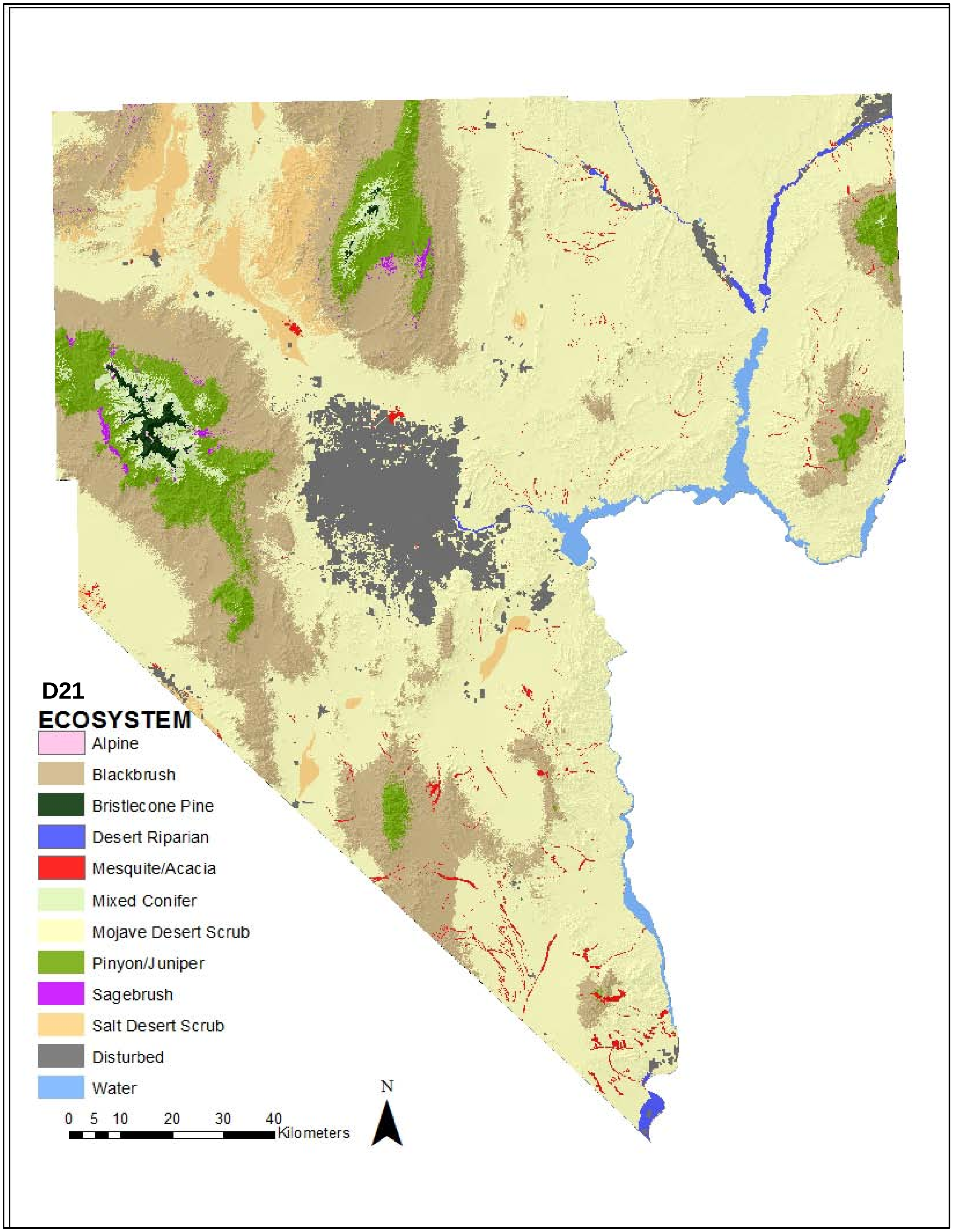

Figure 1. Final Vegetation GIS Data Delivery.

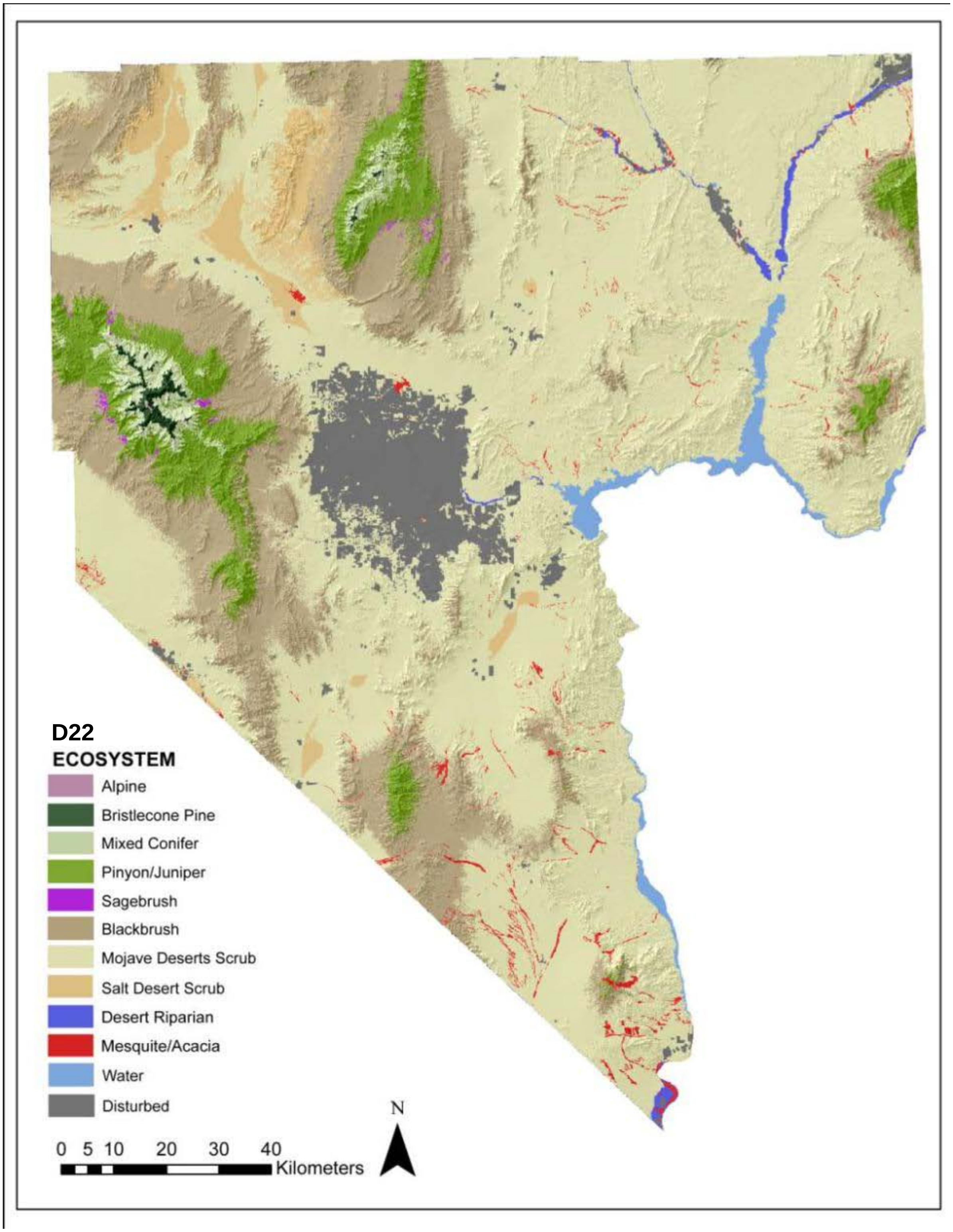

Figure 2. Final Pilot Vegetation GIS Data Delivery.

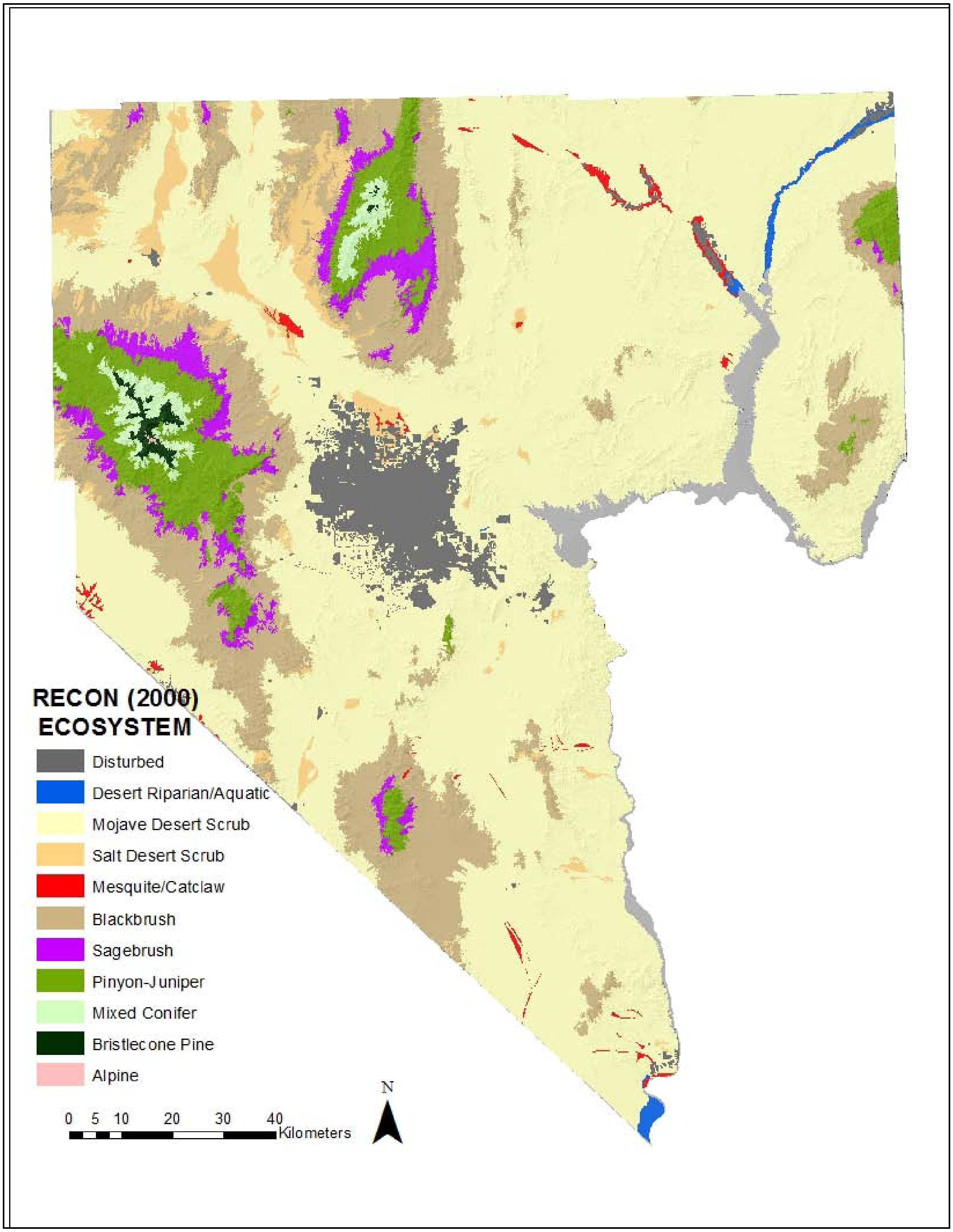

Figure 3. Original MSHCP model (RECON 2000)

2.0 Introduction

The project major deliverables are briefly described here. Refer to the final reports listed in Table 1 for complete details.

