Galveston and Lavaca Watershed Multi-year Land Use and Land Cover Classifications and Curve Numbers

by

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Introduction

The way land is being used along the Texas coast has changed significantly in the past two decades. This project aims to determine where change has taken place and what land use/landcover it has changed to. Another objective of this project is to combine the classification data with soil data to generate curve numbers to determine the amount of runoff for the watersheds.

Methods

The first step in creating the Anderson Level I classification was securing images that covered the required area during the given time periods. The National Aeronautics and Space Administration's (NASA) satellite, LandSat Thematic Mapper (TM) images on the United States Geological Survey (USGS) website's Global Visualization Viewer (GLOVIS) met these requirements. The area being studied required five LandSat TM scenes. The path/row for the scenes being used are 24/39, 25/39, 25/40, 26/39, and 26/40. Having two time periods to classify this required ten LandSat TM scenes, five scenes with two images per path/row. The dates for each scene are in the table below.

Path	Row	Early Date	Late Date
24	39	03/10/1998	04/27/2004
25	39	03/17/1998	05/04/2004
25	40	03/17/1998	05/04/2004
26	39	04/09/1998	04/09/2004
26	40	04/09/1998	04/09/2004

Figure 1

Because some of images were along the same path with the same acquisition date, they were sent as one image (i.e. 25/39 and 25/40 were received as one image containing both rows 39 and 40). The total number of datasets received was 6, three for each year. This was beneficial, in that it reduced the amount of mosaicking and clipping of images.

For the purposes of this project, only an Anderson Level I classification was needed. An Anderson Level I classification consists of generalized classes, including: 1) Urban, 2) Agriculture, 3) Rangeland, 4) Forest, 5) Water, 6) Wetland, 7) Barren Land, 8) Tundra, and 9) Perennial Snow or Ice. An Anderson Level II classification would break these generalized classes down to more specific ones, having the Urban class split into: 1) Residential, 2) Commercial and Services, 3) Industrial, 4) Transportation, Communications, and Utilities, 5) Industrial and Commercial Complexes, 6) Mixed Urban or Built-up Land, and 7) Other Urban or Built-up Land classes. This project only required the use of the first seven Anderson Level I classes because Tundra and Perennial Snow or Ice do not exist in the study area. The National Land Cover Data (NLCD) 1992 and NLCD 2001 are more in depth, analogous to an Anderson Level II classification, necessitating consolidation of some classes. Using Leica Geosytem's image processing software, ERDAS Imagine, NLCD 1992 and NLCD 2001 were recoded to fit the parameters of an Anderson Level 1 classification. The classes being used are Agriculture, Barren Land, Forest, Rangeland, Urban, Water, and Wetland. Below are the class structures for NLCD 1992 and NLCD 2001 along with the class its Anderson Level I classification used in this study.

Class Number	1992 NLCD	2001 NLCD	Anderson Classification
11	Open Water	Open Water	5) Water
12	Perennial Ice/Snow	Perennial Ice/Snow	Not Needed
21	Low Intesity Residential	Developed, Open Space	1) Urban
22	Heavy Intensity Residential	Developed, Low Intensity	1) Urban
23	Commercial/Industrial/Transportation	Developed, Medium Intensity	1) Urban
24	N/A	Developed, High Intensity	1) Urban
31	Bare Rock/Sand/Clay	Barren Land (Rock/Sand/Clay)	7) Barren Land
32	Quarries/Strip Mines/Gravel Pits	Unconsolidated Shore	7) Barren Land
33	Transitional	N/A	7) Barren Land
41	Deciduous Forest	Deciduous Forest	4) Forest
42	Evergreen Forest	Evergreen Forest	4) Forest
43	Mixed Forest	Mixed Forest	4) Forest
51	Shrubland	Dwarf Scrub	3) Rangeland
52	N/A	Shrub/Scrub	3) Rangeland
61	Orchards/Vineyards/Other	N/A	2) Agriculture
71	Grasslands/Herbaceous	Grasslands/Herbaceous	3) Rangeland
72	N/A	Sedge/Herbaceous	3) Rangeland
73	N/A	Lichens	3) Rangeland
74	N/A	Moss	3) Rangeland
81	Pasture/Hay	Pasture/Hay	2) Agriculture
82	Row Crops	Cultivated Crops	2) Agriculture
83	Small Grains	N/A	2) Agriculture
84	Fallow	N/A	2) Agriculture
85	Urban/Recreational Grasses	N/A	1) Urban
90	N/A	Woody Wetlands	6) Wetland
91	Woody Wetlands	Palustrine Forested Wetland	6) Wetland
92	Emergent Herbaceous Wetlands	Palustrine Scrub/Shrub Wetland	6) Wetland
93	N/A	Estuarine Forested Wetland	6) Wetland
94	N/A	Estuarine Scrub/Shrub Wetland	6) Wetland
95	N/A	Emergent Herbaceous Wetlands	6) Wetland
96	N/A	Palustrine Emergent Wetland	6) Wetland
97	N/A	Estuarine Emergent Wetland	6) Wetland
98	N/A	Palustrine Aquatic Bed	6) Wetland
99	N/A	Estuarine Aquatic Bed	6) Wetland

Figure 2. Sources: 1992 NLCD: http://landcover.usgs.gov/classes.php
2001 NLCD: http://www.mrlc.gov/nlcd_definitions.asp

To have a baseline of locations of the Land Use/Land Cover classes, a new dataset was created from the recoded NLCD 1992 and NLCD 2001. Using the modeler in Leica Geosystem's ERDAS Imagine 9.1, pixels that had the same class value kept their classification and pixels that did not have the same class value were masked out to 0. The resulting image will be referred to as the "Combined NLCD" image.

Because the Galveston watershed spread over one image, it was necessary to align all of the scenes. Even though all the images were in the same projection, Universal Transverse Mercator (UTM) World Geodetic System 1984 (WGS84) Zone 15 North, they did not match up perfectly. To align the images a Texas transportation vector file was brought in. First, the transportation file was overlaid on the 25/39 and 40 images for both 1998 and 2004. The 2004 image was aligned with the transportation file, but the 1998 image was a little off so it was manually moved by adjusting the upper left X and Y using ERDAS. Once both center images corresponded with each other and the transportation data, it was time to adjust the other images and the Combined NLCD. Each was done in the same manner as the 25/39 and 40 image for 1998. When all the adjusting was done, the images were aligned with both the other images of the same year and the corresponding image of the other year.

Using ERDAS, the watersheds were overlaid onto the LandSat TM scenes and Areas of Interest (AOI) around the area of the watershed and included a significant buffer within the scene. The images were clipped to the size of the AOI for Galveston and Lavaca Bay areas. Four clipped images were made from this process. One clip was made for Lavaca Bay and 3 for Galveston Bay. The Galveston watershed was too large for one scene so multiple clips were made. About 80% of the Galveston watershed was included in path 25 with the rest falling in path(s) 24 and 26. The Combined NLCD and Digital Elevation Models (DEM) were also clipped to the same AOI as well.

After clipping the Combined NLCD images, a set of random points were generated using ERDAS Imagine 9.0. Two sets of points were created according to the Combined NLCD for Lavaca and the major Galveston subset, one for calibration and one for validation, with the same parameters. Equalized random sampling, with a requirement of a threshold of 9 pixels of a 3x3 window must belong to the same class, was used for all scenes. Each class received 10 points, except the “Barren Land” class because of its miniscule area, giving a total of 60 points per dataset. The “Barren Land” class was still included in the classification but not in the accuracy assessment. For Galveston, the “Rangeland” points were not generated according to the Combined NLCD. There was minimal Rangeland in the Combined NLCD image, so both the NLCD 1992 and NLCD 2001 were looked at individually to determine the amount of Rangeland present in the Galveston watershed. For NLCD 1992, only 1% of all pixels were classified as Rangeland, but for NLCD 2001, almost 6% of pixels were classified as Rangeland. Therefore, Rangeland points were created using NLCD 2001, using the same threshold as before.

After the list of points was generated, they were put into an Excel worksheet and converted to a .dbf file to bring them into ArcView GIS 3.3 to convert them to a shapefile. The points were overlaid on the Combined NLCD and the corresponding watershed images in ArcView. Each point was inspected individually to make sure it matched the class it was given in the Combined NLCD and then to make sure the points matched in both images. If the point did match the land cover in both images, was on the edge of land cover, or was hard to say what the land cover was; the point was manually moved to an easily identifiable, large area of contiguous land cover that also registered on the Combined NLCD location. For the Galveston watershed, the Rangeland points were done the same way except NLCD 2001 was used instead of the Combined NLCD dataset. Each watershed had the same set of points between years. With Galveston spread across three scenes, about 85% in one scene and 5-10% in each of the others, only the image that contained 85% of the watershed had points generated for it. This was done because there were not enough samples of the classes to create an accuracy report for the two small portions of the Galveston watershed.

To perform the classification, Definien's eCognition was used. eCognition is an object oriented classification algorithm. An object-oriented classification algorithm first creates clusters of homogenous pixels through segmentation and then a supervised classification can be performed on the segmented image. eCognition allows the use of many different types of data to be used to create a classification. The layers used included all 7 bands of the LandSat TM image, DEM, and NDVI derived from the LandSat TM image. Segmentation takes several factors into account: how much weight each layer has, scale parameter, color vs. shape, and compactness vs. smoothness. Layer weight determines how important each layer is in the segmentation process. Scale parameter is a variable that determines the size of the cluster; larger scale parameters create larger clusters. The color vs. shape variable is a scale the either puts more emphasis on the color (pixel value) or shape of the object (which is related to the next variable). Compactness vs. smoothness is the last variable, and is a sliding scale, like the color vs. shape variable. Compactness is a function of area to perimeter, with a more compact area having a higher area to perimeter ratio. Smoothness describes the similarity of the object to a square. The parameters used for the segmentation of all images in this project are provided below:

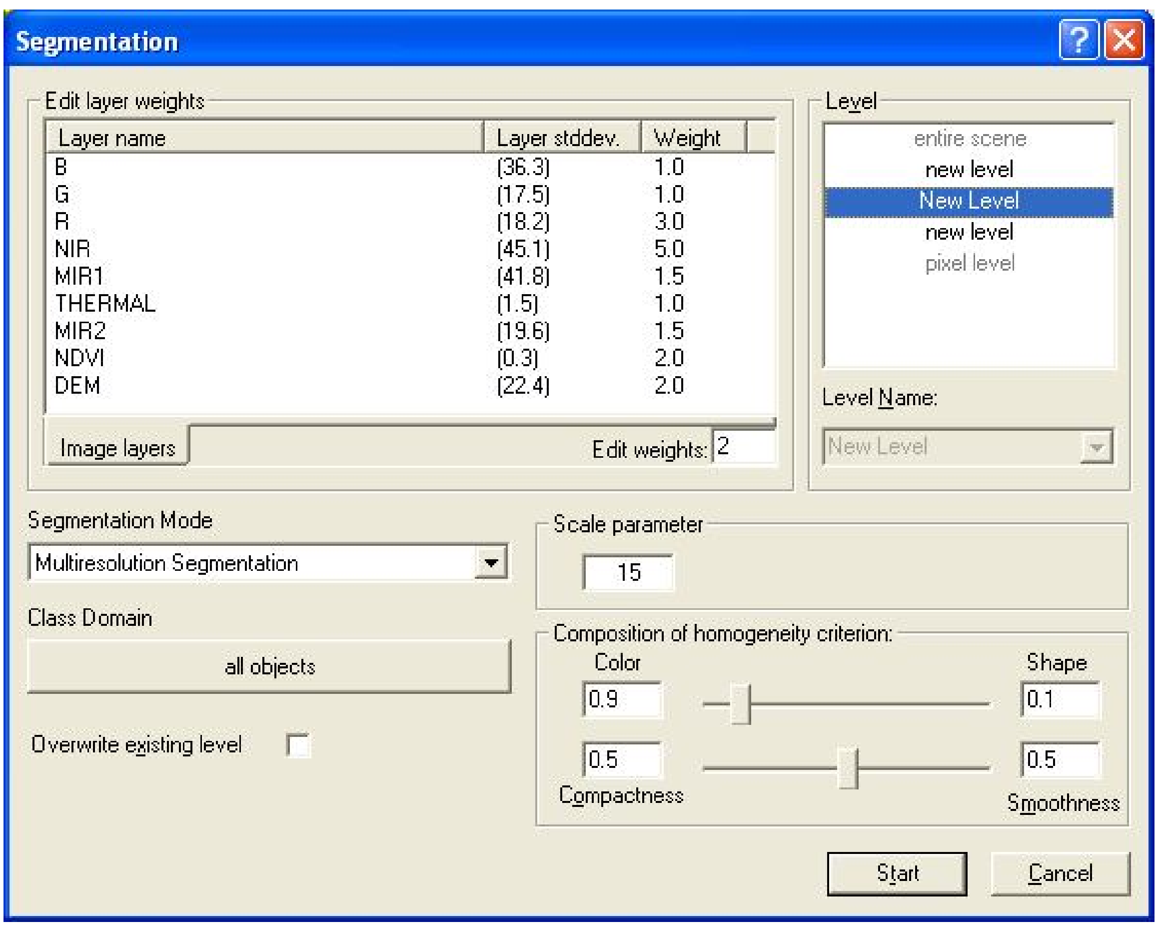


Figure 3. Segmentation dialogue in Definien's eCognition

These parameters were chosen by trial and error. The composition of homogeneity criterion is the default setting, while the scale parameter was increased from 10 to 15. A scale parameter of 10 increased the number of objects significantly, almost to the point of being the same as a pixel-based classification. Scale parameters greater than 15 tended to be too large and contained pixels of different classes in one object. Using a scale parameter of 15 provided a large enough object to be more than just a pixel-based classification while keeping the homogenous integrity of the object. Layers with greater variance were given greater weight.

To choose the training areas from the clusters created during segmentation, the Combined NLCD was overlaid on the corresponding image being classified and viewed in ERDAS. Objects were selected from areas that appeared in the Combined NLCD. After an adequate amount of training areas had been selected, a classification was performed. The accuracy assessment was done by exporting the classified image to ERDAS and using the accuracy assessment tool with the validation points created.

After classification, Galveston's three parts needed to be mosaicked. The large portion of Galveston was used as the reference and was used in the areas of overlap between images because it had the accuracy assessment performed on it. When doing the classification, residential areas were extremely difficult to separate from the Agriculture, Forest, and Rangeland classes because of the vegetation. To keep the Urban class consistent, some post classification processing was performed. The first step was to remove any unwanted Urban classifications from the 1998 image. To do this, the 1998 image was compared to the 2001 NLCD image. When a pixel was classified as Urban in 1998 but not in 2001 it was changed to the 2001 classification. This process removed spurious Urban pixels. Next, the Urban class for the 1992 NLCD image and 1998 classified image with spurious Urban areas removed were merged to create a 1998 image that contained all of the Urban from 1992, no Urban that was not Urban in 2001, and the Urban areas that had developed since 1992. The resulting image, "1998_urban_merged", was used as the 1998 image. The Urban class from the newly created 1998 classification was then merged to the 2001 NLCD, with the resulting Urban class being merged with the 2004 classification. This made sure that anything that was classified as Urban in the previous classification was classified as Urban in the latter classification.

Soil data were downloaded from http://soildatamart.nrcs.usda.gov/ and then queried for the top layer of soil. The table below lists the curve numbers for each soil type (A, B, C, or D) for its corresponding land cover/ land use class.

	A	B	C	D
Urban	61	75	83	87
Agriculture	64	75	82	85
Rangeland	39	61	74	80
Forest	30	55	70	77
Water	98	98	98	98
Wetland	98	98	98	98
Barren	77	85	90	92

source:
http://www.ecn.purdue.edu/runoff/documentation/scs.htm
TR-55 model curve number

Figure 4

The curve numbers for the Water and Wetland classes were provided by Texas Water Development Board (TWDB). Once the curve numbers to be used were known, the classified images were combined with the soils data to generate a new image that used the curve numbers as the pixel values. The soil types are classified according to their drainage potential. Group A soils are deep and absorb water well, are well drained and composed of sand or gravel, therefore having lower curve numbers. Group D soils are at the other end of the continuum and do not absorb water well leading to higher curve numbers. They are thin layers of soil above bedrock or have a high percentage of clay near the surface.

