Land cover change in wetland restoration area: The Case Study of South of Campus Michigan State University

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Abstract

Wetlands are those special places in the landscape where water is visible only part of the year. Some wetland types can store floodwaters, preventing flooding of downstream properties. Runoff water from surrounding lands can be effectively filtered by wetlands. They help to protect the adjacent lake or river from too much sediment, fertilizers, and pesticides. Wetlands also provide valuable habitat, food, and shelter for fish and wildlife (USEPA, 2004).

As activities within wetlands have become more regulated, compensation of wetland loss has become increasingly necessary. Wetland restoration projects are essential to protect, increase and improve wetlands (USEPA, 2004). In order to manage this ecosystem sustainably, aspects of wetland characteristics remain to be studied.

Ecological systems within wetland are extraordinarily complex phenomenon combining far too many elements for exhaustive completely specified deterministic models. However, creating generalizable models using landscape patterns and processes introduces significant information. The use of neutral landscape models was introduced as a method for comparing the quantifiable characteristics of disparate landscapes (Gardner et al. 1987; Hess et al. 1997). Tests of observed landscapes against replicate random maps reveal the degree of differences due to the structure and hypothesized underlying processes.

This project studies one of the wetland restoration sites that are located at south of the campus of Michigan State University in East Lansing, MI. The land cover change of the site between year of 2001 and 2004 is examined. Five landscape metrics, total area, number of patches, mean patch size, patch size standard deviation, and dominance, are calculated and compared with a neutral model to characterize the landscape and detect how has the wetland changed. This research is clearly applicable to wetland restoration project, but is also broadly generalizable.

Objectives

1. Characterize the landscape and detect how has the wetland changed
2. Develop pattern metrics for each class for both DOQQ and the landscape from GPS points
3. Compare each landscape to a neutral model for the same size

Study site

The wetland restoration project is located at south of Michigan State University, by Mt. Hope and farm lane roads (Figure 1).

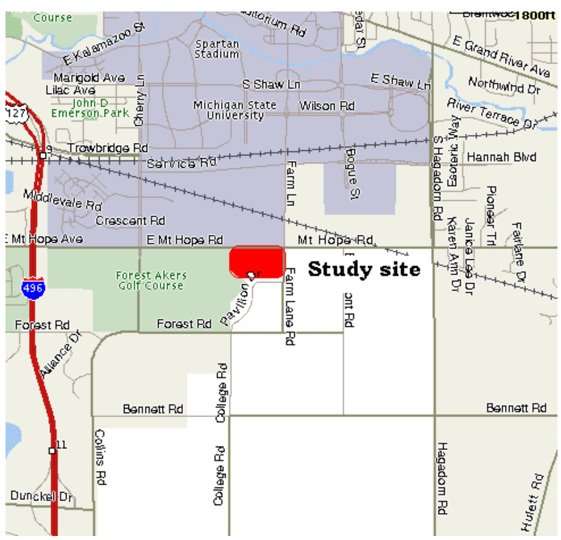


Figure 1. Study site, Source: Mapquest.com

Method

A base map raster data model of the wetland was created from collected GPS points from fieldwork in April 2004. The DOQQ image of 2001 was downloaded and compared with the map generated from GPS points. Pattern metrics for each land use/ land cover (LULC) classes were calculated for number of patches, total area per class, mean patch size, standard deviation of patch size, and dominance. Each landscape type was then compared with neutral model for the same size.

A. Fieldwork

Field survey was done on 4/13/04 to collect 116 data points (Figure 2) representing boundaries of landscape features in the wetland restoration area using the Garmin GPSmap 76. Additional 7 Ground Control Points (GCPs) were collected on 4/20/04 to ensure geographical reference of the image.