2.1 Final Geomorphology Model (D16)

Our objective was to develop a “robust GIS-based characterization of the geomorphology and surficial geology of Clark County, Nevada” (Interlocal Agreement). Although it is a stand-alone GIS product, the impetus for producing this map was to aid in the development of an improved vegetation based ecosystem model for the Clark County Multiple Species Habitat Conservation Program. Thus our emphasis was on sediment rather than bedrock material. However, bedrock was compiled and classified by lithology. Lithology was thought to be more important for vegetation modeling than age. Although our purpose and decision making regarding making this map product was to aid in vegetation modeling, this data set will have multiple environmental applications in Clark County. We developed a 1:150,000 scale geomorphology map of Clark County, Nevada.

2.2 Final Vegetation Model (D21)

The current ecosystem model for the Clark County MSHCP is based on the original GAP product for Nevada (RECON 2000). The goal of Objective 2 (Vegetation Based Ecosystem GIS Dataset) was to update and refine the boundaries of the 11 MSHCP vegetation based ecosystems within Clark County, Nevada, excluding urban areas. It was not our purpose to define new or redefine existing ecosystems. The GIS data were a product of the latest advances in remote sensing based classification methods and included original field work, output from remote sensing based classification, original mapping, and secondary data sources. The final model was a product of four levels of integration 1) non-zone based remote sensing classification; 2) zone-based remote sensing classification; 3) original mapping; and 4) secondary data sources.

2.3 Final Pilot Vegetation Model (D22)

Objective 3 was to develop an enhanced vegetation based ecosystem classification model using spatial statistical methods and the incorporation of geomorphology as a predictor variable. Three pilot areas were to be identified: Ivanpah Valley, Piute Valley, and countywide. We also described in this report our countywide *Yucca brevifolia* (Joshua tree) model. Although this was originally outlined within objective 2, we included this model within this deliverable so that we could include texture and geomorphology into the model classifier.

3.0 County-wide GIS Models

3.1 Methods

3.1.1 Model Development

For the bulk of the ecosystems we used remote sensing based classification methods. This included the bristlecone pine, mixed conifer, pinyon-juniper, sagebrush, blackbrush, Mojave Desert scrub and salt desert scrub ecosystems. We initially compared two multi-class algorithms: Adaptive Boosting (AdaBoost) and Bagging Trees. Although similar in their look, they are distinctly different in concept and theory. Based upon test and simulations we selected the AdaBoost technique.

In order to provide coverage of the mesquite/acacia, alpine, riparian and spring ecosystem we used alternative methods to remote sensing classification. Our coverage of mesquite/acacia was a compilation of 1) existing GIS data (Crampton et al. 2006); 2) revisions of existing GIS data (Crampton et al. 2006); and 3) our own original field mapping. We heads up digitized the alpine ecosystem. We did so using previously modeled versions (RECON 2000; Lowry et al. 2005; our draft models), expert opinion, and satellite imagery (Quickbird D4, Google Earth, and ESRI Base Satellite Imagery). Riparian areas are a compilation of mapped fluvial classes from the Final Geomorphology Model and heads up digitizing. Springs data were compiled from existing data only. In accordance with the project Annual Work Plan D1 no new springs data were generated for this project. Springs were not added to the ecosystem models, but were provided as a standalone dataset.

3.1.2 Accuracy Assessment

Accuracy assessment is a broadly defined term, however it is used here to reflect the quality of the mapped product. In our case we are interested in the classification accuracy-what was mapped correctly or incorrectly. Although it would seem straight forward, there are multiple ways in which to assess accuracy. We present three different map accuracy assessments. The first assessment is strictly a remote sensing based numeric assessment of model performance. This includes only the seven ecosystems that were modeled using remote sensing based classification techniques, and the field sample points that were used to generate and test the model. The second assessment is for the final models and incorporates remote sensing and non-remote sensing based ecosystems to equal the 10 ecosystems. We also evaluated the accuracy of the original MSHCP ecosystem model (RECON 2000). An error matrix is calculated from field data points, those used to create the remote sensing model and data points collected after the fact.

In addition, this assessment also incorporates several hundred riparian and mesquite/acacia-riparian field data points. We collected field data on ephemeral desert and ephemeral montane riparian. The Clark County MSHCP does not include ephemeral riparian in its definition of riparian. When we recorded ephemeral riparian field data points we also recorded the surrounding ecosystem zone, for example, desert riparian within Mojave Desert Scrub ecosystem zone. We did not use these locations in the remote sensing model. Although these locations were within a larger ecosystem zone their spectral signatures likely reflected the qualities of riparian (more vegetation or greener vegetation) not the surrounding ecosystem. As such, we did not include these locations in the remote sensing model so as not to confuse the spectral classifier (i.e. include both Mojave Desert scrub and riparian spectral signatures as Mojave Desert scrub). However, for accuracy assessment purposes we have included these field data points as classified by their ecosystem zone because we did not model ephemeral riparian.

The presence or absence of mesquite/acacia does not necessarily indicate the mesquite/acacia ecosystem. We visited every mesquite/acacia observation recorded in the field by Charlet and mapped it as mesquite/acacia ecosystem if appropriate. For each of the observations that were not deemed large or dense enough to be mapped as a separate ecosystem we noted the surrounding ecosystem zone. None of these observations were included in the remote sensing model for the same spectral confusion problem mentioned above. However, for accuracy assessment purposes we included these field data points as classified by their ecosystem zone. The third accuracy assessment evaluated 99 field sample points identified as being transitional between two ecosystems.

Within each accuracy assessment we used one or more of four numeric measures of accuracy: overall accuracy, kappa coefficient, producer’s accuracy and user’s accuracy.

1. *Overall accuracy* is the total number of correctly classified field samples divided by the total number of field samples taken.
2. The *kappa coefficient* is a statistical measure of agreement and more complex than overall accuracy. Kappa accounts for the possibility that a correct assignment could have been by chance alone.
3. Story and Congalton (1986) coined *producer’s accuracy* (or conversely errors of omission) because the producer of the map is interested in how well a specific area can be mapped.
4. Story and Congalton (1986) coined *user’s accuracy* (or conversely errors of commission) because a map user is interested in the reliability of the map, or how well the map represents what is on the ground.

A simple example to distinguish user’s and producer’s accuracy includes a landscape with three categories: forest, water, and urban (Story and Congalton 1986). Producer’s accuracy for forest is 96% and user’s accuracy is 49%. The producer of the map can stand in a forested site on the ground and know that the probability that the map correctly identified that site as forested was 93%. However, consider the view of the user, a United States Forest Service (USFS) employee. The USFS forester selects a location on the map for timber sale because it was classified as forest. The probability that this site is in fact forest is only 49%. Ideally, both producer’s and user’s accuracy are high.

3.1.3 Area Differences

We calculated the difference in acreage between the Final Vegetation Model, the Final Pilot Vegetation Model and RECON [2000]). The RECON Model (2000) does not include disturbed areas (i.e. developed, agriculture, etc). In order to more closely match our models we included a developed layer from 2001 into the RECON Model (2000). The 2001 developed layer was obtained from Clark County, and is used here for contextual comparison purposes.

3.1.4 Agreement/Disagreement

We compared each of the three models (Final, Final Pilot and RECON [2000]) with one another to identify areas of agreement and disagreement. We did not retain individual ecosystem categories, but simply noted agreement or disagreement. We also identified individual field sample points that had been correctly and incorrectly modeled for the three models.

3.2 Results

3.2.1 Accuracy Assessment One: Remote Sensing

The first accuracy assessment used the five-fold cross-validation method and produced overall, kappa, producer's and user's accuracy. The Final Pilot Vegetation Model numerically produce a better model over the Final Vegetation Model. Overall accuracy and kappa are larger (Table 2). The Final Pilot Vegetation Model generally had higher producer's and user's accuracies.

Table 2. Remote sensing AdaBoost model accuracy assessment. Green indicates the higher and red lower accuracy within the producer's or user's accuracy column, respectively.

	Producer's Accuracy (%)		User's Accuracy (%)	
	Final Vegetation	Final Pilot Vegetation	Final Vegetation	Final Pilot Vegetation
Bristlecone Pine (BR)	**79.0**	**78.1**	**82.3**	**78.8**
Mixed Conifer (MC)	**75.2**	**78.9**	**73.4**	**77.6**
Pinyon-Juniper (PJ)	**79.1**	**82.0**	**78.2**	**80.4**
Blackbrush (BL)	**81.5**	**82.8**	**80.0**	**81.3**
Sagebrush (SA)	**16.6**	**28.3**	**69.7**	**67.7**
Mojave Desert Scrub (MS)	**93.3**	**94.3**	**87.5**	**89.5**
Salt Desert Scrub (SS)	**65.4**	**72.0**	**78.0**	**83.3**
Overall Accuracy	**81.4**	**83.5**		
Kappa	**75.8**	**78.6**		

3.2.2 Accuracy Assessment Two: Final Ecosystem Model

The second accuracy assessment produced overall, producer's and user's accuracy. The Final and Final Pilot Vegetation Models had equivalent overall model accuracies (87%; Table 3 and Table 4), and where both higher than RECON (2000; 74%; Table 5). Average Producer's and User's accuracies were also higher for the two models compared to RECON (2000; Table 6).

Table 3. Accuracy assessment for the Final Vegetation Model. Light green indicates incorrect classifications within adjacent ecosystems. Points outside this area represent incorrect classifications for non-adjacent ecosystems and more problematic misclassifications.