Results

Several outputs were generated by this study: classifications, change detections, curve numbers, and statistics for each classification and change detection. First, accuracy assessments were needed for the classifications. Using eCognition with the parameters above the following accuracies were obtained and found to be adequate for this study:

Watershed	1998	2004
Lavaca Accuracy	88.33%	90.00%
Lavaca Kappa	0.8605	0.8800
Galveston Accuracy	91.67%	86.67%
Galveston Kappa	0.9000	0.8400

Figure 5

These accuracies were calculated using the validation points created earlier. Each point created was identified in the classified image and counted correct if it matched the validation point and incorrect if it did not correspond with the class given by the validation point. The Kappa is a statistic that quantifies agreement.

These classifications resulted in the following landcover percentages for the two Spatial Sciences Lab created classifications (1998 and 2004) and two NLCD classifications (1992 and 2001). (See appendix for larger charts and corresponding tables).

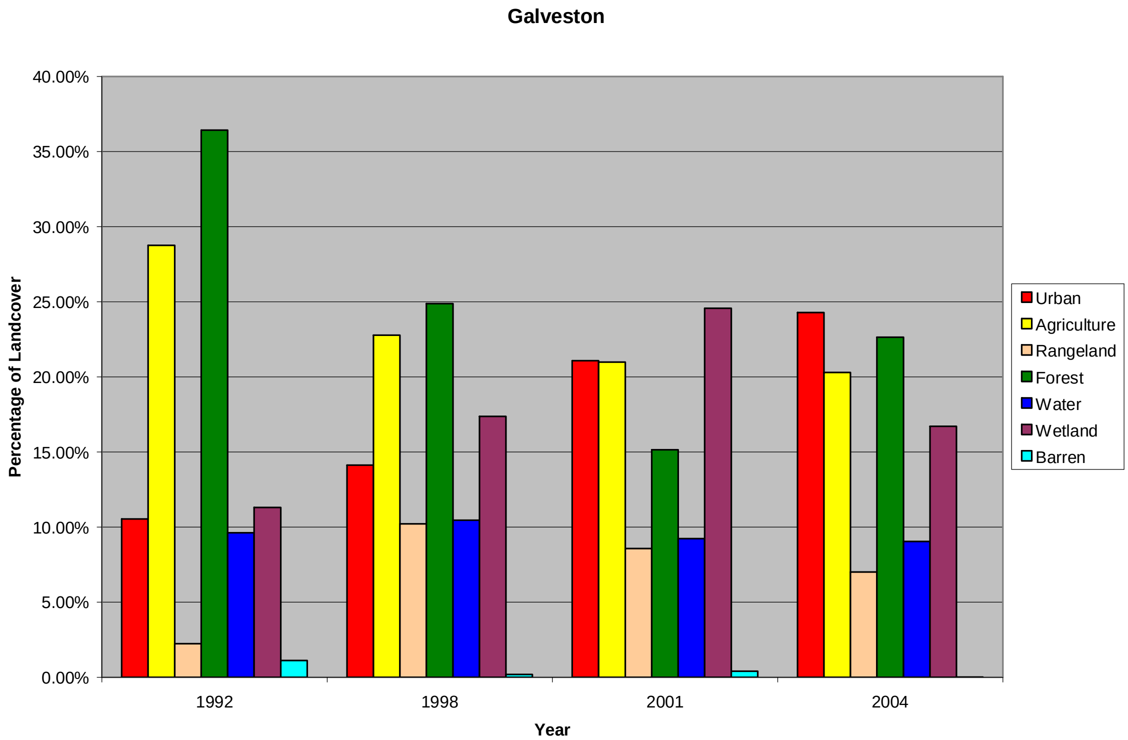


Figure 6

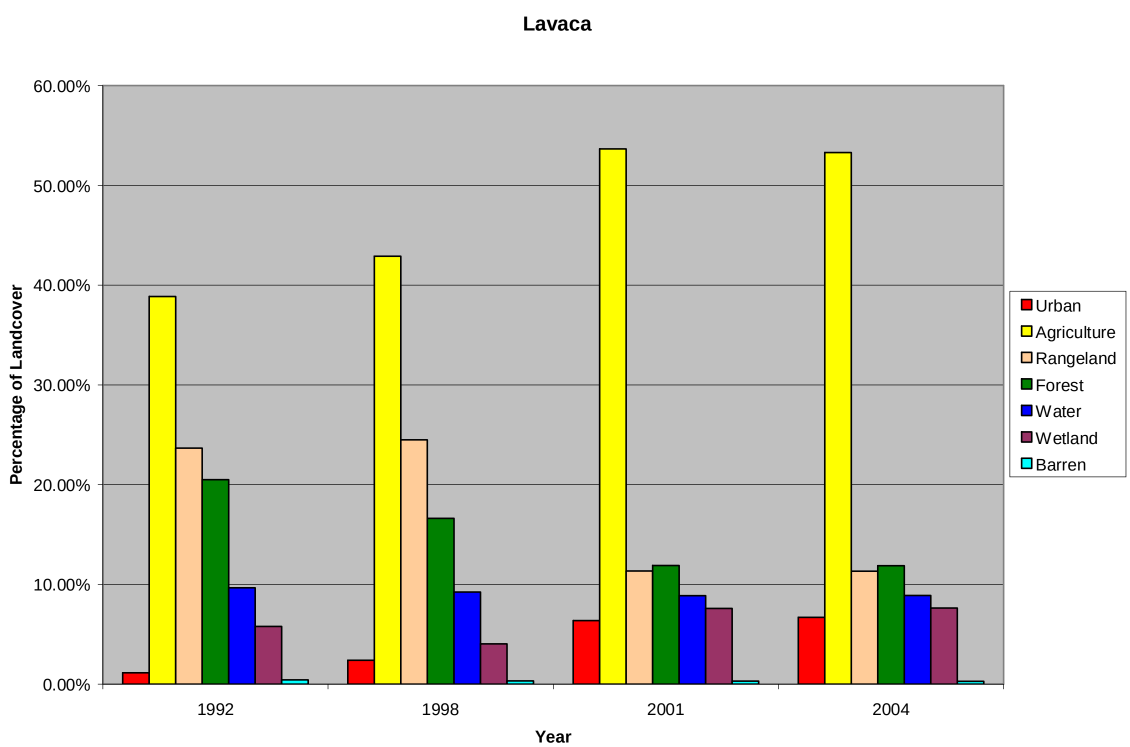


Figure 7

Galveston has a dramatic increase in Urban areas with a large reduction in Forest areas. Lavaca also has an increase in Urban areas, but it is not as noticeable as in Galveston. Lavaca's noticeable change is the increase in Agriculture areas, coming from a decrease in Rangeland and Forest landcover classes.

The last step was creating curve number maps. Using the curve number table referred to earlier, the classifications were recoded to represent the curve number for the land use/landcover class and soil type. Maps for the classifications, curve number maps, and change statistics tables are attached in the appendix. The change statistics tend to have a trend in that for Galveston, the largest change between classes is consistently between Forest and Wetland; and for Lavaca, Rangeland and Agriculture consistently have the largest percentage of change between the two classes. This may be because these were the classes, for their respective watersheds, that were the hardest to separate in the classification. It may be difficult to understand the change statistics charts. To read them, the full bar is the early classification and the segments of that bar are what the previous classification changed to. For example, in the chart below (Figure 9), the full bar would represent the percentage of the 1992 classification that was Agriculture and each segment inside that bar represents the class the pixels were classified as in the 1998 image and their percentage. Looking at the Agriculture bar, in 1992 about 28% of the image was classified as Agriculture. Of those 28% of the image, 3% changed to Urban, 15% stayed Agriculture, 4% changed to Rangeland, 3% changed to Forest, and 3% changed to Wetland in 1998.

Galveston Landcover Change 1992-1998

	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	10.54%	2.32%	0.18%	0.88%	0.02%	0.11%	0.07%
Agriculture	0.00%	15.29%	0.80%	4.69%	0.18%	1.63%	0.17%
Rangeland	0.00%	4.46%	0.26%	4.57%	0.04%	0.67%	0.22%
Forest	0.00%	2.65%	0.06%	20.31%	0.10%	1.31%	0.45%
Water	0.00%	0.34%	0.06%	0.19%	8.70%	1.14%	0.02%
Wetland	0.00%	3.62%	0.88%	5.74%	0.54%	6.42%	0.16%
Barren	0.00%	0.07%	0.01%	0.04%	0.03%	0.02%	0.02%

Figure 8

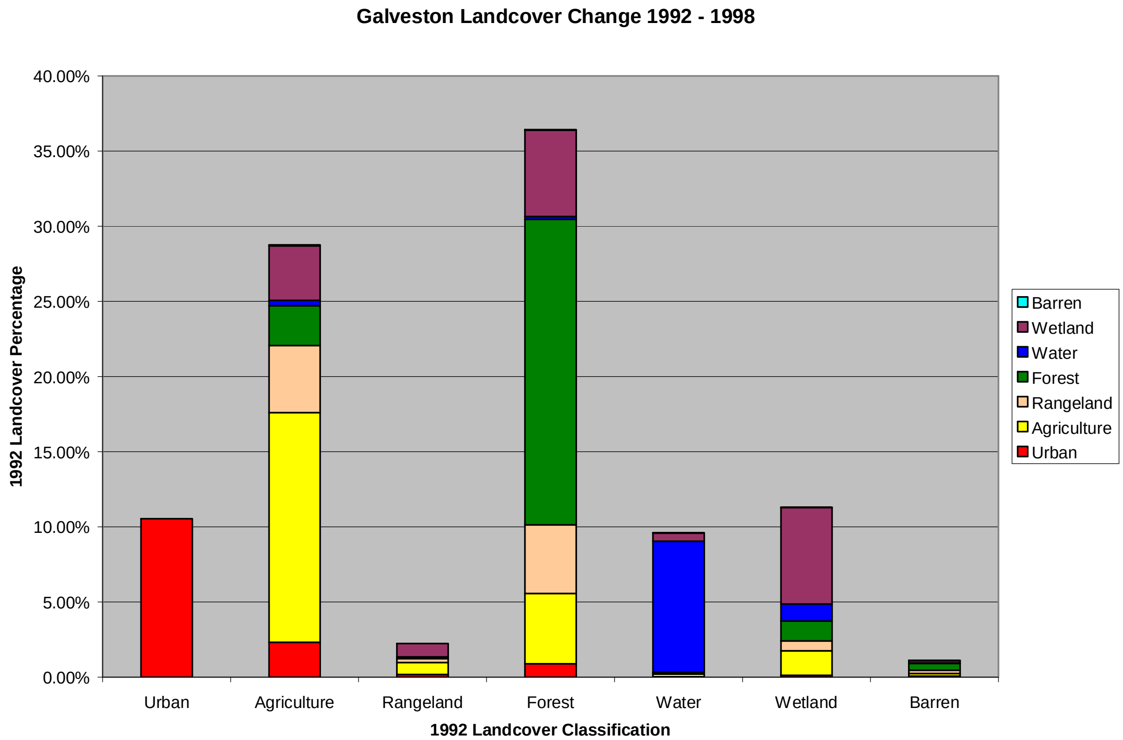


Figure 9

<u>Conclusion</u>

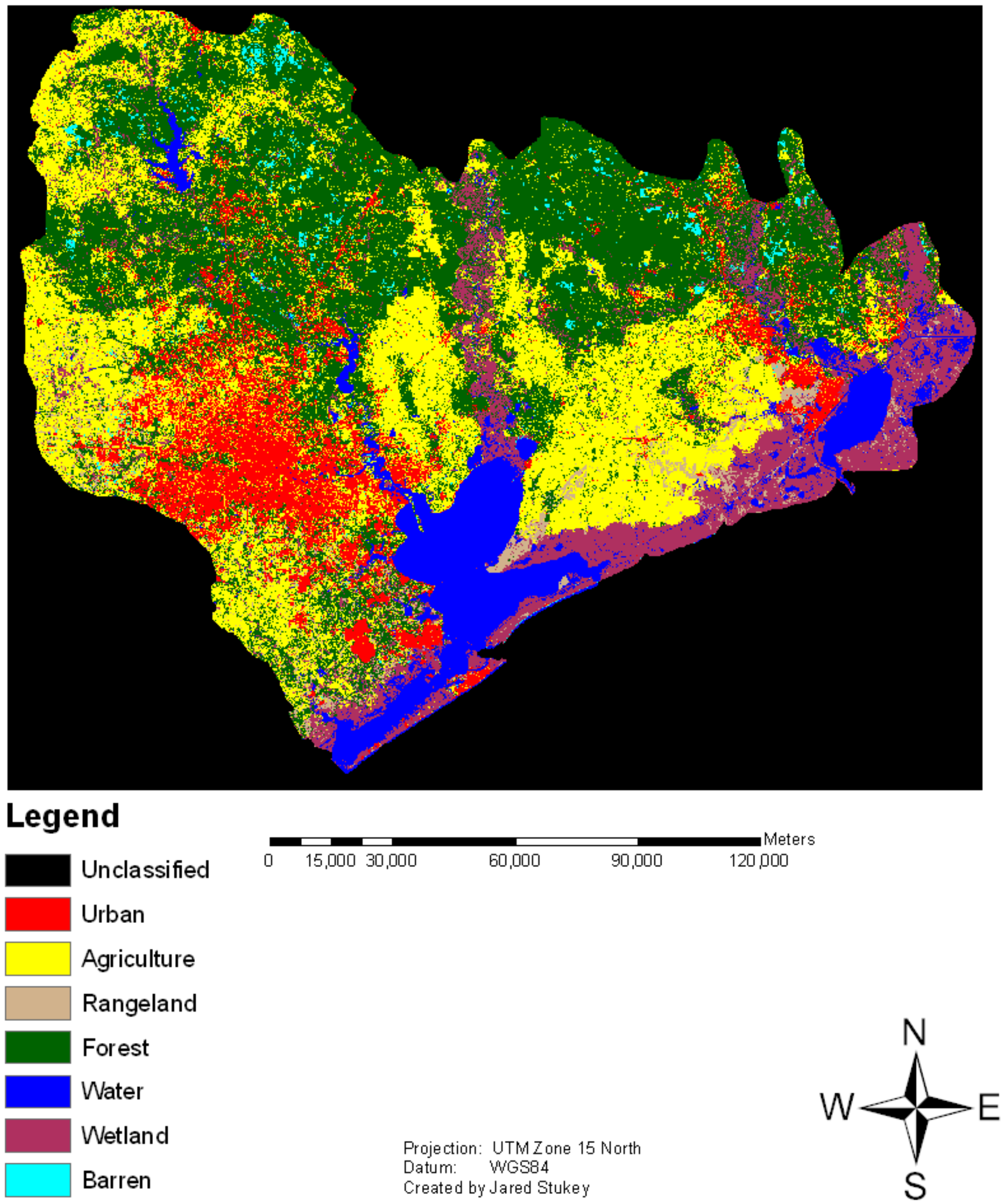
There is significant land use and land cover change throughout the study period. Urban sprawl is evident by looking at the maps and statistics for each classification. Agriculture is also growing, while Forest, Rangeland, and Wetland areas are shrinking.

One difficulty of this project was the NLCD classifications. The 2001 NLCD, specifically, tended to over represent Agriculture in the Lavaca watershed while under representing Forest areas. It also over represented Wetland areas in the Galveston watershed, and again under represented Forest areas. This may account for changes in classes between 1998 and 2001, and 2001 and 2004.