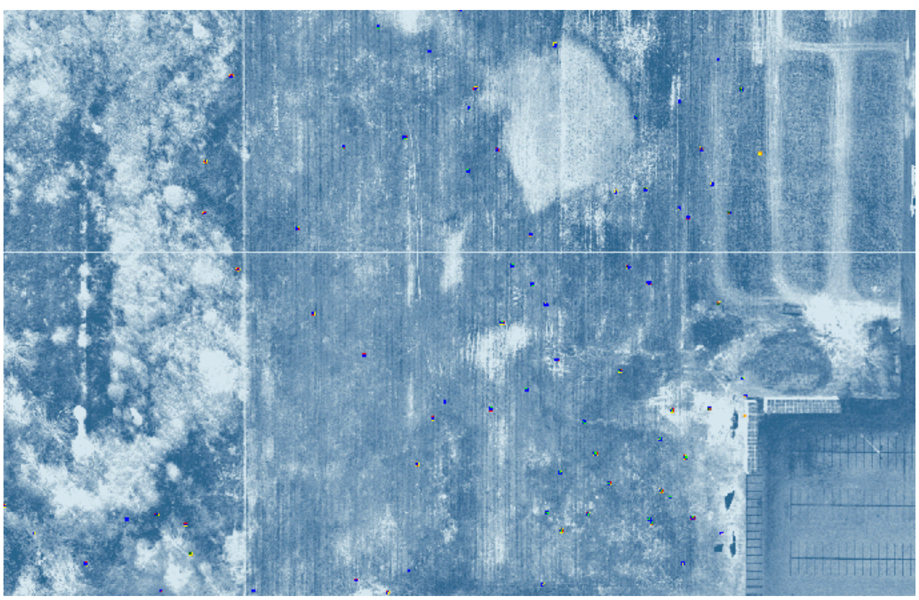


Figure 2. Points representing boundaries of landscape features in the wetland restoration area

B. Create a raster data model

The GPS point data were downloaded and opened in Microsoft Excel Spreadsheet where it was converted into a DataBase .dbf IV format. The dBASE file was then opened in ArcView, and was used to create a point shapefile. The shapefile was converted to a grid file in order to do further analysis.

C. Co-register with DOQQ

GPS point grid file was co-registered with the DOQQ base map using the Geometric Correction method in ERDAS IMAGINE 8.6. Seven GCPs were used in this process. The geometric normalization used polynomial order 1 model, Nearest Neighbor resample method, with registration to the UTM projection zone 16, map unit: centimeters, and cell size: 10 cm. The original DOQQ map spatial resolution was 15.25 cm but for simplification purpose, all the raster data pixel resolution was set to 10 cm.

D. Digitizing process

The geometric corrected point grid file was then used as a base map in digitizing the landscape features boundary in ArcGIS. Next, the digitized thematic map was classified into six categories: 1) extent (primary occupied by grassland), 2) standing water areas, 3) trees, 4) cattail patches, 5) stumps, and 6) rock piles. The classified regions were processed in Arc/Info to create topology. The same digitizing process was also used to create the same entities for DOQQ map. Then, the regions were compared (Figure 3). Red lines in the map represent entities for DOQQ map. Green lines represent entities for digitized thematic map.

Figure 3. Landscape features from DOQQ and digitized thematic map

E. Add the attributes & convert to grid

Class Name and Code were assigned to the attribute tables. All key landscape entities were contained in 2004 map (Figure 4) but classes 4 and 5 were not presented in 2001 map (Figure 5). Individual trees (class 3) were not digitized due to the lack of 2004 tree data to compare. Not every GPS point of individual trees were collected from 2004 field work due to limited time and the weather condition. Most trees were not accessible, such as surrounded by water. Therefore, it is useless to digitize trees from 2001 image. Next, the coverages were converted to raster grid format to be used in Land Use Land Cover Change (LULCC) analysis in ERDAS IMAGINE. After the analysis, the raster grids were converted to TIFF data format. Next step, the Pattern landscape matrices were created with a program developed using the Interactive Data Language (IDL) software comparing the quantifiable characteristics of landscapes. The images Extent was 4815 x 3501 and Grain was 10 cm for all images. Class area for each entity was calculated and they were summarized in Table 1.

Table 1. Summary of classified images of 2001 and 2004

Class	Area of 2001 (m^2)	Area of 2004 (m^2)
1: Grassland	113400.8	46466.83
2: Standing water area	4093.66	69949.53
3: Trees	0	55.44
4: Cattail patches	0	919.25
5: Stumps	0	101.53
6: Rock piles	36.26	51.35