	Field Locations												
Modeled Values	AL	BCP	MC	PJ	SB	BB	MDS	SDS	MA	DR	Row Total	Commission Error	User's Accuracy
Alpine (AL)	5	1	0	0	0	0	0	0	0	0	6	17%	83%
Bristlecone Pine (BCP)	4	97	17	0	1	0	0	0	0	0	119	18%	82%
Mixed Conifer (MC)	0	9	234	24	0	0	0	0	0	0	267	12%	88%
Pinyon-Juniper (PJ)	0	0	35	361	12	4	0	0	0	0	412	12%	88%
Sagebrush (SB)	0	0	1	5	26	0	0	0	0	0	32	19%	81%
Blackbrush (BB)	0	0	0	53	27	690	33	10	10	0	823	16%	84%
Mojave Desert Scrub (MDS)	0	0	0	3	0	44	1399	23	41	4	1514	8%	92%
Salt Desert Scrub (SDS)	0	0	0	0	0	7	13	201	4	0	225	11%	89%
Mesquite/Acacia (MA)	0	0	0	3	0	6	46	7	77	0	139	45%	55%
Desert Riparian (DR)	0	0	0	0	0	0	1	5	0	20	26	23%	77%
Column Total	9	107	287	449	66	751	1493	247	132	24	3110		
Omission Error	44%	9%	18%	20%	61%	8%	6%	18%	42%	17%		Overall Model accuracy	
Producer's Accuracy	56%	91%	82%	80%	39%	92%	94%	82%	58%	83%			87%

Table 4. Accuracy assessment for the Final Pilot Vegetation Model. Light green indicates incorrect classifications within adjacent ecosystems. Points outside this area represent incorrect classifications for non-adjacent ecosystems and more problematic misclassifications.

	Field Locations												
Modeled Values	AL	BCP	MC	PJ	SB	BB	MDS	SDS	MA	DR	Row Total	Commission Error	User's Accuracy
Alpine (AL)	5	1	0	0	0	0	0	0	0	0	6	17%	83%
Bristlecone Pine (BCP)	4	94	11	0	0	0	0	0	0	0	109	14%	86%
Mixed Conifer (MC)	0	12	250	16	1	0	0	0	0	0	279	10%	90%
Pinyon-Juniper (PJ)	0	0	26	375	16	12	0	0	0	0	429	13%	87%
Sagebrush (SB)	0	0	0	7	26	0	0	0	0	0	33	21%	79%
Blackbrush (BB)	0	0	0	47	23	662	24	6	9	0	771	14%	86%
Mojave Desert Scrub (MDS)	0	0	0	1	0	57	1411	26	48	4	1547	9%	91%
Salt Desert Scrub (SDS)	0	0	0	0	0	14	10	202	7	0	233	13%	87%
Mesquite/Acacia (MA)	0	0	0	3	0	6	46	7	68	0	130	48%	52%
Desert Riparian (DR)	0	0	0	0	0	0	1	5	0	20	26	23%	72%
Column Total	9	107	287	449	66	751	1493	247	132	24	3113		
Omission Error	44%	12%	13%	16%	61%	12%	5%	18%	48%	17%		Overall Model accuracy	
Producer's Accuracy	56%	88%	87%	84%	39%	88%	95%	82%	52%	83%			87%

Table 5. Accuracy assessment for RECON (2000). Light green indicates incorrect classifications within adjacent ecosystems. Points outside this area represent incorrect classifications for non-adjacent ecosystems and more problematic misclassifications.

	Field Locations												
Modeled Values	AL	BCP	MC	PJ	SB	BB	MDS	SDS	MA	DR	Row Total	Commission Error	User's Accuracy
Alpine (AL)	8	1	0	0	0	0	0	0	0	0	9	11%	89%
Bristlecone Pine (BCP)	1	75	17	1	1	0	0	0	0	0	95	21%	79%
Mixed Conifer (MC)	0	27	194	27	1	0	0	0	0	0	249	22%	78%
Pinyon-Juniper (PJ)	0	4	78	336	26	23	0	0	0	0	467	28%	72%
Sagebrush (SB)	0	0	0	53	26	104	0	0	0	0	183	86%	14%
Blackbrush (BB)	0	0	0	28	12	442	38	13	18	0	551	20%	80%
Mojave Desert Scrub (MDS)	0	0	0	4	0	132	1413	86	80	1	1716	18%	82%
Salt Desert Scrub (SDS)	0	0	0	0	0	50	26	103	6	0	185	44%	56%
Mesquite/Acacia (MA)	0	0	0	0	0	0	10	34	27	2	73	63%	37%
Desert Riparian (DR)	0	0	0	0	0	0	2	4		17	23	26%	74%
Column Total	9	107	289	449	66	751	1489	240	131	20	2641		
Omission Error	11%	30%	33%	25%	61%	41%	5%	57%	79%	15%			
Producer's Accuracy	89%	70%	67%	75%	39%	59%	95%	43%	21%	85%		Overall Model accuracy	74%

Table 6. Summary accuracy information for the Final, Final Pilot and RECON (2000) models.

	Producer's Accuracy			User's Accuracy		
	Final Vegetation	Final Pilot Vegetation	RECON	Final Vegetation	Final Pilot Vegetation	RECON
Alpine (AL)	56%[1]	56%	89%	83%	83%	89%
Bristlecone Pine (BCP)	91%	88%	70%	82%	86%	79%
Mixed Conifer (MC)	82%	87%	67%	88%	90%	78%
Pinyon-Juniper (PJ)	80%	84%	75%	88%	87%	72%
Sagebrush (SB)	39%	39%	39%	81%	79%	14%
Blackbrush (BB)	92%	88%	59%	84%	86%	80%
Mojave Desert Scrub (MDS)	94%	95%	95%	92%	91%	82%
Salt Desert Scrub (SDS)	82%	82%	43%	89%	87%	56%
Mesquite/Acacia (MA)	58%	52%	21%	55%	52%	37%
Desert Riparian (DR)	83%	83%	85%	77%	77%	74%
Average Producer's/User's	**76%**	**75%**	**64%**	**81%**	**81%**	**66%**
Overall Accuracy	**87%**	**87%**	**74%**			

[1] Accuracies ≥ 85% are subjectively considered **good**; 70-84 **moderate** and < 70 **poor**. The highest producer's and user's accuracies are highlighted green.

3.2.3 Accuracy Assessment Three: Transition Field Points

As part of our field surveys, we collected data at 99 locations that were identified as transitions between or on ecosystems boundaries. We compared these locations to transitions in the GIS models. A transition in the model was identified as a 'salt and pepper' pixilated pattern or a clear line between ecosystems in the final model. Of these 99 locations 60% and 62% were within 200m of a model transition, for the Final and Final Pilot Vegetation Models, respectively (Table 7 and Table 8).

The Final Vegetation Model captured the mixed conifer/pinyon-juniper transition better than the Final Pilot Model (82% versus 73%, respectively). The Final Pilot Vegetation Model captured the blackbrush/Mojave Desert scrub (41% versus 32%, respectively) and the Mojave Desert scrub/salt desert scrub (67% versus 53%, respectively) better than Final Vegetation Model.

Table 7. Final Vegetation Model accuracy assessment of transition locations.

Transition	0-200m	<500m	<1000m	<1500m	<3000m	Total
Alpine - Bristlecone Pine	0 (0%)	0	0	0	1	1
Bristlecone Pine - Mixed Conifer	7 (100%)	0	0	0	0	7
Mixed Conifer - Pinyon/Juniper	18 (82%)	2	1	1	0	22
Pinyon/Juniper - Sagebrush	4 (100%)	0	0	0	0	4
Pinyon/Juniper - Blackbrush	5 (38%)	3	3	1	1	13
Pinyon/Juniper - Mojave Desert Shrub	0 (0%)	0	1	0	0	1
Pinyon/Juniper - Mesquite/Acacia	1 (100%)	0	0	0	0	1
Sagebrush - Blackbrush	3 (43%)	1	1	2	0	7
Blackbrush-Mojave Desert Shrub	7 (32%)	4	3	4	4	22
Blackbrush - Mesquite/Acacia	3 (100%)	0	0	0	0	3
Mojave Desert Shrub - Mesquite/Acacia	3 (100%)	0	0	0	0	3
Mojave Desert Shrub-Salt Desert Shrub	8 (53%)	3	1	1	2	15
Total	59 (60%)	13 (72%)	10 (82%)	9 (91%)	8 (100%)	99

Table 8. Final Pilot Vegetation Model accuracy assessment of transition locations.

Transition	0-200m	<500m	<1000m	<1500m	<3000m	Total
Alpine - Bristlecone Pine	0 (0%)	0	0	0	1	1
Bristlecone Pine - Mixed Conifer	7 (100%)	0	0	0	0	7
Mixed Conifer - Pinyon/Juniper	16 (73%)	3	2	1	0	22
Pinyon/Juniper - Sagebrush	4 (100%)	0	0	0	0	4
Pinyon/Juniper - Blackbrush	5 (38%)	6	1	0	1	13
Pinyon/Juniper - Mojave Desert Shrub	0 (0%)	1	0	0	0	1
Pinyon/Juniper - Mesquite/Acacia	1 (100%)	0	0	0	0	1
Sagebrush - Blackbrush	3 (43%)	1	1	1	1	7
Blackbrush-Mojave Desert Shrub	9 (41%)	2	5	2	4	22
Blackbrush - Mesquite/Acacia	3 (100%)	0	0	0	0	3
Mojave Desert Shrub - Mesquite/Acacia	3 (100%)	0	0	0	0	3
Mojave Desert Shrub-Salt Desert Shrub	10 (67%)	1	1	1	2	15
Total	61 (62%)	14 (76%)	10 (86%)	5 (91%)	9 (100%)	99

3.2.4 Area Differences

We used a combination of GIS datasets to calculate area differences. Different GIS datasets contained different total acreages. This can be accounted for by real gains and losses, difference in the area modeled as Clark County, and simply the fact that the datasets were generated by different entities. It is important to remember that GIS datasets are not reality, but a representation of reality.

Although total acreage is important, the percent change provides a context for the significance of that change. There was a total increase in acreage from RECON (2000) to that calculated in our Final and Final Pilot Vegetation Models (34,148 acres). A net loss for the County included NRS 243.293 that transferred 27,227 acres to Nye County. A net gain for the County can be attributed to a drop in Lake Mead levels that exposed 45,334 acres of land. A gain of approximately 16,000 acres is attributed to raster processing and the differences in the border of Clark County used to constrain the models. We used the boundary of Clark County provided by Clark County. The 34,148 acre difference is accounted for in these figures (i.e. 5,056,690 (RECON 2000) – 27,227 (Nye County) + 45,334 (exposed Lake Mead) + 16,000 (GIS differences) = 5,090,797 (our models; a nominal difference of 41 acres). Absolute acreage increase and decrease, as well as percent change are presented in Table 9.

Table 9. Total area in acres represented by each ecosystem within Clark County from the RECON (2000; calculated from GIS data) and our new models. Red represents loss of ecosystem acreage and green gain of ecosystem acreage between models.