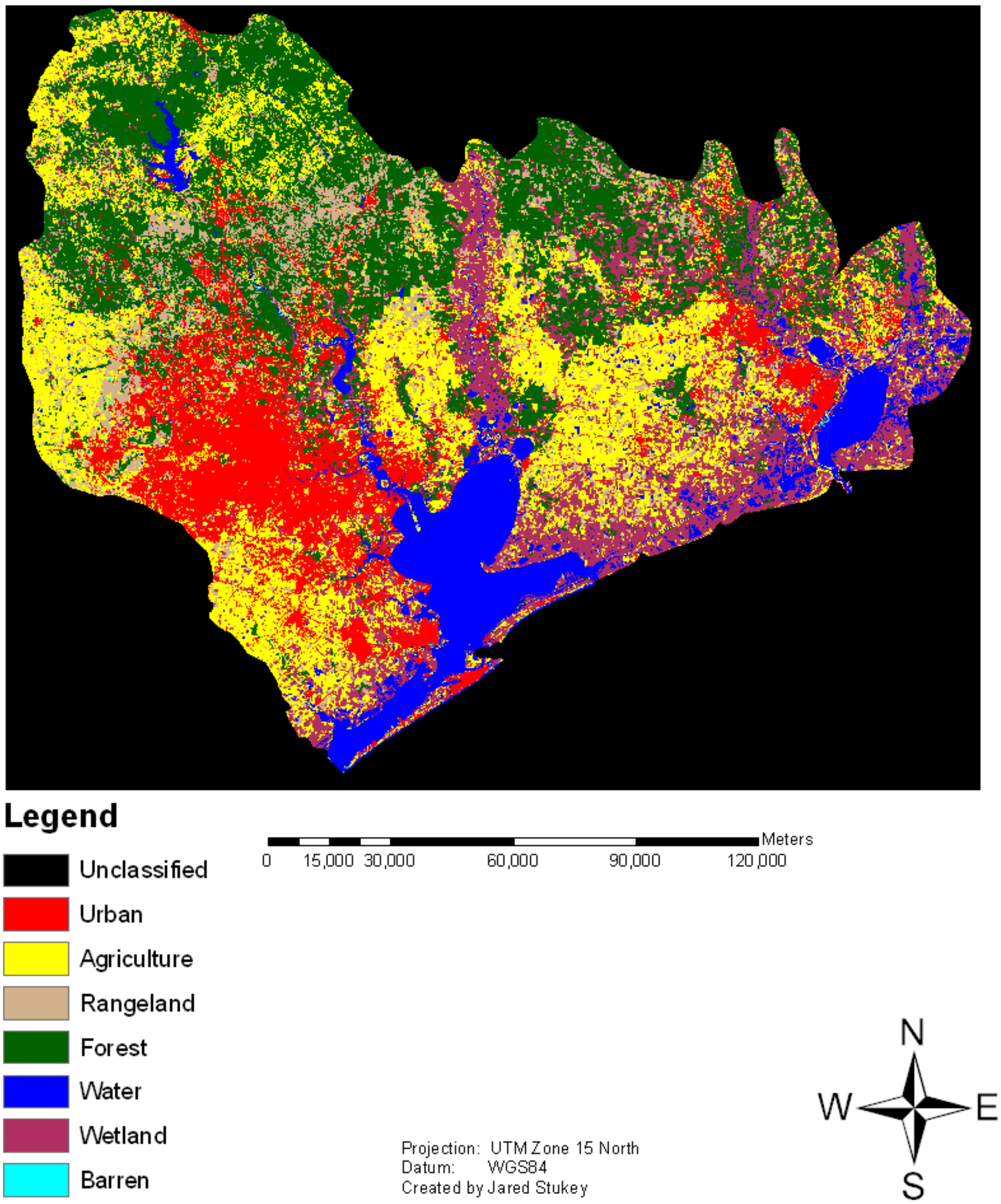
The 1992 and 2001 NLCD were created differently and had different classes, as shown in Figure 2, were. The use of the different class scheme may have led to more being classified as one class than they should have been. This is most evident in the 2001 Galveston classification. The Wetland class dominates the Forest class. This could be due to the multiple classes for Wetlands used in the 2001 NLCD. This could also explain shrinking of the Forest class in the 2001 Lavaca NLCD. With the Wetlands class expanding its scope, what can be classified as Forest is reduced. This is especially true for woody wetlands.

Appendix

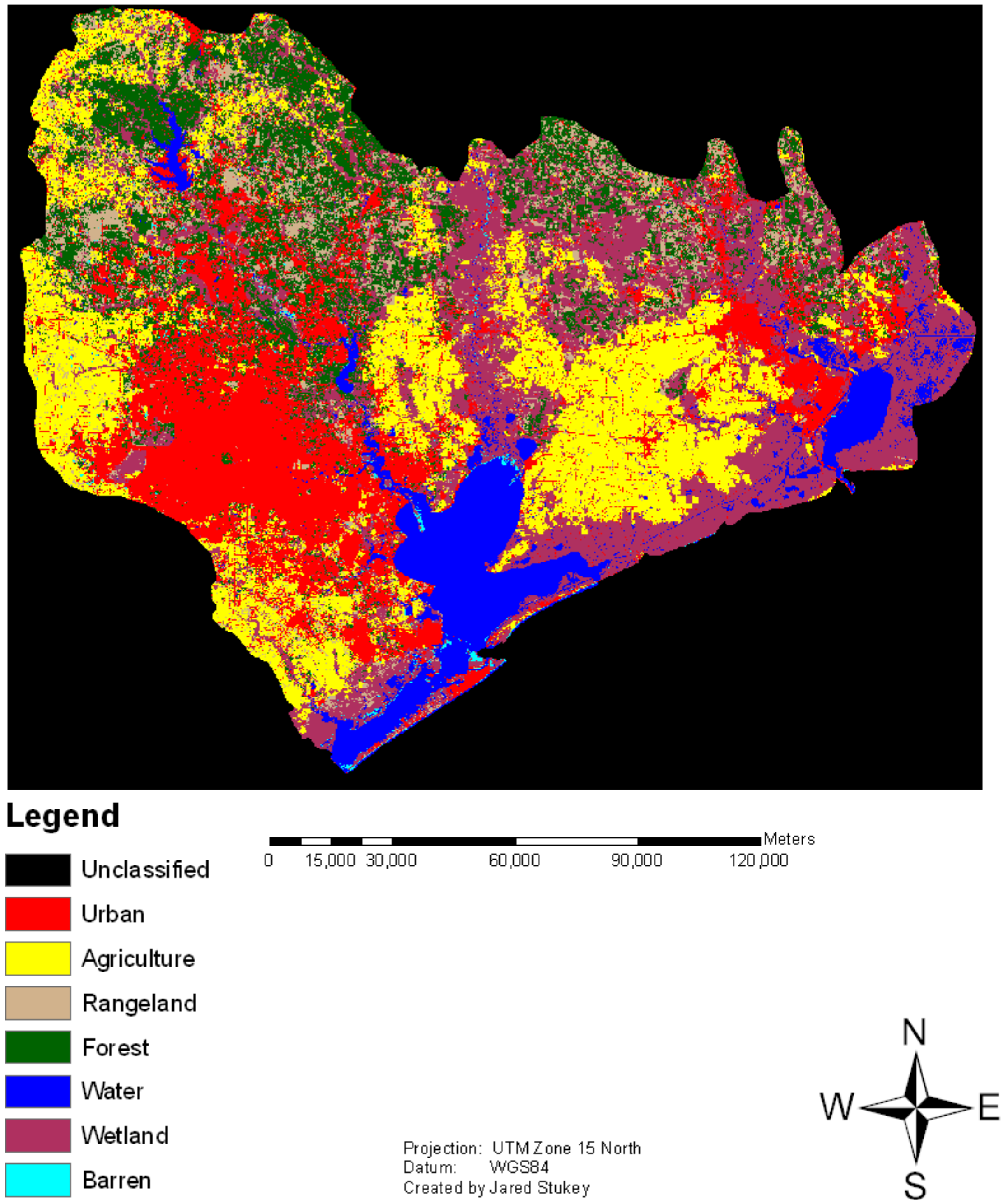
1992 Galveston Land Use/Landcover



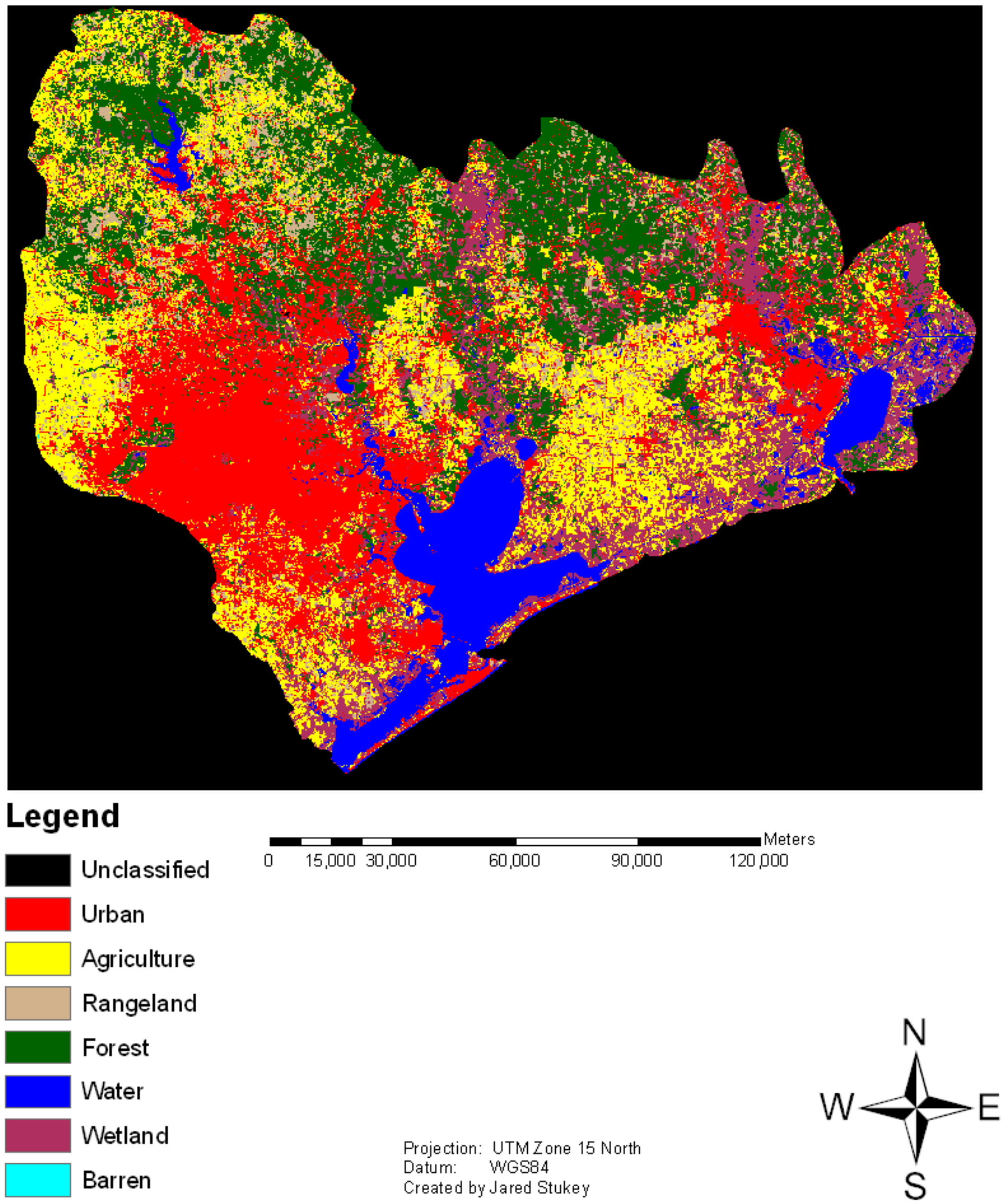
1998 Galveston Land Use/Landcover

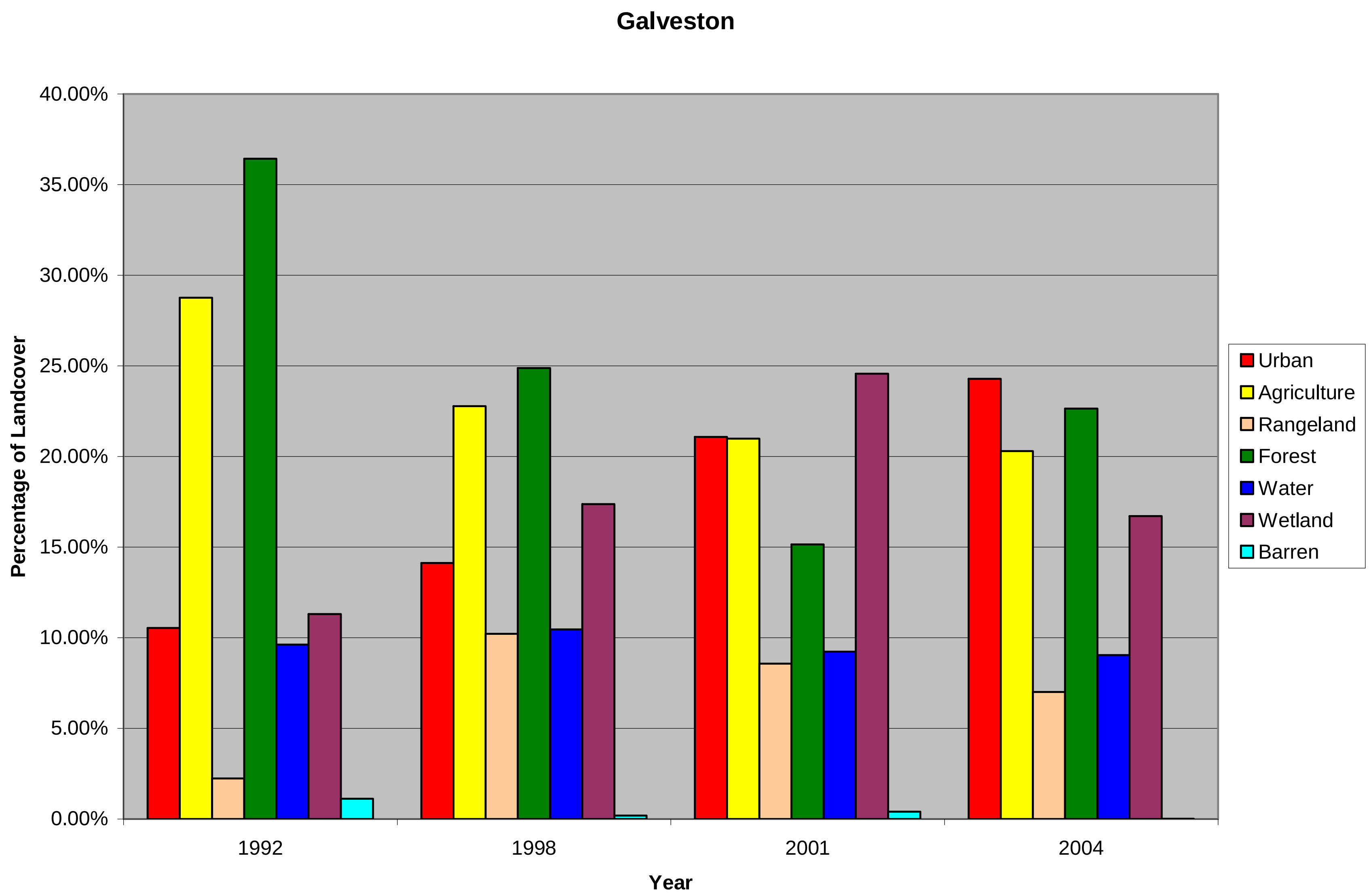


2001 Galveston Land Use/Landcover



2004 Galveston Land Use/Landcover




Galveston
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Percentage of Landcover
1992
1998
2001
2004
Year
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren

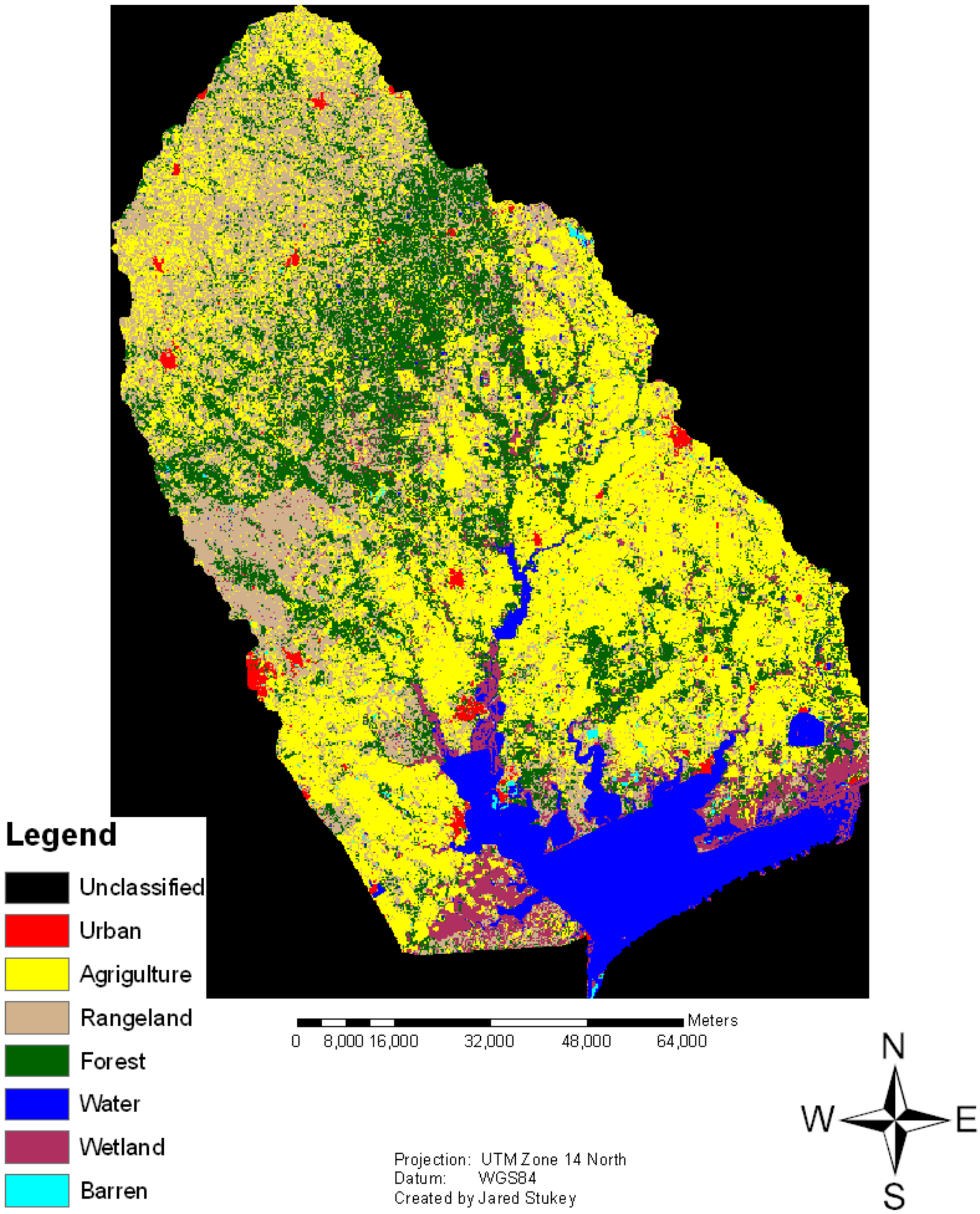
Galveston Classification Statistics

Class	1992	1998	2001	2004
Urban	10.54%	14.12%	21.08%	24.29%
Agriculture	28.76%	22.78%	20.99%	20.29%
Rangeland	2.24%	10.21%	8.58%	7.01%
Forest	36.42%	24.88%	15.15%	22.64%
Water	9.62%	10.45%	9.23%	9.05%
Wetland	11.31%	17.37%	24.57%	16.71%
Barren	1.12%	0.19%	0.41%	0.02%

Lavaca Classification Statistics

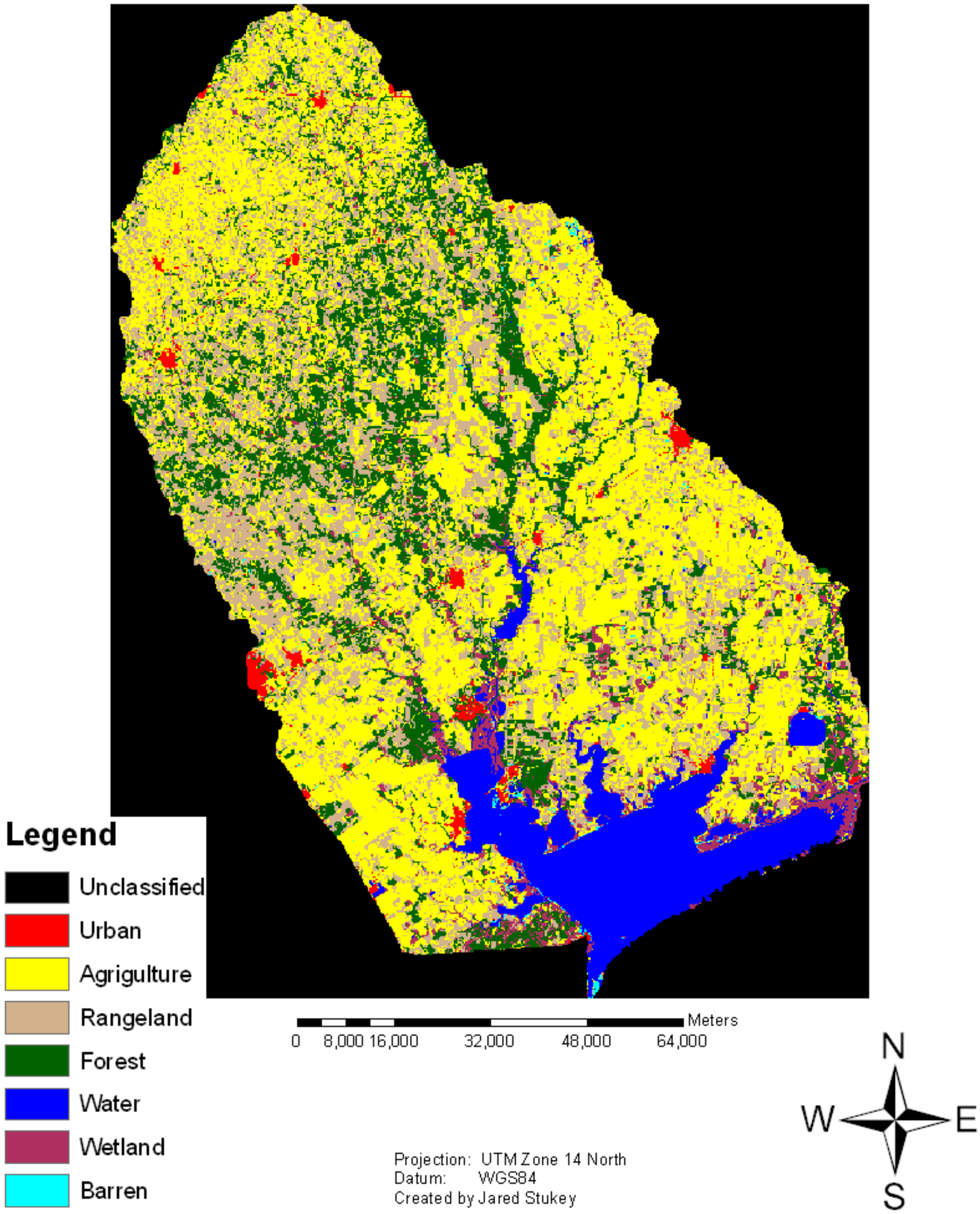
Class	1992	1998	2001	2004
Urban	1.13%	2.40%	6.37%	6.84%
Agriculture	38.86%	42.89%	53.64%	41.20%
Rangeland	23.65%	24.49%	11.34%	17.85%
Forest	20.50%	16.61%	11.90%	19.77%
Water	9.65%	9.23%	8.87%	9.36%
Wetland	5.78%	4.05%	7.59%	4.84%
Barren	0.42%	0.33%	0.31%	0.14%