Ecosystem	RECON_veg98[2]	RECON_veg98 + land2001fall[3]	Final Vegetation Model (D21)[4]	Acreage Change	Percent Change	Final Pilot Vegetation (D22)	Acreage Change	Percent Change
Alpine	479	479	306	-173	-36%	306	-173	-36%
Bristlecone Pine	15,856	15,856	18,692	2,836	18%	15,471	-385	-2%
Mixed Conifer	56,413	56,408	67,550	11,142	20%	66,589	10,181	18%
Pinyon-Juniper	281,695	281,642	286,334	4,692	2%	300,982	19,340	7%
Sagebrush	138,949	138,949	11,609	-127,340	-92%	6,954	-131,995	-95%
Blackbrush	831,531	831,531	1,027,018	195,487	24%	989,079	157,548	19%
Salt Desert Scrub	208,565	201,092	207,996	6,904	3%	194,914	-6,178	-3%
Mojave Desert Scrub	3,467,118	3,280,785	3,128,827	-151,958	-5%	3,173,983	-106,802	-3%
Mesquite/Acacia	34,466	27,738	41,628	13,890	50%	41,628	13,890	50%
Desert Riparian Perennial	21,599	18,148	22,888	4,740	26%	22,888	4,740	26%
Disturbed	0	204,522	278,042	73,520	36%	278,042	73,520	36%
	5,056,690		5,090,838			5,090,838		

[2] File provided by Clark County. Area calculated based upon the original attribute Shape_Area (m^2) and converted to acres using Hawths Tools.

[3] In order to estimate change between the RECON_veg98 and our two models we incorporated the oldest developed coverage that we had for Clark County. land2001fall, provided by Clark County. As stated in the metadata, this data set is not intended to represent 100% of the urban area in Clark County.

[4] Area calculated by multiplying the number of cells by 900 (30x30 meter pixels = $900m^2$) then multiplying that number by 0.000247105381467165 to achieve acres.

3.2.5 Agreement/Disagreement (Results and Discussion)

In addition, we ran an agreement/disagreement analysis between the Final Vegetation, Final Pilot Vegetation and the RECON (2000) Models. We visually observed the following differences between the models, a follow up analysis could look at differences on a pixel by pixel basis. The Final and Final Pilot Vegetation Models largely disagree only within bands around changes in elevation, indicative of differences in transitions between ecosystems (Figure 4). There is disagreement in the northwest corner of the county, largely due to salt desert scrub/Mojave Desert scrub differences. There is also disagreement in the most southern tip of the county in the Newberry Springs due to the location of pinyon-juniper. However, if you look at both models (Figure 1 and Figure 2), the pattern is not that different, only the classification of individual pixels varies. Besides the differences in disturbed, land transfer and exposed Lake Mead sediments the Final and Final Pilot Vegetation Models disagree with RECON (2000) around riparian and mesquite/acacia areas, as well as much larger bands of disagreement with respect to transitions along elevation bands (Figure 5 and Figure 6).

In the case of the Final and Final Pilot Vegetation Models there are no areas that stand out as being disproportionately misclassified with respect to field data sample points (Figure 7 and Figure 8). Most misclassified locations are near transitions between ecosystems. Misclassified locations largely centered within a sea of Mojave Desert scrub are Mojave Desert scrub/mesquite/acacia or Mojave Desert scrub/salt desert scrub confusion. There are more misclassified locations within RECON (2000; Figure 9). There also appears to be a large concentration of misclassified field samples throughout the Sheep Mountains, as well as throughout the Spring Mountains. Within the northeastern portion of the county few samples were correctly classified in the Virgin and Gold Butte Mountain ranges.

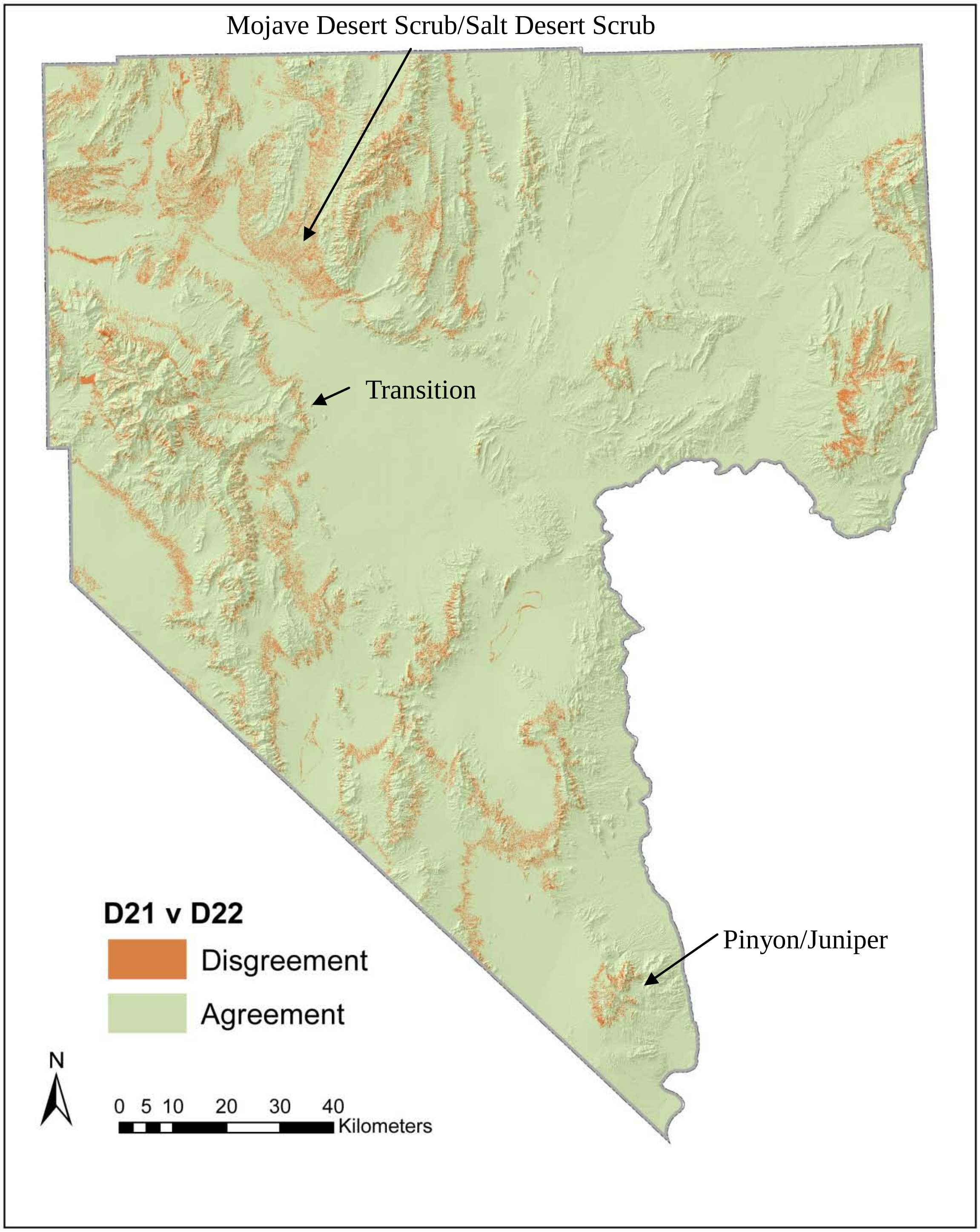

Figure 4. Comparison between Final Vegetation (D21) and Final Pilot Vegetation (D22) Models.

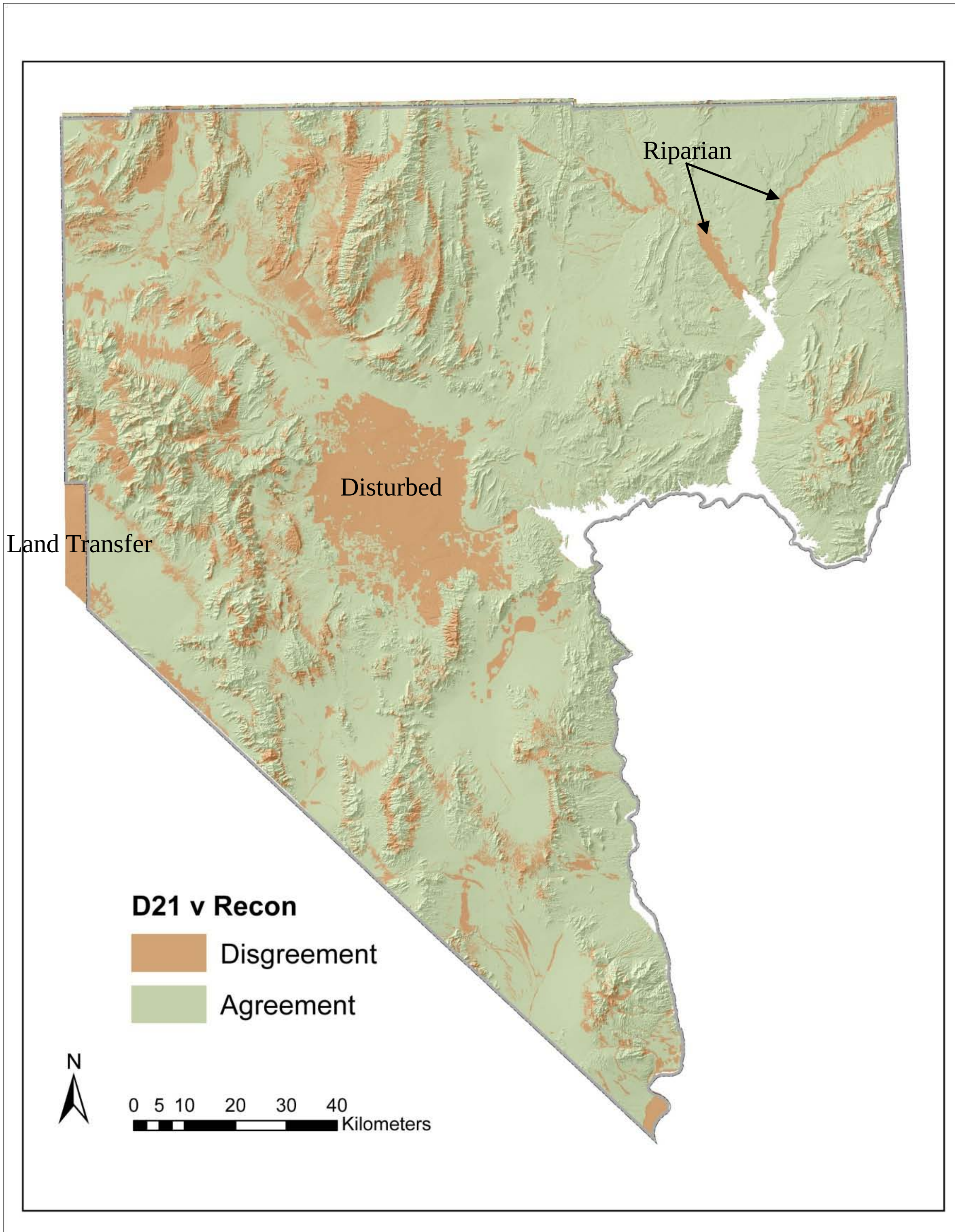

Figure 5. Comparison between Final Vegetation Model and RECON (2000).

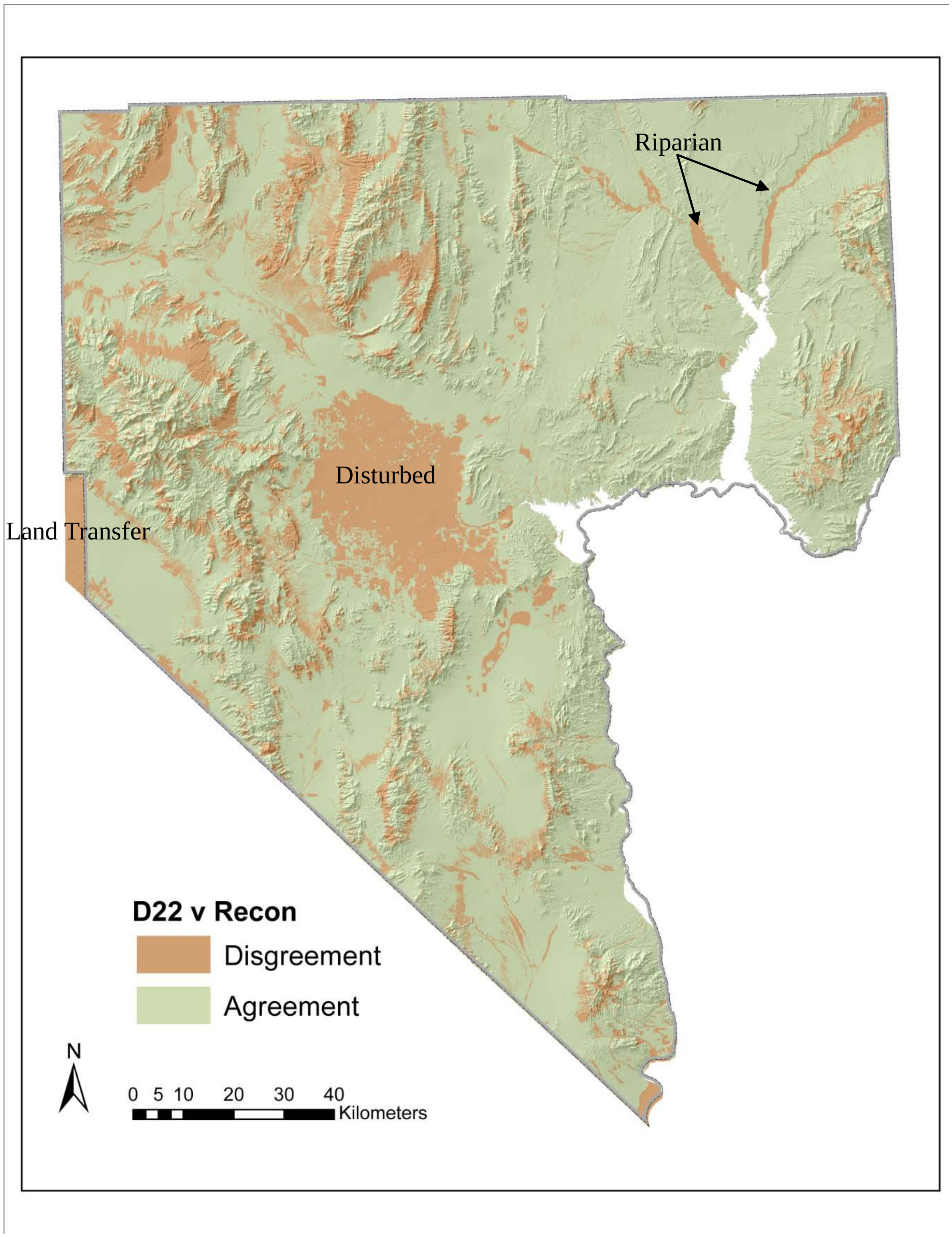

Figure 6. Comparison between Final Pilot Vegetation Model and RECON (2000).

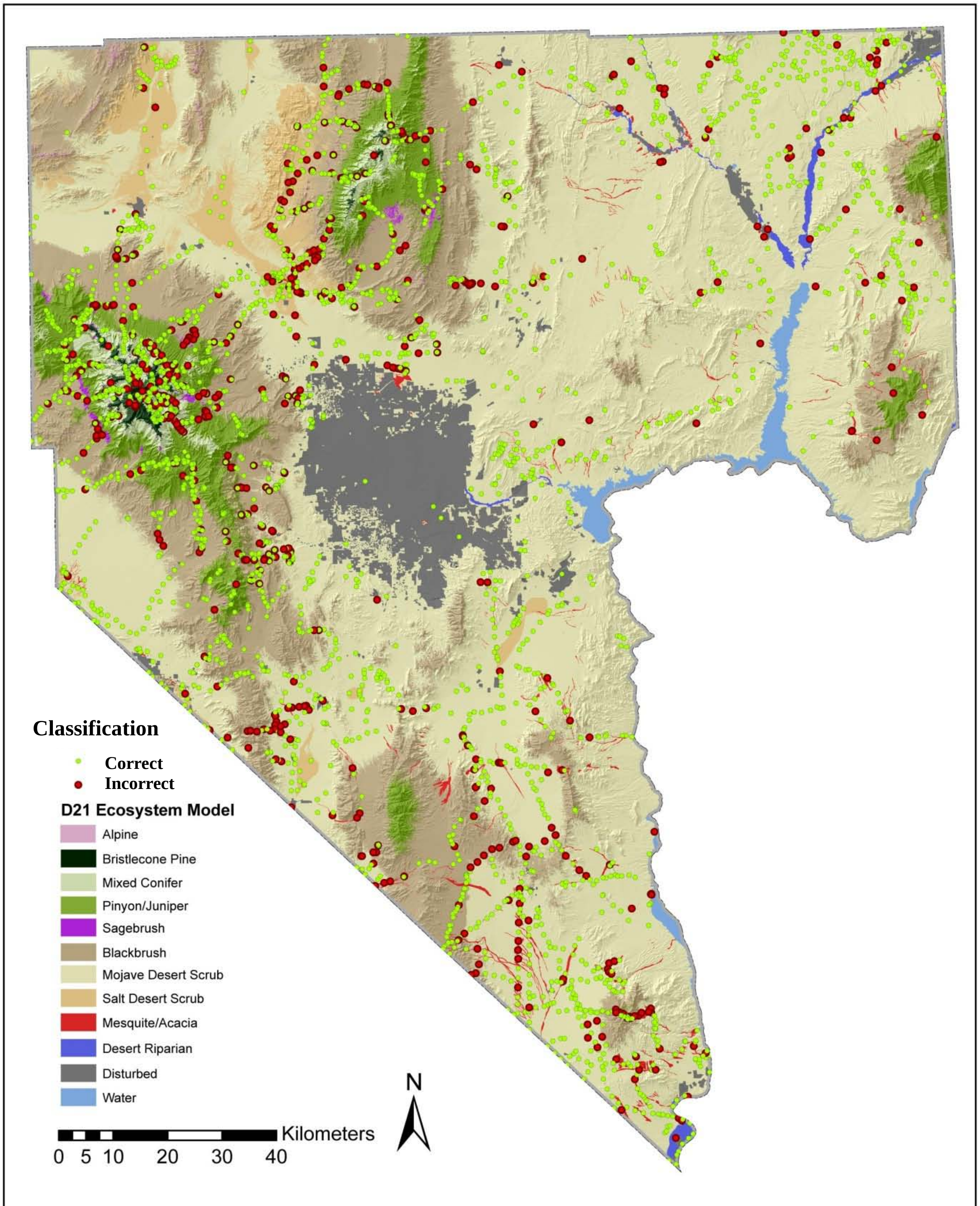

Figure 7. Final Vegetation Model (D21) correctly and incorrectly classified field data points.

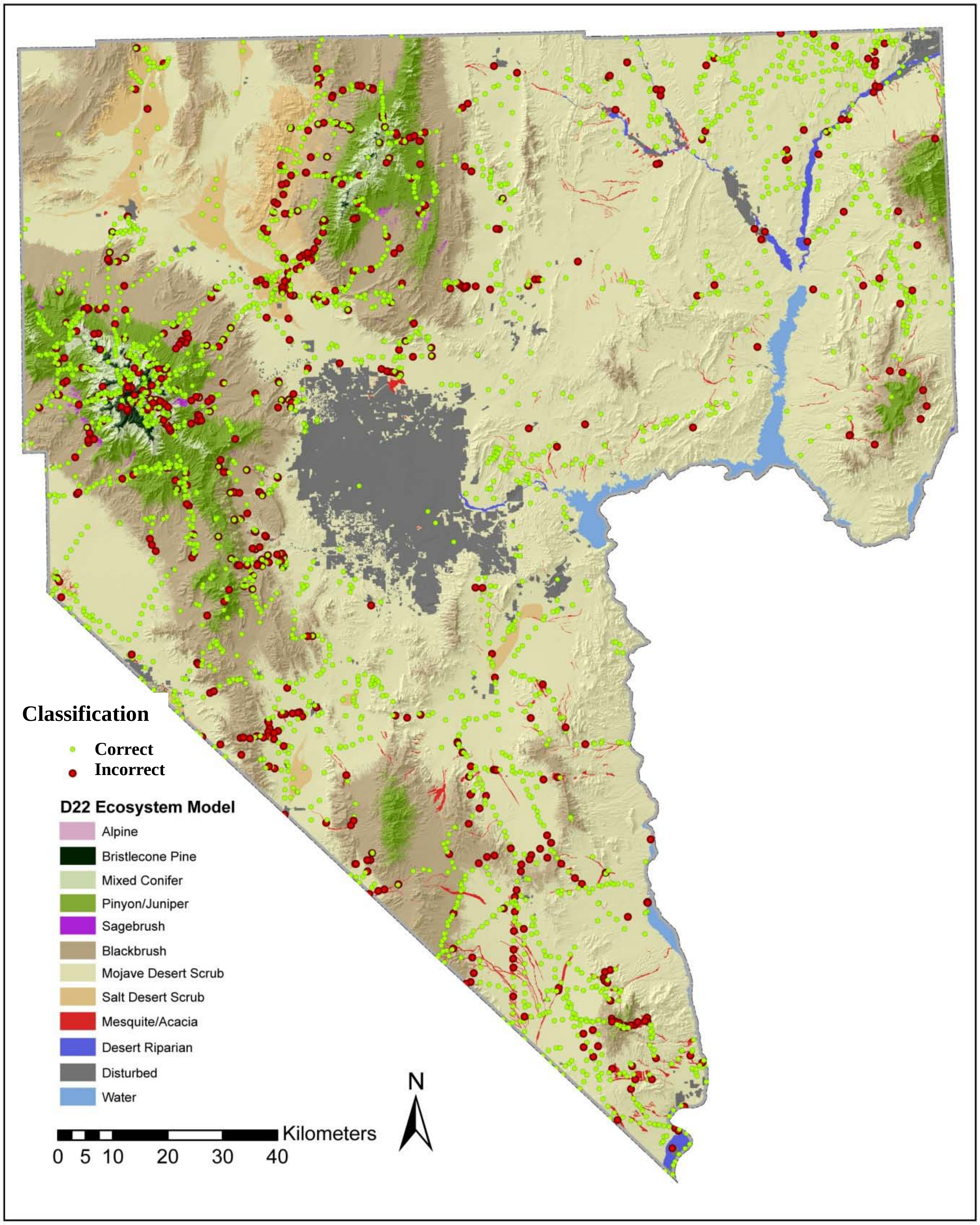

Figure 8. Final Pilot Vegetation Model (D22) correctly and incorrectly classified field data points.