1992 Lavaca Land Use/Landcover

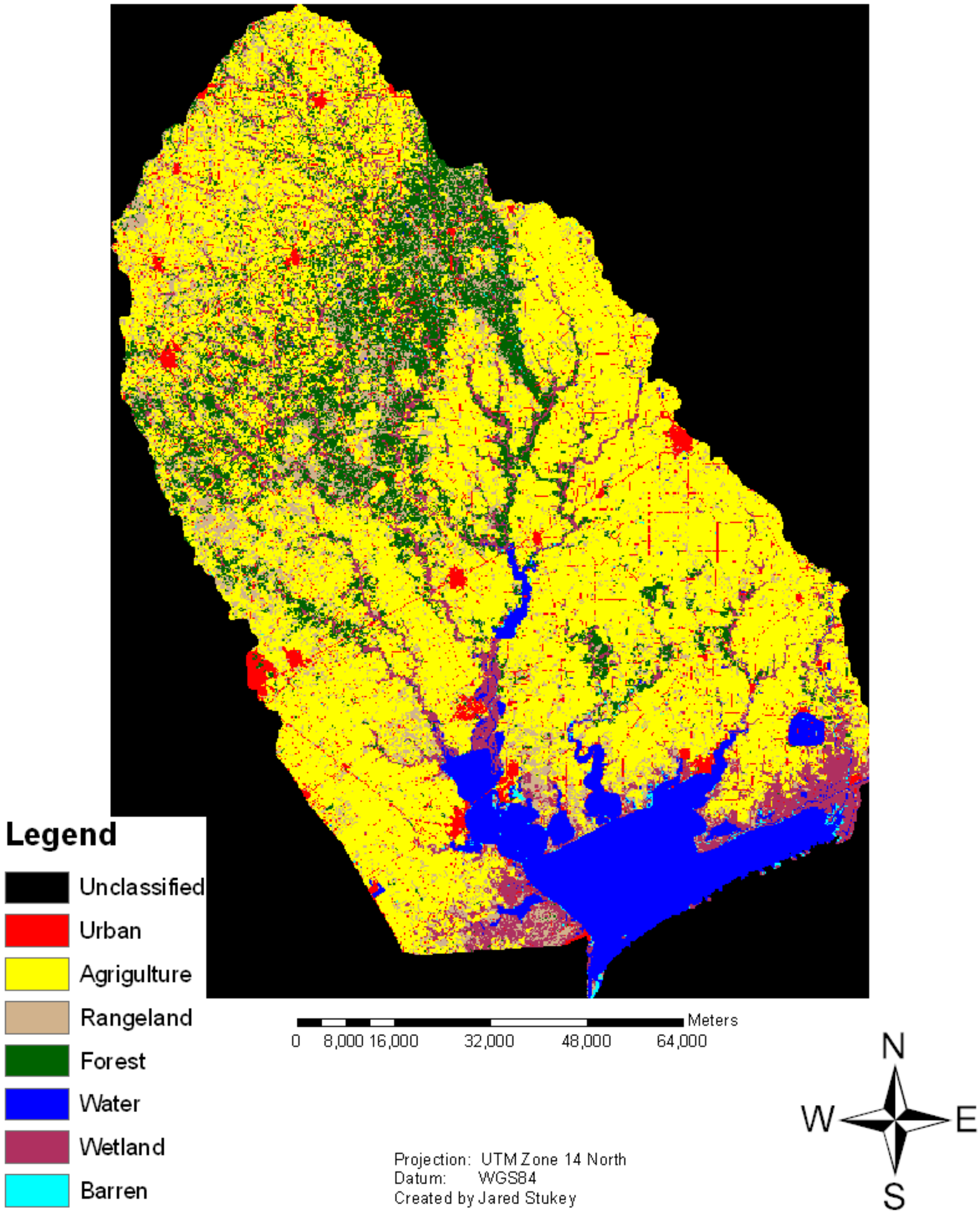


Projection: UTM Zone 14 North
Datum: WGS84
Created by Jared Stukey

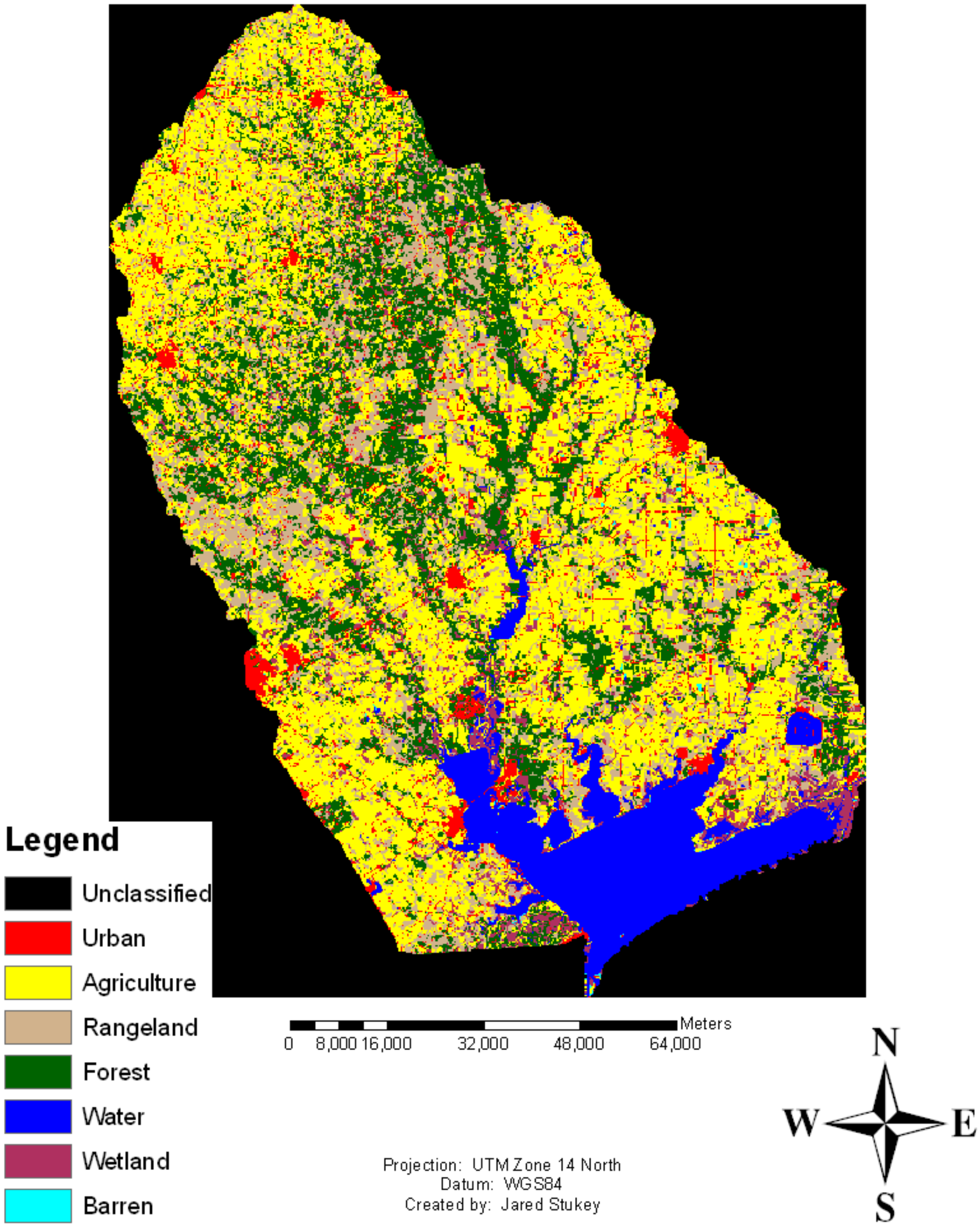
1998 Lavaca Land Use/Landcover

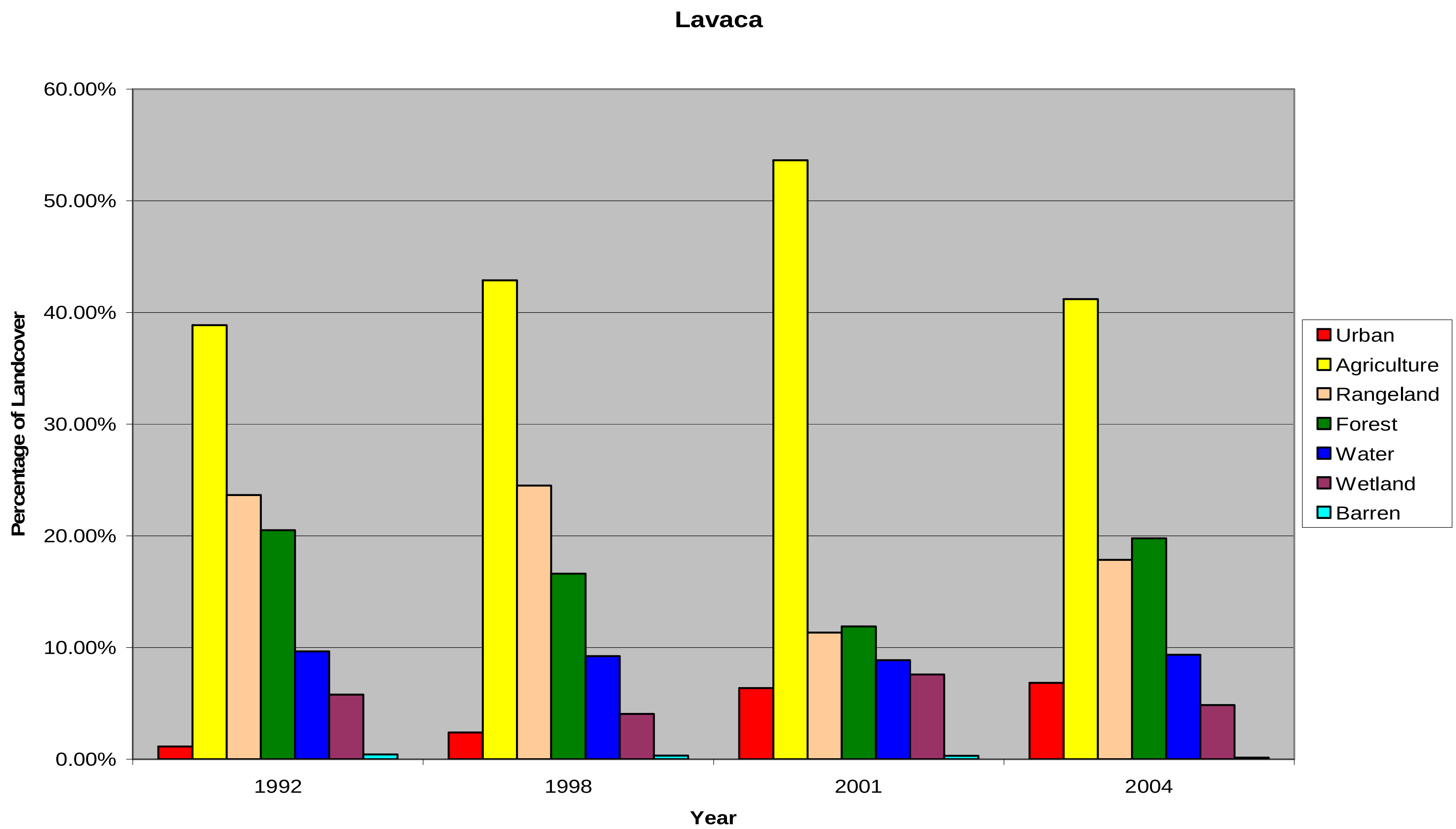


2001 Lavaca Land Use/Landcover



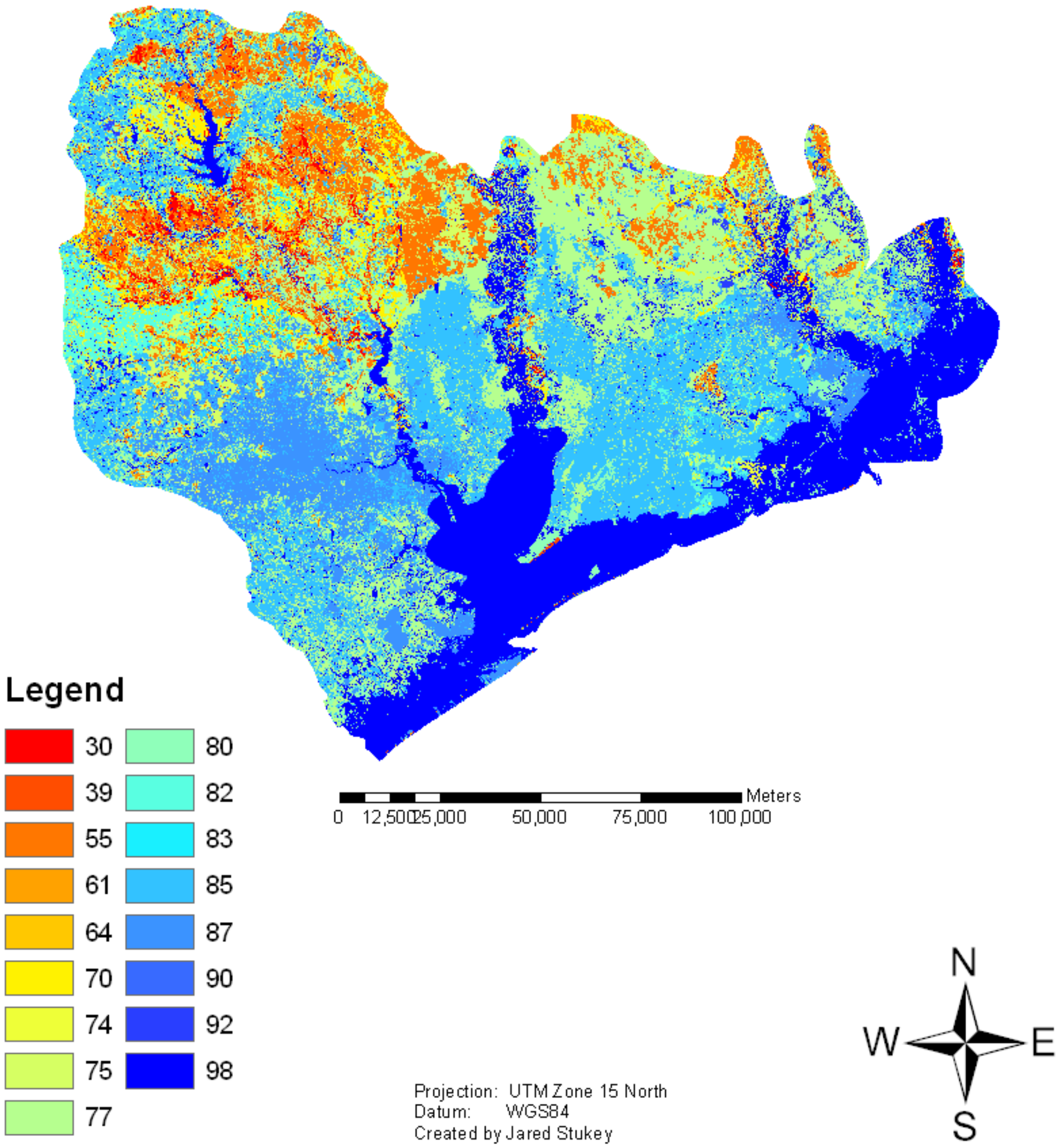
2004 Lavaca Land Use/Landcover





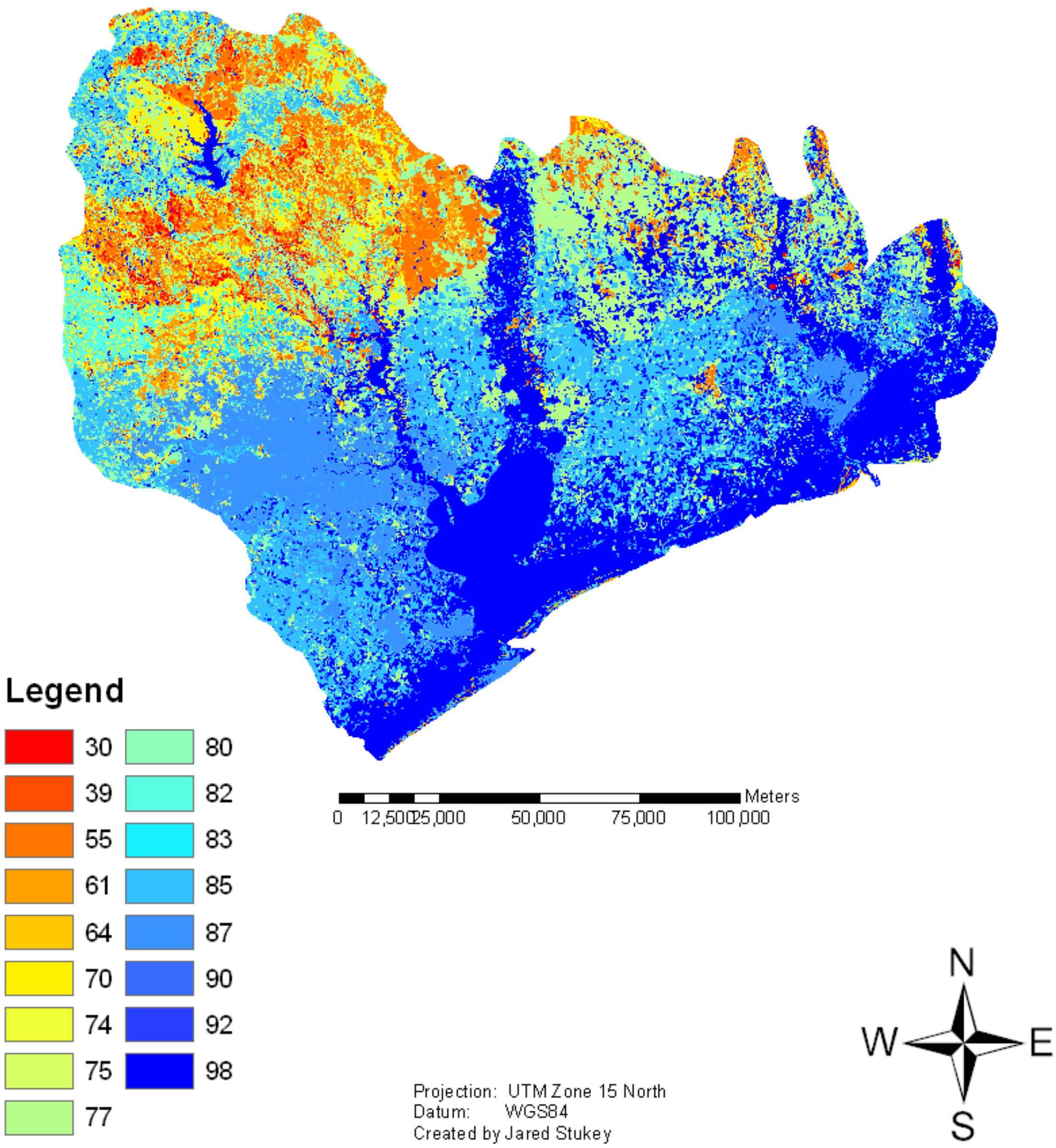
Lavaca
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Percentage of Landcover
1992
1998
2001
2004
Year
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren

1992 Galveston Curve Numbers

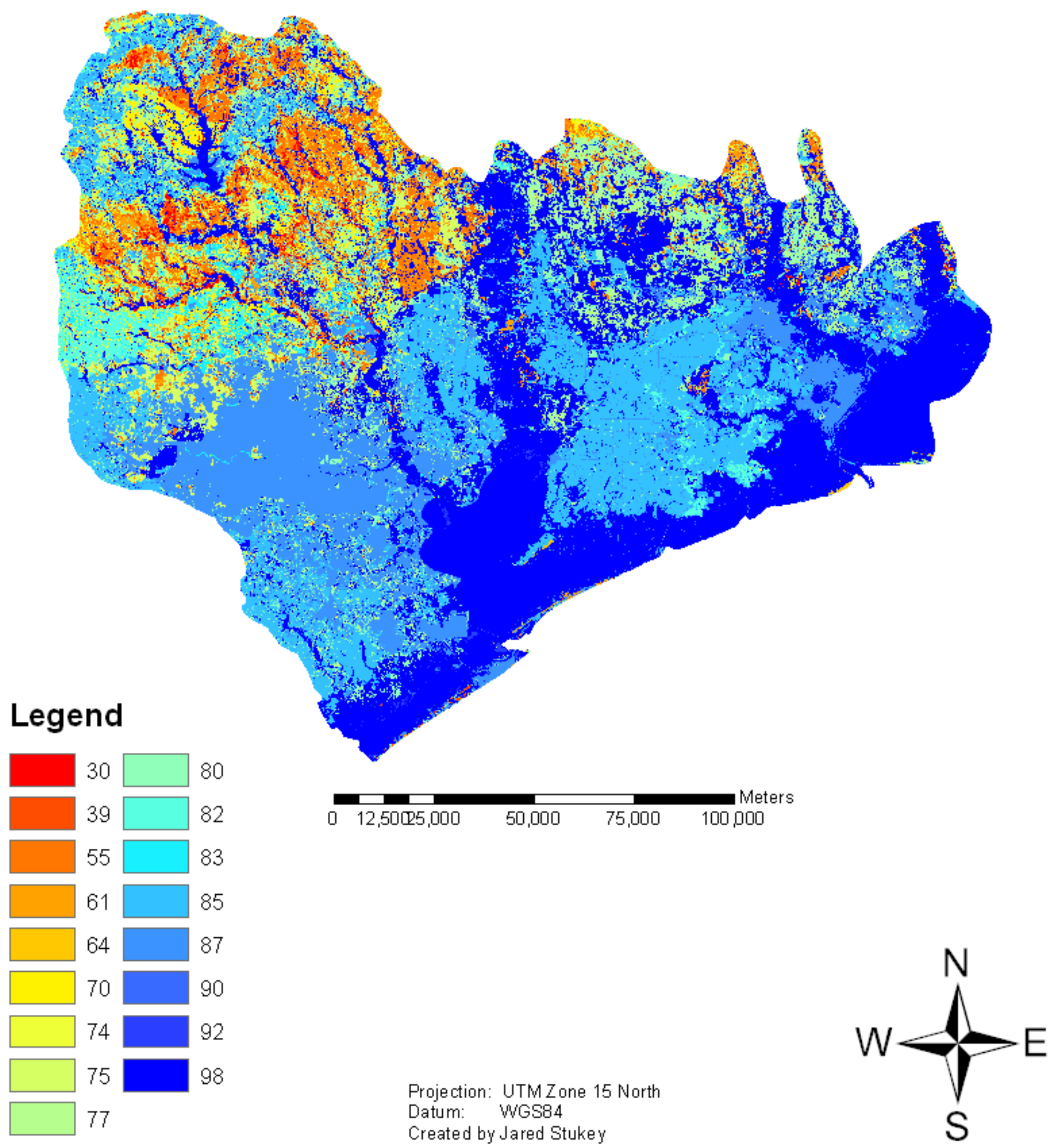


Projection: UTM Zone 15 North
Datum: WGS84
Created by Jared Stukey

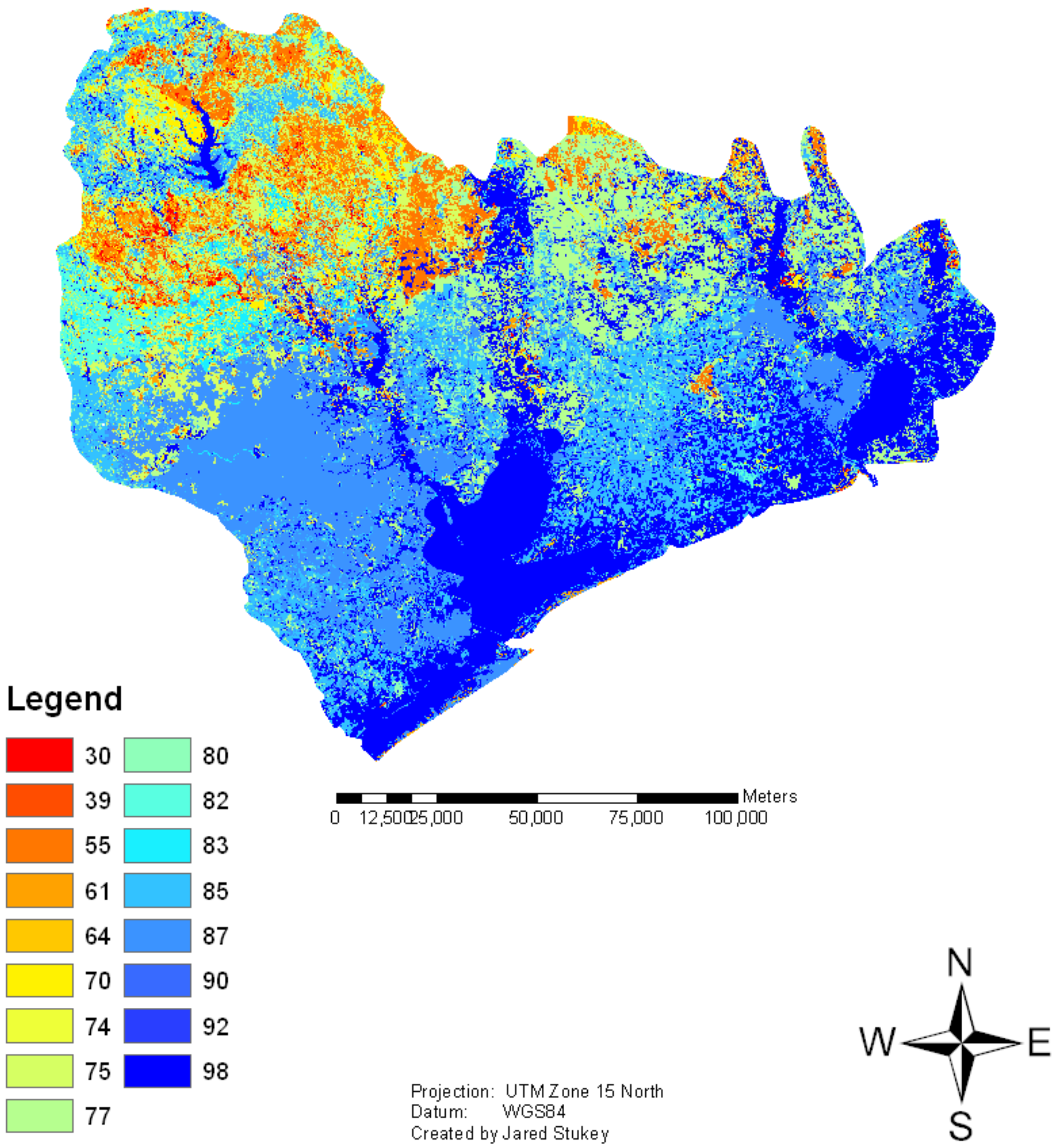
1998 Galveston Curve Numbers



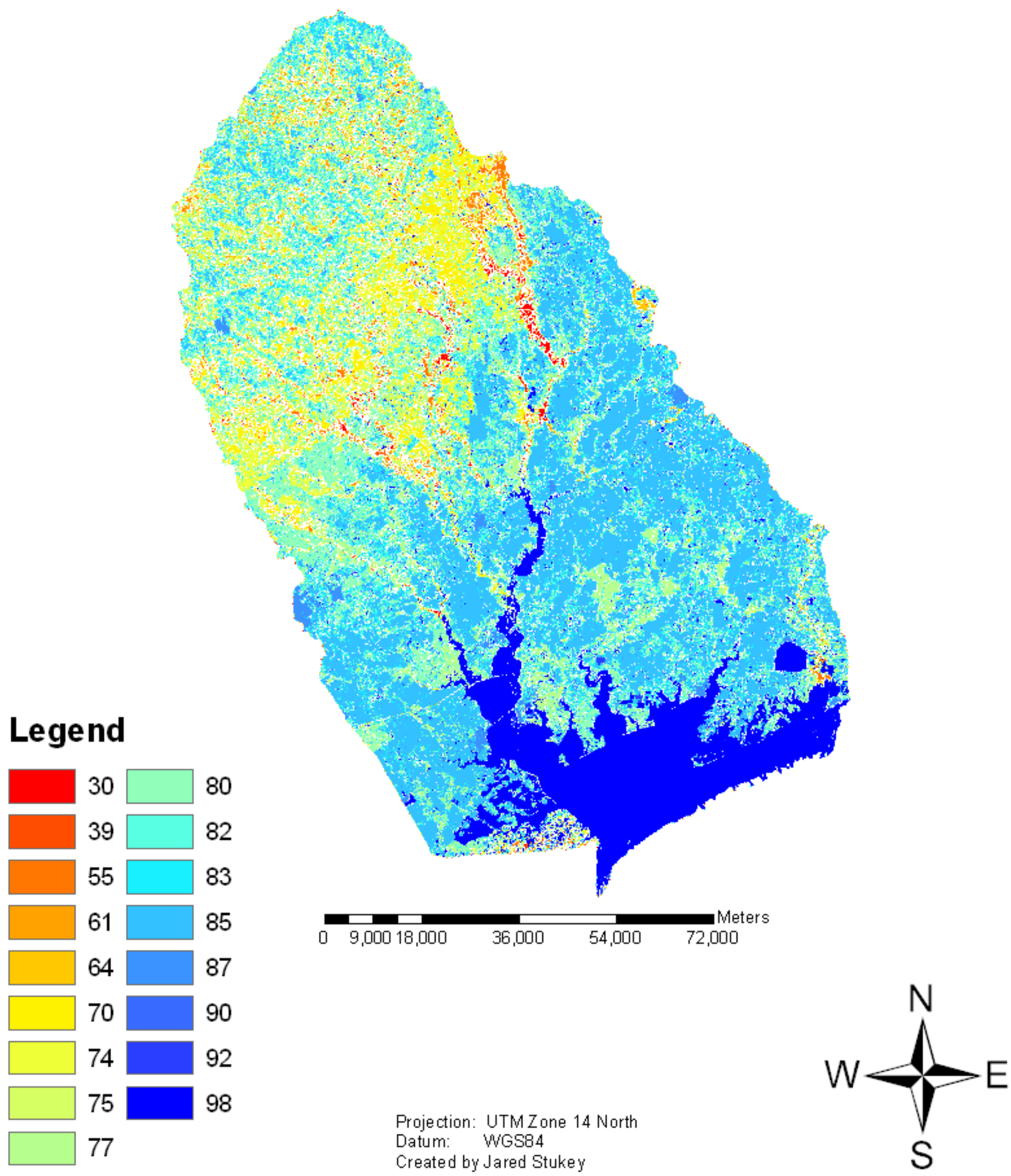
2001 Galveston Curve Numbers



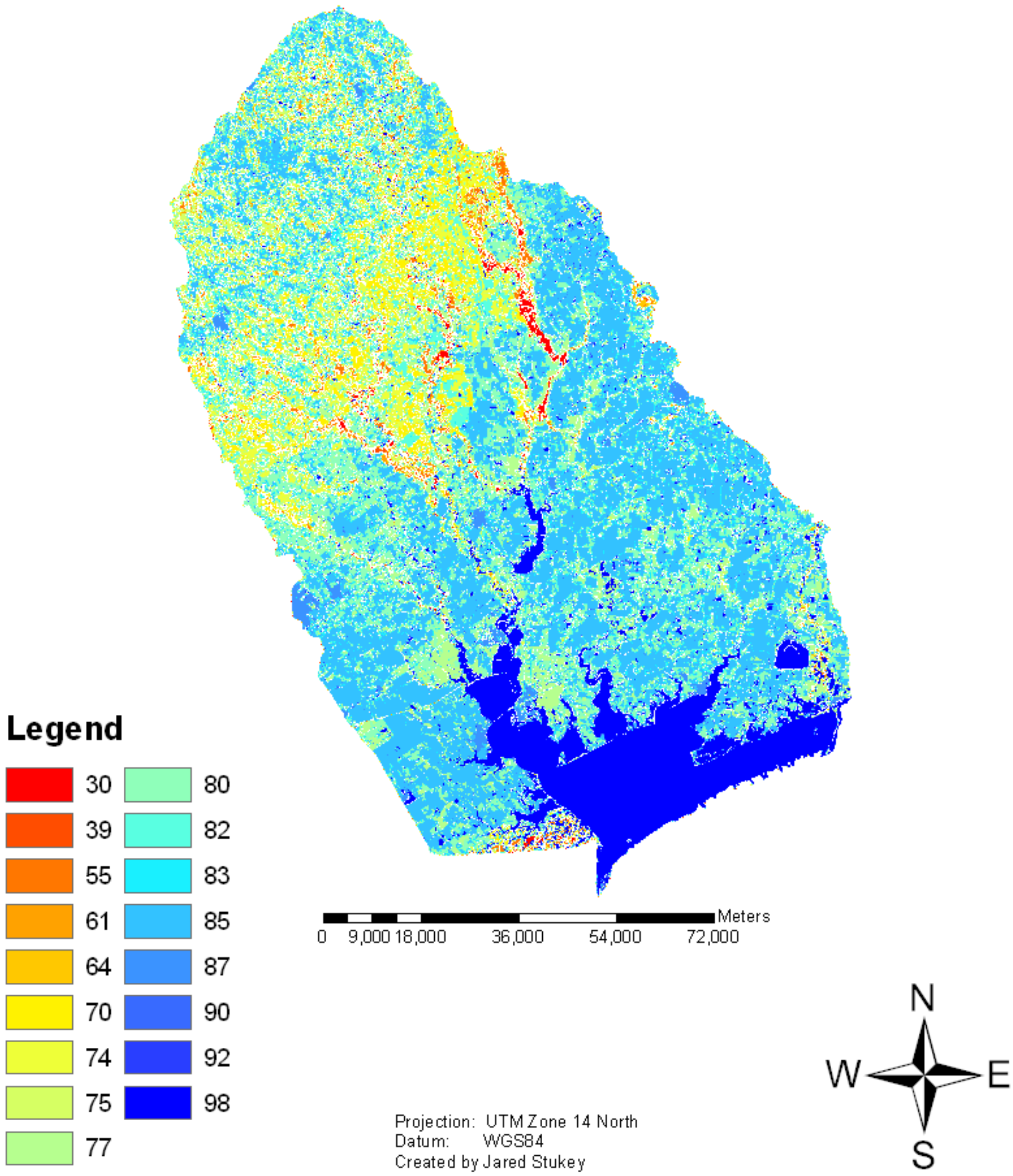
2004 Galveston Curve Numbers

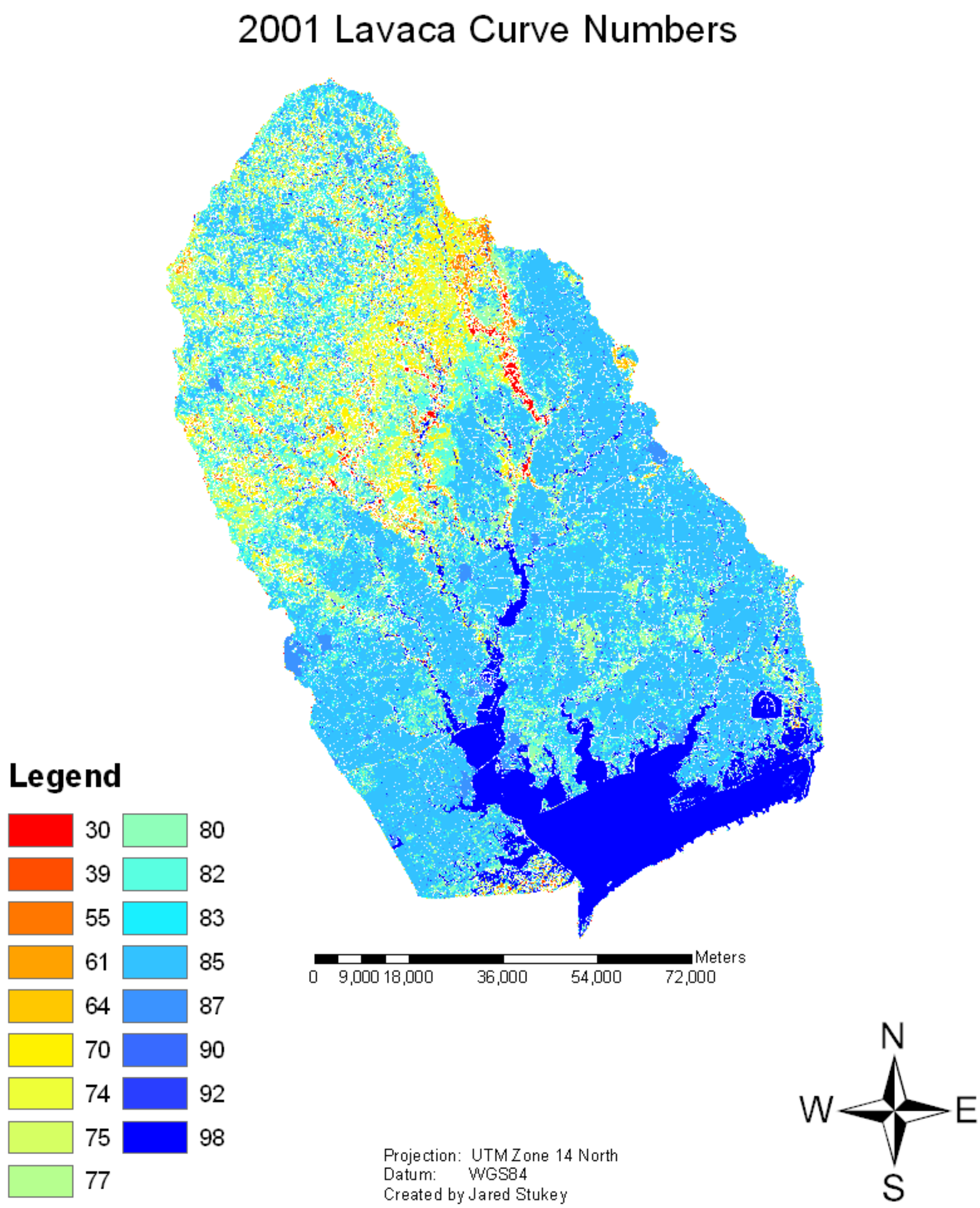


1992 Lavaca Curve Numbers

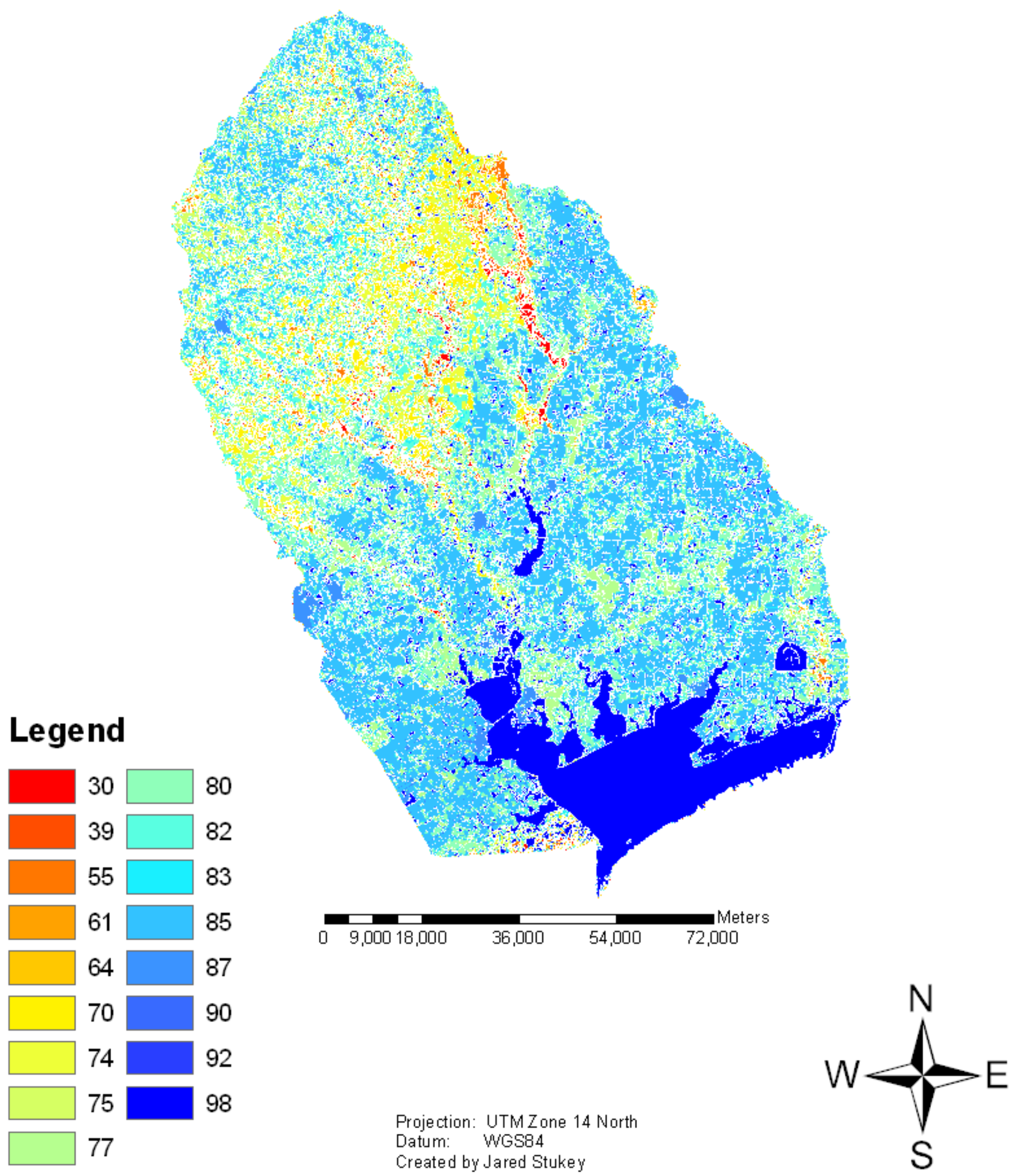


1998 Lavaca Curve Numbers




2001 Lavaca Curve Numbers
Legend
30
39
55
61
64
70
74
75
77
80
82
83
85
87
90
92
98
Meters
0
9,000
18,000
36,000
54,000
72,000
Projection: UTM Zone 14 North
Datum: WGS84
Created by Jared Stukey
N
W
E
S

2004 Lavaca Curve Numbers



1992 – 1998 Galveston Landcover Change Statistics

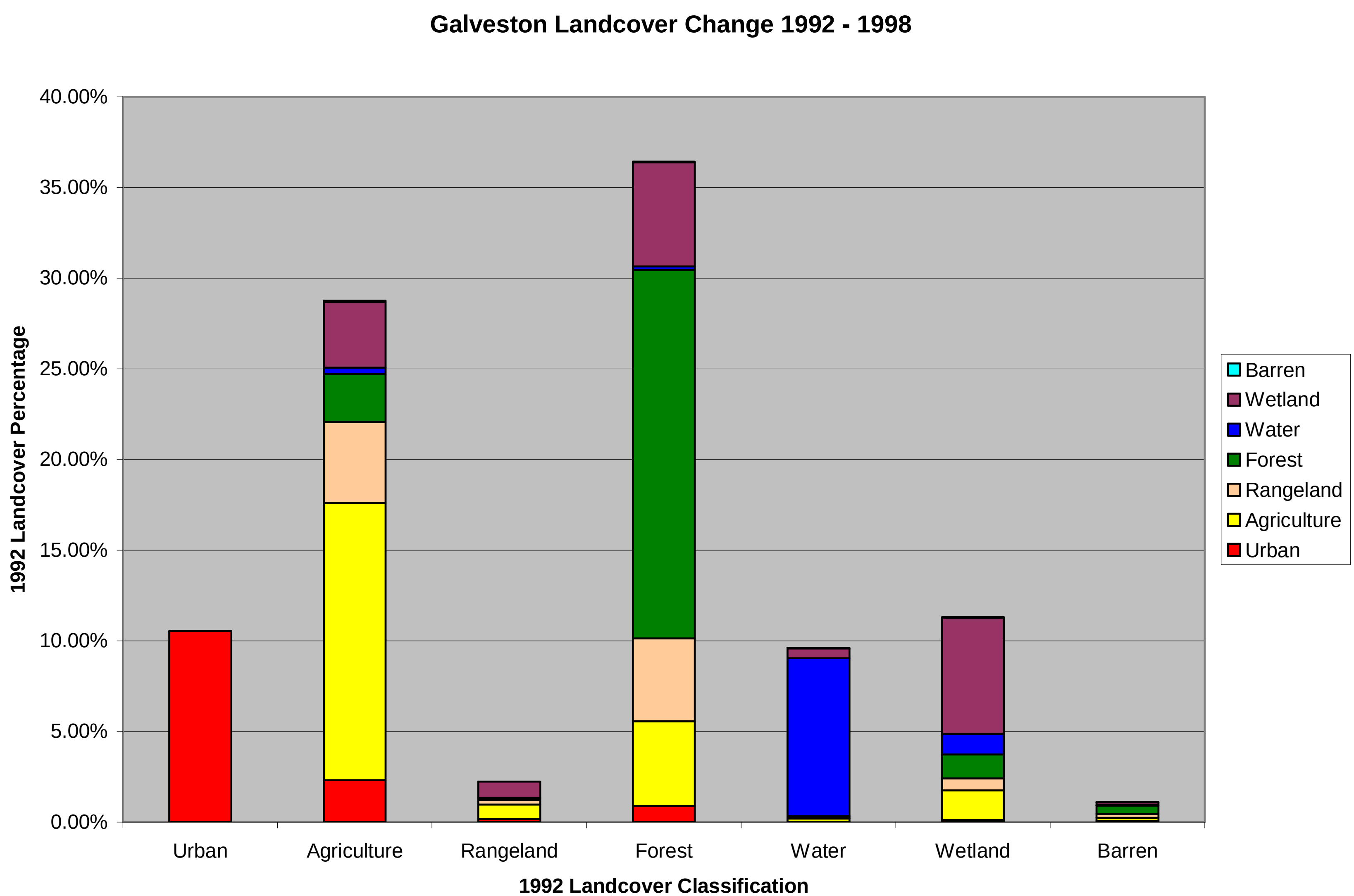
	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	10.54%	2.32%	0.18%	0.88%	0.02%	0.11%	0.07%