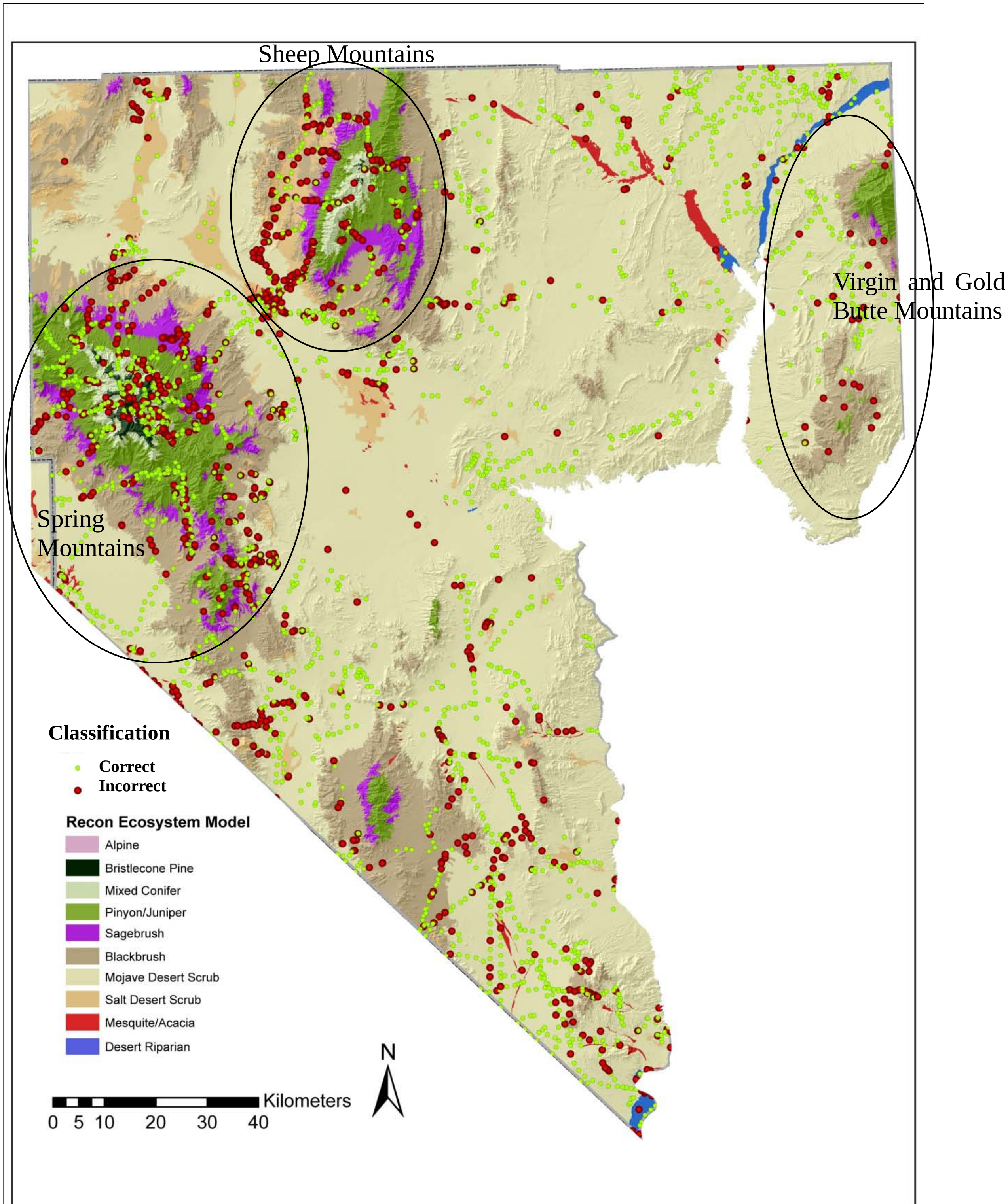

Figure 9. RECON (2000) correctly and incorrectly classified field data points.

3.3 Discussion

Because we mapped broad level and widely distributed ecosystems (i.e. zones) it is unlikely that there have been major natural shifts between these ecosystems since 1998, the publication date of the GAP product that was used to produce the original ecosystem map (RECON 2000). This is not to suggest that changes within an ecosystem have not occurred. After the large 2005 burn season large swaths of primarily *Coleogyne ramosissima* (blackbrush) were converted to native perennial forbs and exotic grasslands; *C. ramosissima* is one of the most diminished species after fires (Abella, et al. 2009; Abella 2009). However, changes from *C. ramosissima* to exotic grasses, for example, do not convert an area to a new ecosystem zone. In this case, the zone remains blackbrush, however there is a recorded loss in individuals of *C. ramosissima* and other species found within the blackbrush ecosystem. Nonetheless, the question remains how a conversion of this type might affect a remote sensing classification that relies a great deal on spectral signatures. Our last date of imagery used for spectral consideration was 2004, so our results are unaffected by this change. Our last date of imagery used for texture consideration (which relies on spectral information) was 2006. Texture was only considered in the Final Pilot Vegetation Model. We compared known burned areas against the Final Pilot Vegetation Model. In areas in which it appeared that there could have been an influence caused by fire we then compared that area to the Final Vegetation Modell-which was unaffected by the large 2005 burn season-to determine if the patterns were also present. We found one area in the Final Pilot Vegetation Model in which the result may have been affected by fire-Gold Butte region. The 2005 Fork fire covered a large portion of Gold Butte and burned Mojave Desert scrub, blackbrush, and pinyon-juniper ecosystems. With respect to blackbrush ecosystem the general pattern of difference is a reduction between the Final Pilot Vegetation Model and the Final Vegetation Model. However, in the area around Gold Butte that reduction seemed much greater between the two models. There are few primary or secondary field data points in this region.

We contend that due to the broad level of classification and scale of the vegetation communities mapped and the long-term ecosystem processes that created them there is little evidence of shifts between the Clark County MSHCP ecosystem types. We can look to the long-term studies of perennial vegetation from the Beatley permanent study plots at the Nevada Test Site (Webb et al. 2003) to support this assertion. Beatley's primary focus was on perennial vegetation; which was measured and photographed for each plot in 1963-1964, 1974-1975 and again in 2000-2003. Plots covered the salt desert scrub, Mojave Desert scrub, blackbrush, pinyon-juniper, and sagebrush ecosystems. There were shrub deaths from drought and freeze, biomass increases, and increases and decreases in shrub height and cover depending on species, but no reported shifts among these ecosystems (Webb et al. 2003). The only shifts were in burned plots, which shifted from their original ecosystem to an annual dominated grass/invasive species ecosystem. In one burned plot there was reported as few as one blackbrush establishment event on burned sites during the past 36-50 years (Webb et al. 2003). "Despite the increases in woody vegetation, the species composition is not even close to the undisturbed plots, and extrapolation suggests that as long as a millennium will be required for recovery of species composition" (Webb et al. 2003; pg12). It is unlikely that the much longer lived and slower growing mixed conifer, bristlecone pine and alpine ecosystems would change faster. The Mojave Desert is largely unaffected by the increases in pinyon-juniper woodlands over the last 150 yrs in the North American semi-arid grassland as a result of reduced fire, increased herbivory and reduced competition (Van Auken 2000). This may not be the case in the future, but currently is not a cause for concern with respect to shifting between Clark County MSHCP ecosystems from 1998 to 2010.

In the following sections we discuss model differences for each ecosystem. As mentioned in the results there were real gains and losses in acreage to Clark County in the intervening years between models. However, the following ecosystems were not affected, or largely not, by these changes: alpine, bristlecone pine, mixed conifer, sagebrush, pinyon juniper and black brush.

3.3.1 Alpine

The strictest definition of alpine is vegetation that occurs above the upper elevation limit of woody plants. As such, this is fairly simple to apply in the field, or in our case heads up digitization. We heads up digitized the alpine ecosystem; as a result the ecosystem is identical between the Final and Final Pilot Vegetation Models. The difference in mapped alpine between the original MSHCP ecosystem area and our version result in a net loss of 173 acres of alpine on the Mt. Charleston Peak of the Spring Mountains. This reduction is strictly due to differences in model predictions. Areas removed were below the timberline. However, we mapped a previously unmapped area of alpine ecosystem (20.5 acres) on Mummy Mountain, approximately 4.5 km northeast of Mt. Charleston Peak. This area was above the timberline. Although both producer's and user's accuracy were higher for RECON (2000), our opinion is that it overestimated the distribution of alpine in the Spring Mountains. Two of the misclassified alpine field locations were just one cell away from modeled alpine and the other two misclassified locations were only two cells away. If these four are considered to be correct both the Final and Final Pilot Vegetation Model producer's accuracy improves from 56% to 100%.

3.3.2 Bristlecone Pine

The bristlecone pine ecosystem was recognized by the overwhelming dominance of the site by *Pinus longaeva*. A few *Abies concolor* may be present at lower elevations, and *Pinus flexilis* may occasionally occur up to 10,700 ft, but otherwise no other tree species are present in this ecosystem.

Bristlecone pine exist in the Spring and Sheep Mountains. Both the Final and Final Pilot Vegetation Models identified two new areas of bristlecone pine in the Spring and one in the Sheep Mountains that were not previously mapped (RECON 2000). One area in the Spring Mountains is supported by primary and secondary field data. There are no field data in the newly mapped bristlecone pine in the Sheep Mountains, however bristlecone pine is known to exist there. In addition, the Final Vegetation Model extended the most northern mapped area of bristlecone pine northward by a few kilometers. Beyond these areas the models generally agree on the majority of the area mapped as bristlecone pine. Differences can be attributed to minor expansions and contractions of the RECON (2000) boundary. The Final Vegetation Model generally expands the boundary, although it does contract it in some places and the Final Pilot Vegetation Model generally contracts the boundary, although it expands it in some places. By all accounts of numerical accuracy the Final and Final Pilot Vegetation Models did a better job of modeling bristlecone pine than RECON (2000).

3.3.3 Mixed Conifer

Not all mixed conifer stands are in this zone, nor are all forests in this zone comprised of more than one species of conifer. However, certain diagnostic species and proportions provide opportunities to separate this from other conifer-dominated ecosystems. The key diagnostic conifers present in this zonal ecosystem are Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum*) and Rocky Mountain white fir (*Abies concolor* var. *concolor*). In stands where either of these species dominate or co-dominate, the location is Mixed Conifer Ecosystem. At the lower end of the zone, singleleaf pinyon (*Pinus monophylla*) commonly appears with the ponderosas and white fir. Rocky Mountain juniper (*Juniperus scopulorum*) can co-occur anywhere in the elevation range of the zone, and limber pine (*Pinus flexilis*) and bristlecone pine (*Pinus longaeva*) commonly occur in the middle to upper elevations of the zonal range. Pending further analysis, *Acer glabrum* appears to be somewhat narrowly confined to this zone. As such, it is probably a good indicator of a site being in the zone, although it is not omnipresent in the zone, and so its absence does not mean that the site is not in the zone.

The name mixed conifer implies that the ecosystem is strictly forested. However, certain sites are susceptible to disturbance regimes (from fire, avalanche, flood, and mass wasting) that prevent the long-term dominance of conifers, and so are not properly called mixed conifer forest or even mixed conifer and may be dominated instead by grasses, shrubs (e.g., *Ribes cereum*), or flowering trees (e.g., *Populus tremuloides, Acer glabrum*). Also, special edaphic situations such as cliffs, bedrock outcrops, and alluvial flats suitable for meadow development, have no forest but are surrounded by what is clearly mixed conifer forest as here defined. In spite of not being dominated by tall conifers, the species that do dominate these sites and their associates are mostly common members of mixed conifer forest, and so these meadows, shrublands, cliffs, outcrops, and riparian areas with these characteristics were assigned to the Mixed Conifer Zone.

RECON (2000) mapped mixed conifer in the Spring and Sheep Mountains only. In both of our models we map mixed conifer in the Virgin Mountains. Although not supported by primary or secondary field data used to produce our models, mixed conifer is known to exist in the area of the Virgin Mountains found in Clark County. We map over 10,000 acres more of mixed conifer, however, the newly mapped area in the Virgin Mountains only accounts for a small increase in mixed conifer (470 acres for the Final Vegetation Model and 371 acres for the Final Pilot Vegetation Model). The bulk of the newly mapped mixed conifer is largely due to redefining its southern boundary, and in some cases newly mapped areas in the Spring and Sheep Mountains. By all accounts of numerical accuracy the Final and Final Pilot Vegetation Models did a better job of modeling mixed conifer than RECON (2000).

3.3.4 Pinyon-Juniper

The pinyon-juniper ecosystem is recognized by the dominance of any of several species of typically short (8-10 m tall at maturity) conifers, including pinyon pines (*Pinus monophylla* and

Pinus californiarum) and junipers (*Juniperus californica*, *Juniperus osteosperma*, and *Juniperus scopulorum*).

Beyond general differences in mapping of the pinyon-juniper boundaries there are two main differences between RECON (2000) and our models. First, we did not map pinyon-juniper on Black Mountain except for a small amount in the Final Pilot Vegetation Model. Second, we mapped pinyon-juniper in the Newberry Springs Mountains, which was not mapped in RECON (2000). The addition of mapped pinyon-juniper in the Newberry Springs Mountains is supported by our primary field data. By all accounts of numerical accuracy the Final and Final Pilot Vegetation Models did a better job at modeling pinyon-juniper than RECON (2000).

3.3.5 Sagebrush

Sagebrush communities are present on the landscape only in special edaphic situations such as deep soils in terraces associated with major washes or streams, or in sites formerly occupied by, and currently surrounded by either blackbrush or pinyon-juniper communities in which fire, anthropogenic disturbances (homesteads), and flooding had removed those species and sagebrush was currently dominating the site. Sagebrush communities were typically found as relatively small patches, dominating no more than 100m radius. Sagebrush as an ecosystem zone, does not occupy a significant portion of Clark County. Only in the Sheep Mountains is there a distinct “zone” where the sagebrush ecosystem dominates portions of the landscape. The original MSHCP overestimated the sagebrush ecosystem in Clark County.

There is a significant reduction in the amount of sagebrush between RECON (2000) and our two models. Sagebrush was greatly overestimated in the original GAP map of Nevada, and was significantly reduced in the SWReGAP product (Sajwaj 2004). As a result it was overestimated in RECON (2000). Sagebrush may be overestimated still in the Spring Mountains, but the sagebrush acreage is more realistically represented in our model than in RECON (2000). Nonetheless sagebrush remains a difficult ecosystem to model. The poor producer’s accuracy indicates that the ecosystem is not well mapped. However, the higher user’s accuracy (especially compared to RECON 2000) indicates that much of what is mapped is in fact sagebrush. Although we did not improve on producer’s accuracy, the Final and Final Pilot Vegetation Models significantly improved user’s accuracy for sagebrush over RECON (2000).

3.3.6 Blackbrush

The blackbrush ecosystem is most easily identified by the dominance of blackbrush (*Coleogyne ramosissima*) in the short shrub (0.5 -1.0 m tall) or dwarf shrub (< 0.5 m tall) layer. However, shrublands were classified as blackbrush ecosystem in the absence of blackbrush in situations where it was clear that *Coleogyne* was eliminated by some kind of disturbance, usually a fairly recent fire (<40 yrs previous). In these cases, shrublands were classified as being in the blackbrush ecosystem if they possessed many of the typical blackbrush ecosystem associates, such as *Salazaria mexicana, Fallugia paradoxa, Thamnosma montana*, and *Yucca baccata* and did not possess *Ambrosia dumosa* as an abundant or dominant short or dwarf shrub. Confirmation of this conclusion was usually nearby in such situations, in the form of small or large patches of unburned blackbrush in similar elevation and topographic settings.

We mapped more blackbrush ecosystem than RECON (2000). This can primarily be attributed to areas formally mapped as sagebrush. One area of difference worth mentioning is that we mapped blackbrush through the area of Searchlight, NV connecting the Highland Range on the west to the Eldorado Mountains on the east. This is the rise that separates Eldorado Valley to the north from Piute Valley to the south. Primary field data supports mapping of this area as blackbrush. A related side is that this rise is thought to be a significant enough barrier to desert tortoises to manifest in genetic differentiation between tortoises found in Eldorado Valley versus Piute Valley (Hagerty 2009). Mojave Desert tortoises do not readily occupy blackbrush habitats, namely as a result of their higher elevations and thus colder climates. By all accounts of numerical accuracy, but especially in producer's accuracy, the Final and Final Pilot Vegetation Models did a better job of modeling blackbrush than RECON (2000)

3.3.7 Mojave Desert Scrub

Creosotebush (*Larrea tridentata*) is often the dominant tall shrub in the salt desert scrub, Mojave Desert scrub, and blackbrush zones because of its very broad ecological amplitude. Mojave Desert scrub can be described as the plant community containing dominant *Larrea* without the components of the adjacent ecosystems.

The reduction in Mojave Desert scrub acreage (although percent change is small) between the RECON (2000) and ours can be attributed to increases in modeled blackbrush, development, transfer of land to Nye County, and mesquite/acacia. The difference between the Final and Final Pilot Vegetation Models is attributed to differences in blackbrush. The Final Vegetation Model mapped more blackbrush and less Mojave Desert scrub. The Final and Final Pilot Vegetation Models did not improve on the already very high producer's accuracy for Mojave Desert scrub, but did improve user's accuracy over RECON (2000)

3.3.8 Salt Desert Scrub

The salt desert scrub zonal ecosystem occupies the lowest positions of terminal basins (e.g., Pahrump Valley, Dry Lake Valley, El Dorado Valley, Mesquite Valley), or lowlands along riparian areas (e.g., upper Las Vegas Wash, Corn Creek, Colorado River). It is recognized by the dominance of any of a number of members of Family Chenopodiaceae, notably *Atriplex canescens, Atriplex confertifolia, Atriplex hymenelytra, Atriplex polycarpa*, and/or *Kraschenninikova lanata*). The salt desert scrub zone communities sometimes have an overstory of *Larrea tridentata* (creosotebush).

The difference in total acreage between RECON and the Final and Final Pilot Vegetation Models is minor given the large amount of salt desert scrub in Clark County. There are however significant differences in the distribution of those acres. A number of areas originally mapped as salt desert scrub are all together unmapped as such in our models. This includes little to no salt desert scrub along the blackbrush fringe around the Spring Mountains and in Las Vegas Valley, the southern tip of the McCollough Mountains, the Eldorado Mountains, and the western slopes leading down to the Colorado River. The bulk of the remaining differences between RECON and our two models is in the northwestern portion of the county between the Sheep Mountains on the east and the Spotted Range on the west. We have mapped considerably more salt desert scrub in this region. By all accounts of numerical accuracy the Final and Final Pilot Vegetation Models did a better job of modeling salt desert scrub.

3.3.9 Mesquite/Acacia

Locations with the ecosystem mesquite/acacia contained catclaw (*Acacia greggii*), honey mesquite (*Prosopis glandulosa*) and/or screwbean mesquite (*Prosopis pubescens*). Mesquite/acacia are also found within desert riparian and dune habitats. Mesquite/acacia is a difficult ecosystem to map, as it is azonal and present in many cases within other ecosystems.

We used non-remote sensing methods to map mesquite/acacia; as a result the ecosystem is identical between the Final and Final Pilot Vegetation Models. We significantly increased the amount of mesquite/acacia, almost exclusively by adding acacia. Almost no new mesquite habitat was added. Mesquite/acacia boundaries have been modified and mapped in greater detail and extent in the southern portions of Clark County. Despite this increase in acreage much of the mesquite/Acacia habitat along the Muddy River has been mapped as desert riparian or reduced in extent as a result of more detailed mapping. Some mesquite/acacia was lost to development and the transfer of lands to Nye County.

Mesquite/acacia was most frequently incorrectly mapped as Mojave Desert scrub. Mesquite/acacia is a difficult ecosystem to model, for which the actual presence is not an indication of the ecosystem. It is not surprising that the bulk of the misclassified locations were within Mojave Desert scrub. As previously stated for ecosystems such as mesquite/acacia, and other azonal ecosystems, we recorded the surround ecosystem. For the Final Vegetation Model 37 of the 41 and for the Final Pilot Vegetation Model 40 of the 48 mesquite/acacia field samples modeled as Mojave Desert scrub where in fact surrounded by the Mojave Desert scrub ecosystem. If these were to be removed from the assessment altogether the Final Vegetation Model mesquite/acacia producer’s accuracy would increase from 58% to 81% and the Final Pilot Vegetation Model producer’s accuracy would increase from 52% to 75%. Regardless, this highlights the fact that mesquite/acacia is difficult to find, difficult to map, and even when standing among the species difficult to assign or not to the mesquite/acacia ecosystem.

3.3.10 Desert Riparian

The desert riparian/aquatic ecosystem (RECON 2000) as defined in the MSHCP is indicated only along the Colorado River south of Laughlin, the terminus of the Muddy River where it enters the Overland Arm of Lake Mead, and along much of the Virgin River. This classification does not encompass any other riparian areas including both perennial streams and/or ephemeral washes. Our final models adhere to this definition. However, we provided additional data layers and a recommendation to consider desert and montane perennial and ephemeral riparian classifications if appropriate.