Agriculture	0.00%	15.29%	0.80%	4.69%	0.18%	1.63%	0.17%
Rangeland	0.00%	4.46%	0.26%	4.57%	0.04%	0.67%	0.22%
Forest	0.00%	2.65%	0.06%	20.31%	0.10%	1.31%	0.45%
Water	0.00%	0.34%	0.06%	0.19%	8.70%	1.14%	0.02%
Wetland	0.00%	3.62%	0.88%	5.74%	0.54%	6.42%	0.16%
Barren	0.00%	0.07%	0.01%	0.04%	0.03%	0.02%	0.02%

1998 – 2001 Galveston Landcover Change Statistics

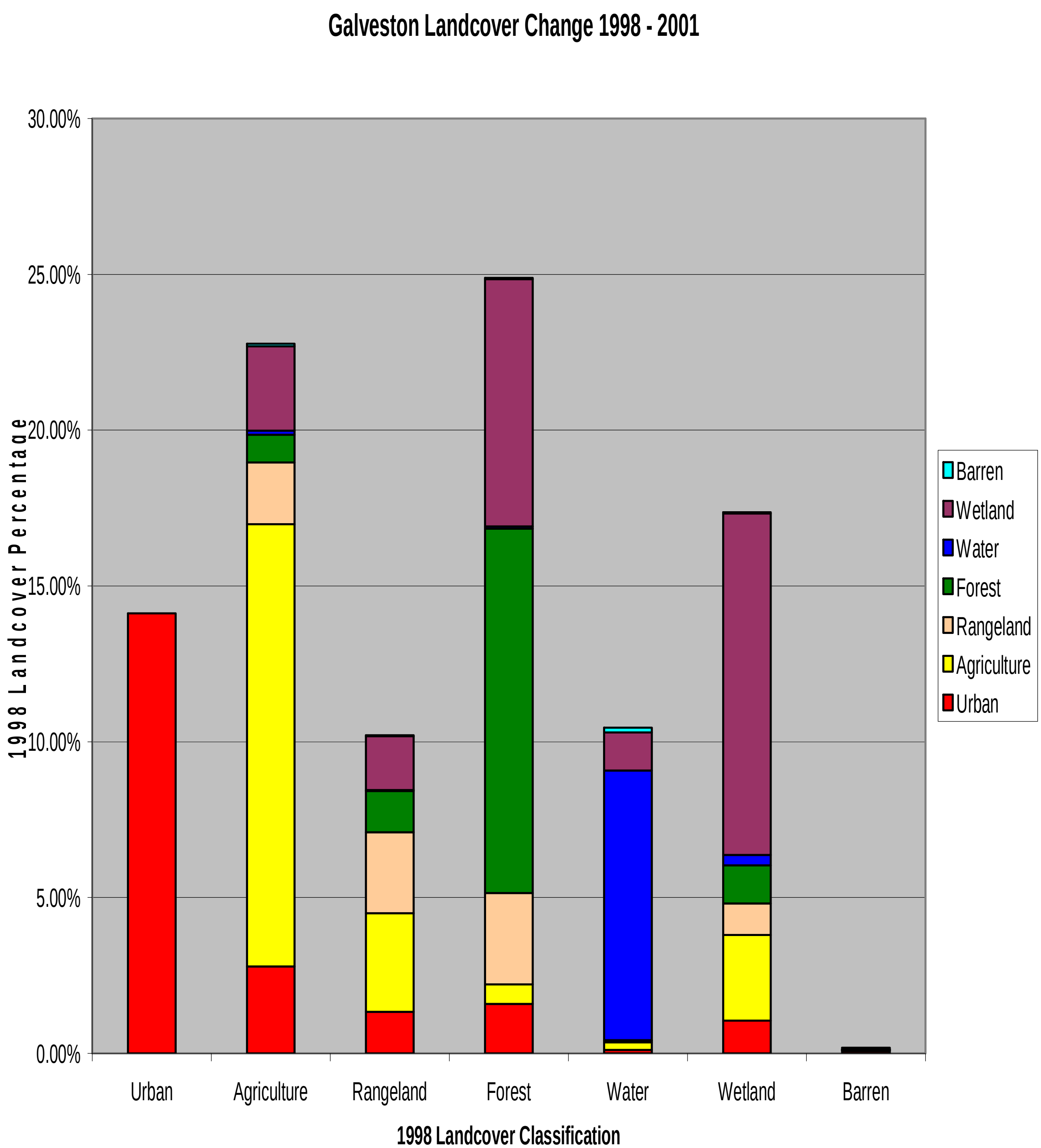
	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	14.12%	2.79%	1.33%	1.59%	0.11%	1.06%	0.07%
Agriculture	0.00%	14.19%	3.16%	0.62%	0.25%	2.74%	0.03%
Rangeland	0.00%	1.98%	2.60%	2.93%	0.04%	1.01%	0.01%
Forest	0.00%	0.89%	1.33%	11.69%	0.02%	1.22%	0.00%
Water	0.00%	0.13%	0.03%	0.07%	8.65%	0.33%	0.01%
Wetland	0.00%	2.71%	1.73%	7.94%	1.22%	10.96%	0.01%
Barren	0.00%	0.08%	0.03%	0.04%	0.16%	0.05%	0.06%

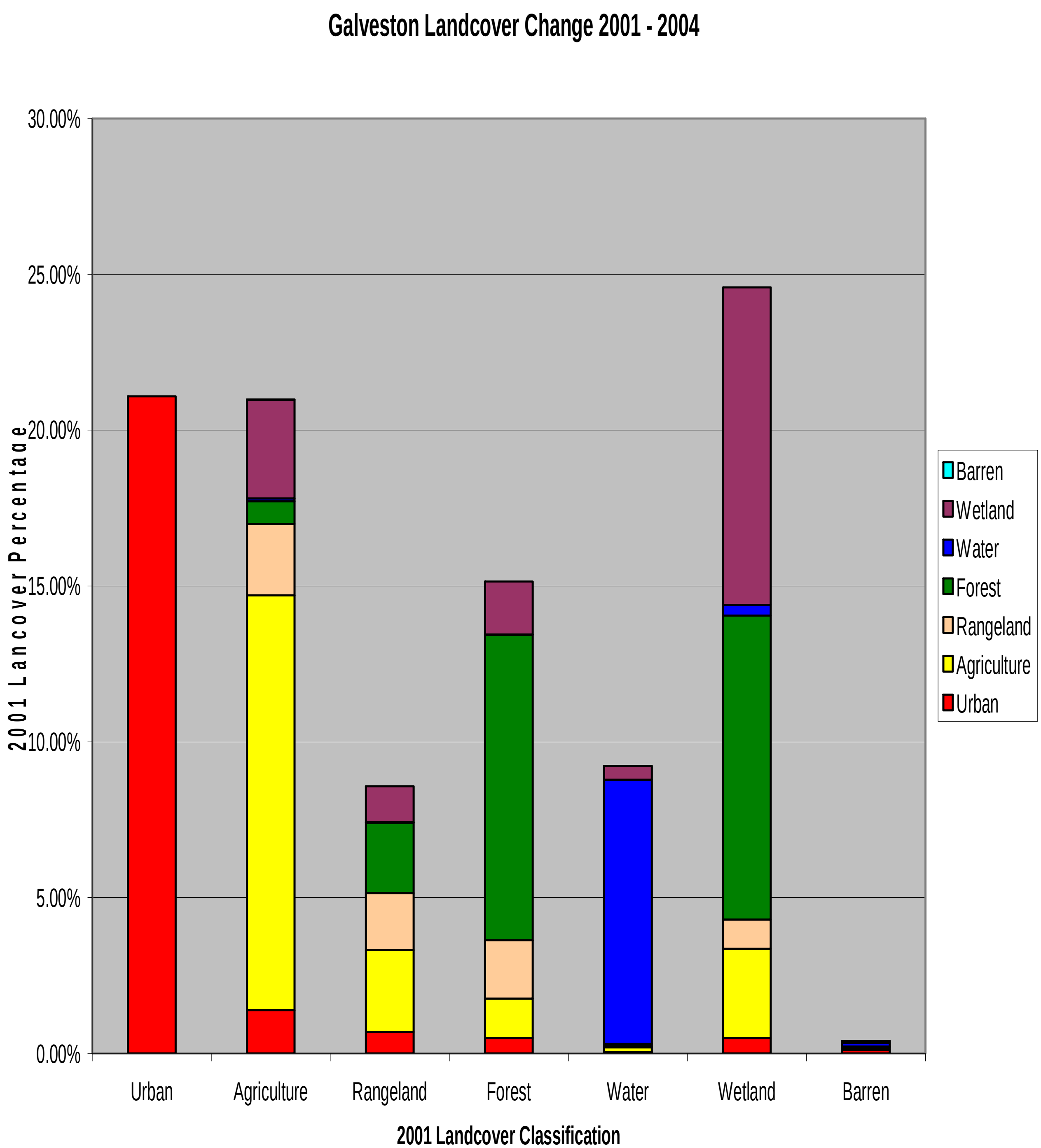
2001 – 2004 Galveston Landcover Change Statistics