Adhering to the MSHCP intent of desert riparian we mapped more desert riparian than RECON (2000), although in some areas the amount of mapped desert riparian was reduced. Additions include more detailed mapping up into the Muddy River, Meadow Valley Wash, Pahranagat Wash, and Las Vegas Wash and as related to the reduction in the shoreline of Lake Mead. Revision of existing boundaries, resulting in reduction of mapped desert riparian, occurred along the Virgin River. We mapped considerably more disturbed area along the Virgin River and the cities of Mesquite and Laughlin then what was originally mapped as desert riparian.

The RECON (2000) producer’s accuracy was slightly higher than our models, however our models had higher user’s accuracy than RECON (2000), however the differences are nominal given the relatively small sample size for this ecosystem.

3.3.11 Disturbed

RECON (2000) reported in writing 209,600 acres of disturbed land. However, the GIS model did not include disturbed as a category. The 2001landfall GIS coverage includes 204,522 acres of urban land. In December 2011 Clark County reported a total of 63,259.88 new acres of disturbed land (Desert Conservation Program 2011). The difference between the total Clark County calculation based disturbed land of 272,859.88 acres (209,600 + 63,259.88) and what we report (278,042 acres) is 5182.12 acres.

The increase in disturbed land between RECON (2000) and our two models is due to real development (63,260 acres), unaccounted disturbances and differences in mapping. Differences may also be attributed to inaccurate reference data or accounting of urban and agriculture. For example, although RECON (2000) reports 209,600 acres of urban and agriculture, Appendix A, Figure 2-2 of the MSHCP shows virtually no urban area for the City of Mesquite. The land2001fall coverage does identify urban areas for the City of Mesquite.

3.4 Final Recommendations on County Wide Model

In the absence of a real numeric accuracy advantage between our models we recommend the Final Vegetation Model as the model to be used for MSHCP management purposes in Clark County. The following reasons guide our recommendation. First, the Final Vegetation Model is a simpler model, having half the number of input variables compared to the Final Pilot Vegetation Model. Second, texture which is present in the Final Pilot Vegetation Model only, may be contributing to classification problems around the Gold Butte area due to fire. Third, the Final Pilot Vegetation Model predicts pinyon-juniper in the Black Mountains, where they are not present. Fourth, although both models predict a very small amount of sagebrush, the Final Vegetation Model predicts twice as much as the Final Pilot Vegetation Model, although accuracy is no better. In this case, with such a geographically limited ecosystem some over prediction is better than under prediction. The very low user’s accuracy of RECON (2000), however suggest that it was too over predicted. Fifth, the blackbrush community is significantly threatened by fire and the Final Vegetation Model predicts more blackbrush, primarily at the expense of Mojave Desert scrub. This is another case in which you would whether over predict the limited or imperiled habitat.

The importance of geomorphology in controlling the distribution of plants is well documented (Krukeberg 2002), and it was an important classifier in the remote sensing model however it largely did not improve the overall model usefulness or predictability. Geomorphology was a categorical input variable (n = 44) in the model. Many mapped geomorphology units went under sampled, or un-sampled in the case of geographically small units. We would recommend further research into larger mapped units, i.e. reduced bedrock classes, alluvial fans be two or three age classes, alluvial fans by caliche development, etc.

Although texture contributed to the model, it largely did not improve its overall usefulness, or predictability. We included texture in an attempt to discern between different ecosystems via individual shrub density and pattern as detected by their spectral signatures. Individual species vary in size and pattern distribution, creating a community that can be described by cover and spatial pattern. Although mechanistically we may not always understand cover and spatial pattern, they do vary within and between desert plant species. There is an extensive literature on spatial patterns in desert shrubs-for and against mechanistic reasons. Phillips and MacMahon (1981) provide a good overview of the proceeding literature, and since publication has been cited 127 times. We would suggest this publication as a starting point to review spatial patterning in desert vegetation.

Nonetheless, despite ample evidence of geomorphological controls and pattern differences between individual vegetation species neither of these as manifest in our models were able to significantly improve our ability to predict vegetation distribution. Although knowledge and data exist in support of the relationship between geomorphology and vegetation and pattern differences in vegetation, we were unable to implement spatial data in support of these relationships.

4.0 Ivanpah GIS Models

We applied the same methods used for the county-wide models in Ivanpah. We developed six different models that included or excluded one or both of the two geology layers and/or texture.

- Exclude surficial geology and exclude texture
- Exclude surficial geology and include texture
- Include 1:150k surficial geology and exclude texture
- Include 1:150k surficial geology and include texture
- Include 1:50k surficial geology and exclude texture
- Include 1:50k surficial geology and include texture

There are only six ecosystems (not including springs) in Ivanpah Valley: salt desert scrub, Mojave Desert scrub, blackbrush, pinyon-juniper, mixed conifer and mesquite/acacia.

Our expert opinion is that the 1:150,000 geology/including texture is the best model, this is also supported numerically. The two models with no geology overestimated salt desert scrub. The no geology/including texture and 1:50,000 geology/including texture overestimated the extent that blackbrush extended into the valley southeast of the Spring Mountains. The 1:150,000 geology/excluding texture failed to capture the extent of blackbrush between the McCullough and Lucy Grey Mountains. Both models that included 1:50,000 geology overestimated salt desert scrub.

Our overall assessment is that the 1:50,000 geology data did not improve model performance; however this may be due to sampling. We think, as is the case with all of the geology data, that there were many more catagorical data classes than were possible to sample. Texture, although included in the model that we believed performed the best, did not add value to the remaining two models. We believe that the much larger sample size and range of variables included county wide produced a better model in Ivanpah versus the models restricted geographically to just Ivanpah. We would not recommend the use of the any of the Ivanpah models for management purposes.

5.0 Joshua Tree GIS Model

We used stepwise logistic regression to develop a county wide Joshua tree model using an extensive presence/absence data set (Figure 10). There was significant over prediction of Joshua tree in the area between Las Vegas and the Virgin Mountains and southern portions of the County. The addition of latitude and longitude into the model did not improve model performance so we manually removed Joshua tree from these areas. Our model both expands and contracts areas predicted to contain Joshua tree (Little 1976, Cole et al. 2003, Cole et al. 2011). Cole et al. (2011) improved on Cole et al. (2003) which was an improvement on Little (1976); however we believe that both Cole et al. (2003, 2011) models are too limiting in their distribution. There are areas that clearly contain Joshua tree as indicated by our presence data. We believe our model, though liberal in predicting habitat in some areas, is more likely to identify areas containing Joshua tree, without being so inclusive as to suggest that the entire county contains Joshua tree (Ingram 2008).

Although we believe we have produced a good predictive model of Joshua tree in Clark County we recommend more work on development of mechanics models. Climate change is a significant threat to the Joshua tree (Cole 2011). Although climatic conditions are predicted to be suitable in large areas the natural history and dispersal capabilities of Joshua tree may limit their expansion into these areas. The transition from predictive to mechanistic models are required in order to implement successful management actions to mitigate against the potential impacts of climate change.

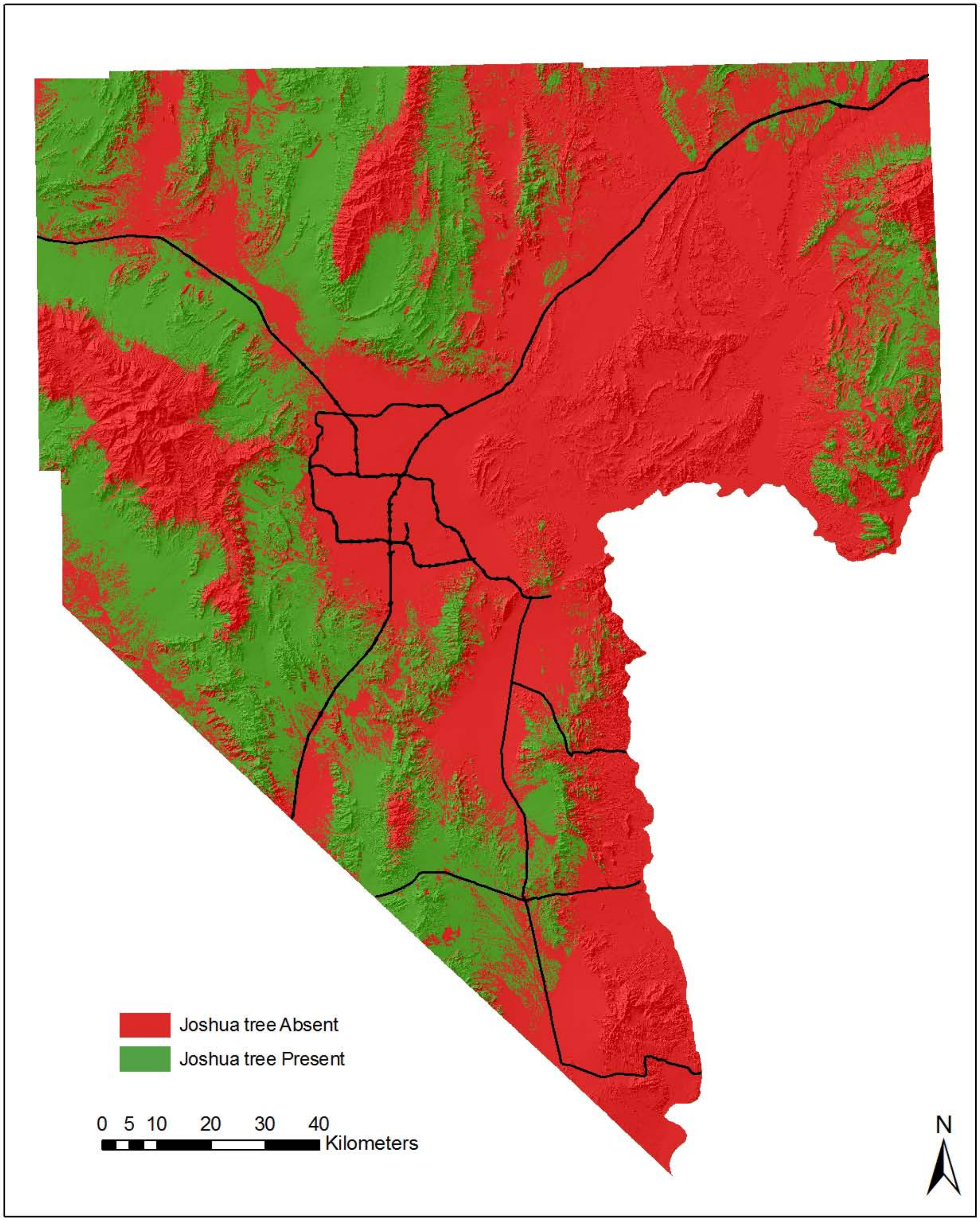

Figure 10. Final county wide Joshua Tree Model.

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