	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	21.09%	1.38%	0.69%	0.49%	0.04%	0.50%	0.11%
Agriculture	0.00%	13.31%	2.63%	1.27%	0.16%	2.86%	0.07%
Rangeland	0.00%	2.29%	1.83%	1.87%	0.03%	0.94%	0.03%
Forest	0.00%	0.73%	2.26%	9.81%	0.07%	9.76%	0.01%
Water	0.00%	0.09%	0.02%	0.01%	8.48%	0.34%	0.11%
Wetland	0.00%	3.16%	1.15%	1.70%	0.45%	10.18%	0.07%
Barren	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%



Galveston Landcover Change 1992 - 1998
1992 Landcover Percentage
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren
1992 Landcover Classification
Barren
Wetland
Water
Forest
Rangeland
Agriculture
Urban


Galveston Landcover Change 1998 - 2001
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1998 Landcover Percentage
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren
1998 Landcover Classification
Barren
Wetland
Water
Forest
Rangeland
Agriculture
Urban


Galveston Landcover Change 2001 - 2004
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
2001 Lancover Percentage
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren
2001 Landcover Classification
Barren
Wetland
Water
Forest
Rangeland
Agriculture
Urban

1992 – 1998 Lavaca Landcover Change Statistics

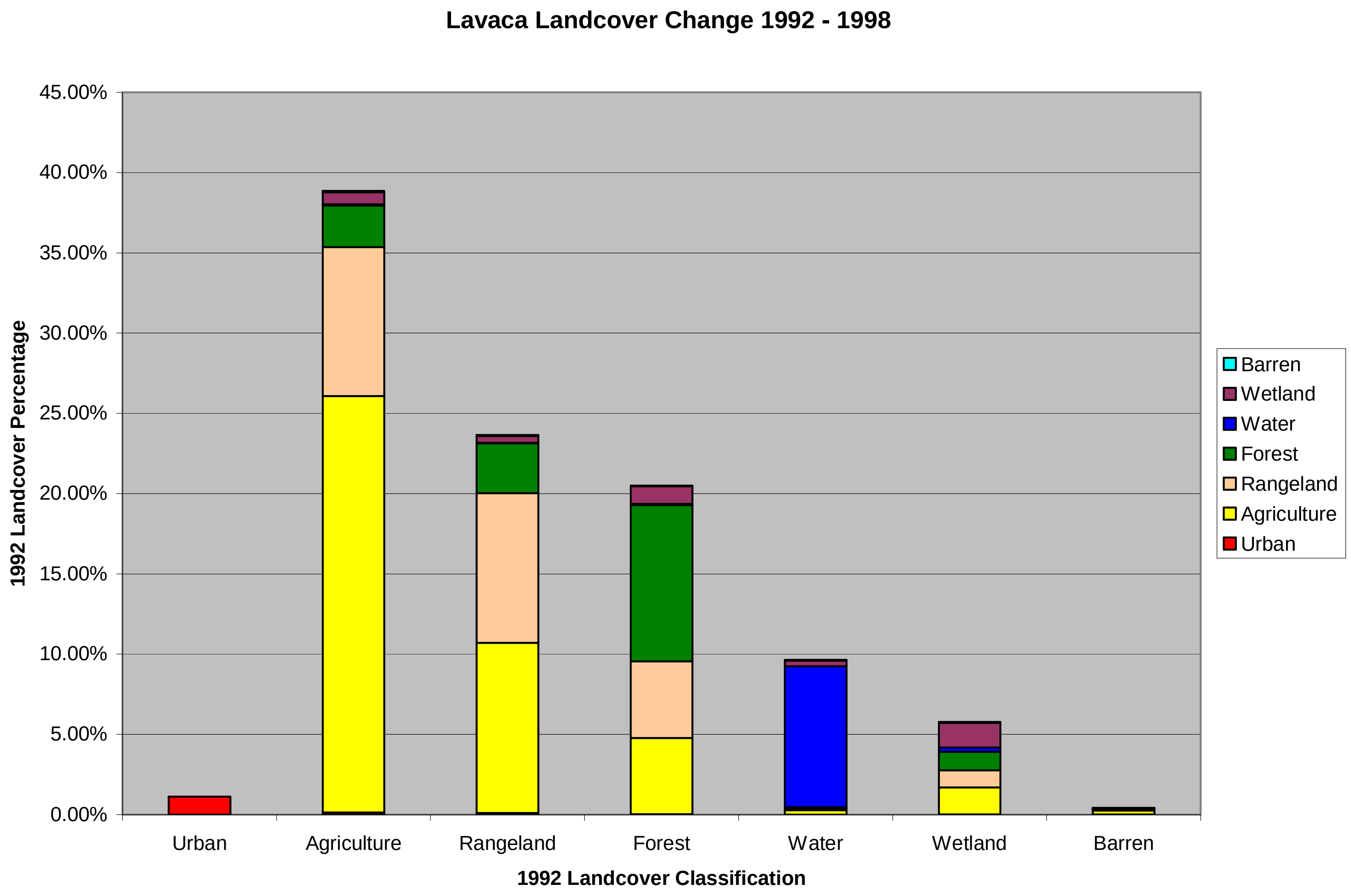
	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	1.13%	0.13%	0.11%	0.03%	0.01%	0.01%	0.01%
Agriculture	0.00%	25.94%	10.59%	4.74%	0.27%	1.68%	0.24%
Rangeland	0.00%	9.29%	9.32%	4.79%	0.11%	1.07%	0.08%
Forest	0.00%	2.59%	3.10%	9.73%	0.09%	1.15%	0.02%
Water	0.00%	0.07%	0.04%	0.08%	8.78%	0.27%	0.01%
Wetland	0.00%	0.75%	0.43%	1.10%	0.35%	1.52%	0.01%
Barren	0.00%	0.09%	0.06%	0.05%	0.05%	0.07%	0.05%

1998 – 2001 Lavaca Landcover Change Statistics

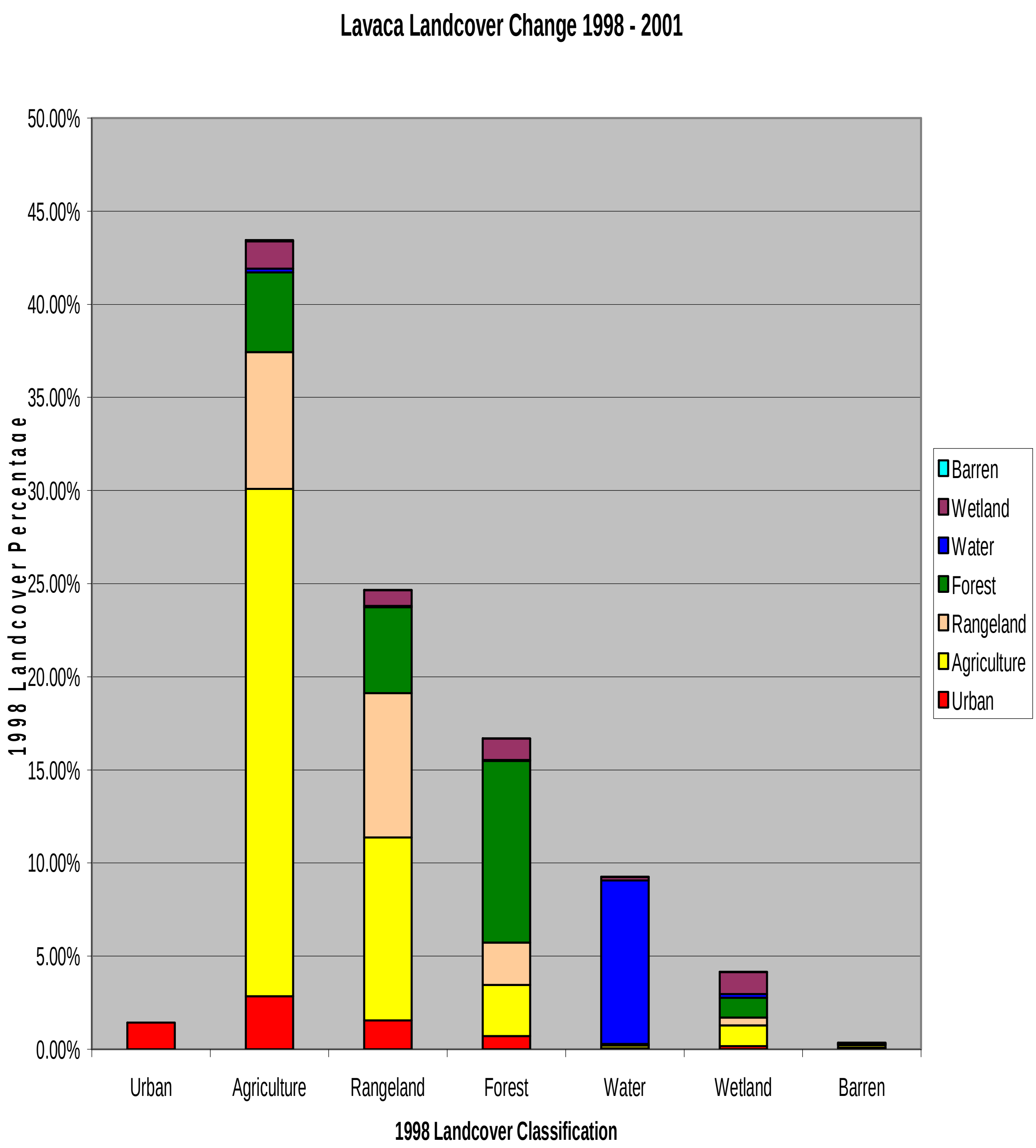
	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	1.43%	2.84%	1.55%	0.71%	0.06%	0.16%	0.09%
Agriculture	0.00%	27.24%	9.83%	2.74%	0.15%	1.12%	0.13%
Rangeland	0.00%	7.36%	7.75%	2.27%	0.03%	0.42%	0.03%
Forest	0.00%	4.27%	4.62%	9.75%	0.05%	1.07%	0.03%
Water	0.00%	0.21%	0.07%	0.06%	8.79%	0.20%	0.03%
Wetland	0.00%	1.46%	0.83%	1.15%	0.18%	1.18%	0.04%
Barren	0.00%	0.07%	0.02%	0.00%	0.01%	0.01%	0.02%

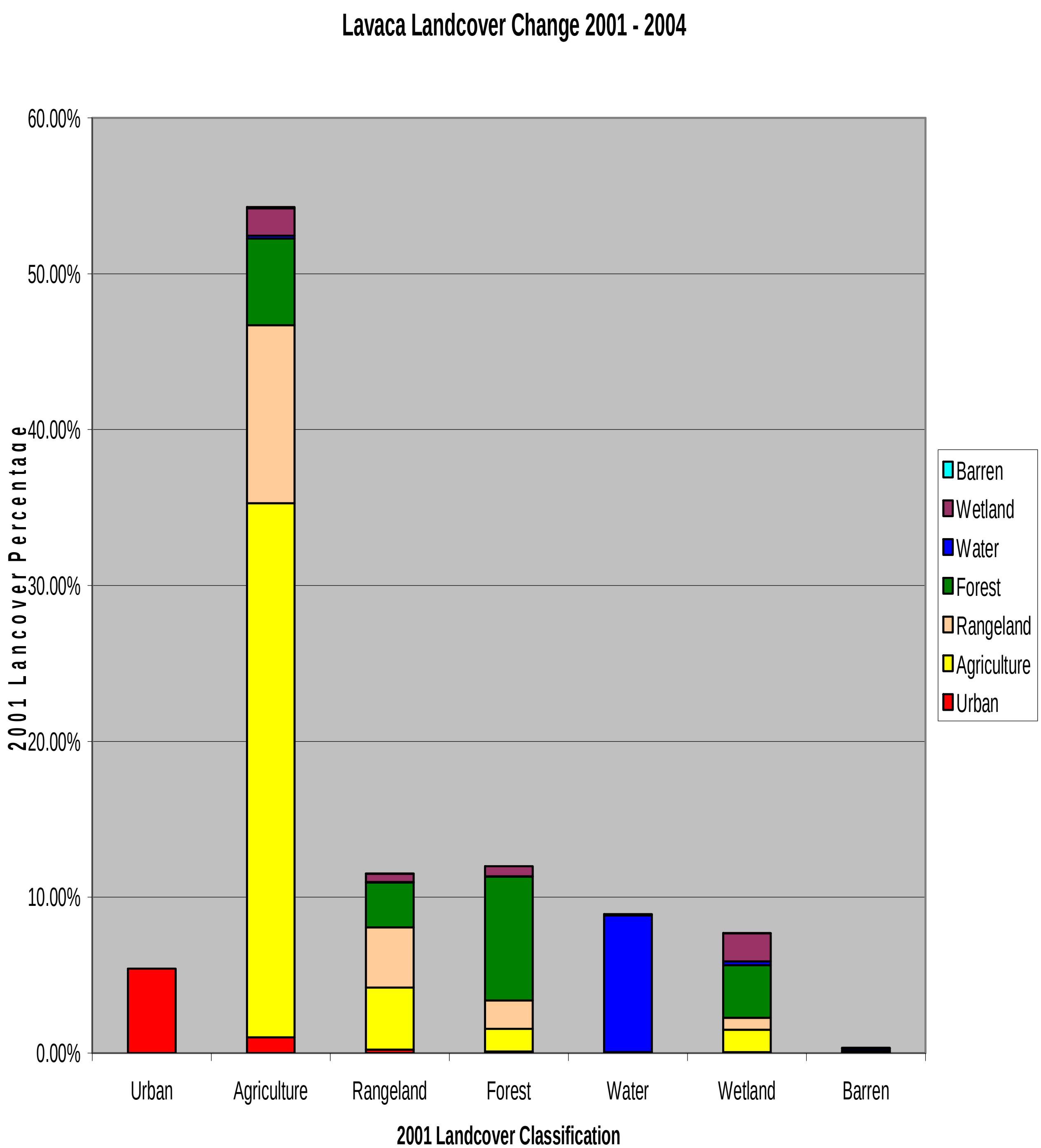
2001 – 2004 Lavaca Landcover Change Statistics

	Urban	Agriculture	Rangeland	Forest	Water	Wetland	Barren
Urban	5.41%	1.01%	0.22%	0.09%	0.01%	0.07%	0.05%
Agriculture	0.00%	34.26%	3.99%	1.47%	0.04%	1.43%	0.07%
Rangeland	0.00%	11.42%	3.86%	1.81%	0.01%	0.78%	0.01%
Forest	0.00%	5.57%	2.86%	7.96%	0.02%	3.38%	0.02%
Water	0.00%	0.19%	0.04%	0.01%	8.76%	0.23%	0.14%
Wetland	0.00%	1.75%	0.52%	0.64%	0.07%	1.82%	0.04%
Barren	0.00%	0.08%	0.02%	0.00%	0.01%	0.02%	0.02%



Lavaca Landcover Change 1992 - 1998
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1992 Landcover Percentage
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren
1992 Landcover Classification
Barren
Wetland
Water
Forest
Rangeland
Agriculture
Urban


Lavaca Landcover Change 1998 - 2001
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1998 Landcover Percentage
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren
1998 Landcover Classification
Barren
Wetland
Water
Forest
Rangeland
Agriculture
Urban


Lavaca Landcover Change 2001 - 2004
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
2001 Lancover Percentage
Barren
Wetland
Water
Forest
Rangeland
Agriculture
Urban
Urban
Agriculture
Rangeland
Forest
Water
Wetland
Barren
2001 Landcover Classification