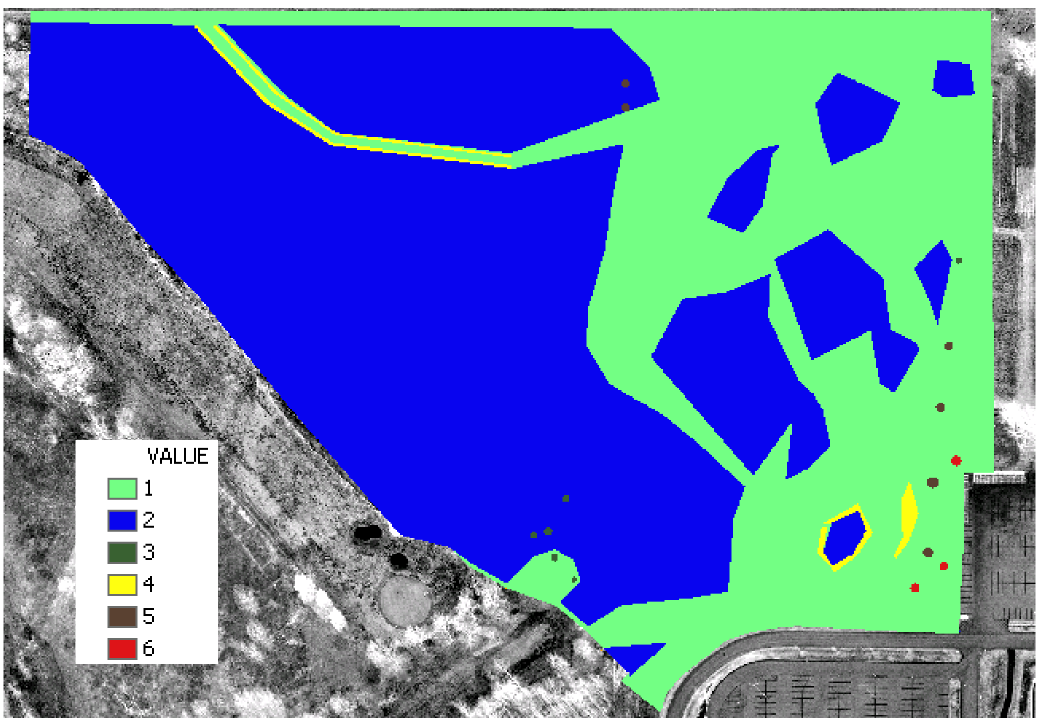


Figure 4. Classified wetland restoration area 2004

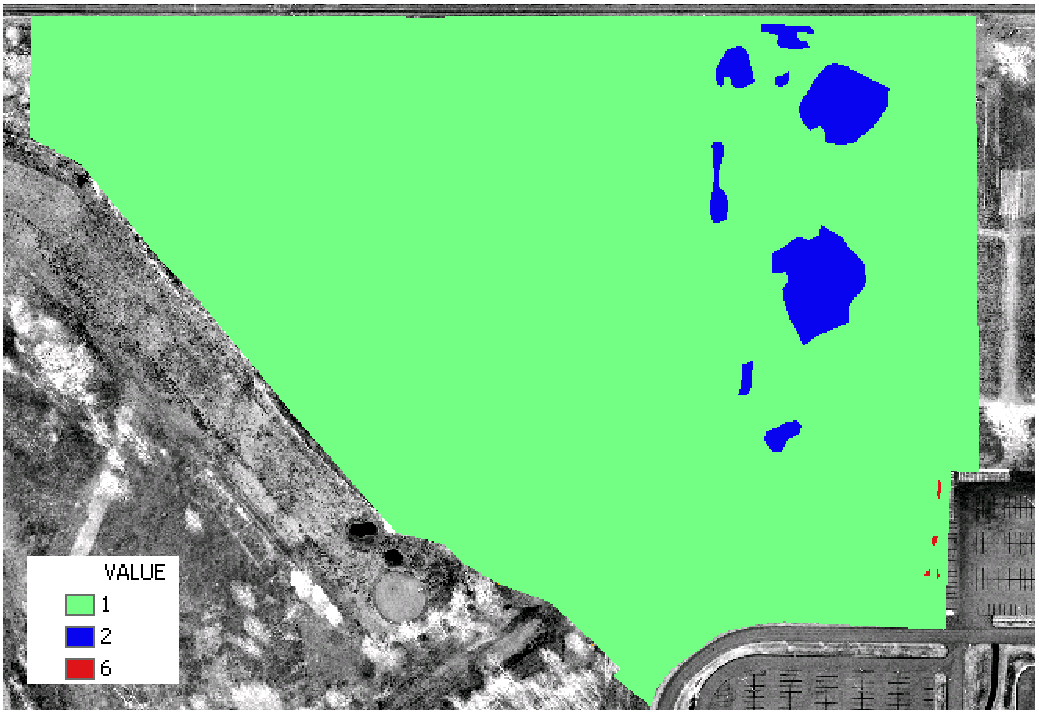


Figure 5. Classified wetland restoration area 2001

F. Pattern metrics analysis

In many studies, landscape pattern matrics have been used to describe changes in a landscape through time or to compare landscape (e.g., Iverson, 1988)

For this study, five landscape metrics 1) Number of patches per class per year, 2) Total area per class per year, 3) Mean patch size per class per year, 4) Patch size standard deviation per class per year, and 5) Dominance were calculated in IDL. TIFF image files were used throughout this process. The programming code is attached in the appendix A and B.

Largest patch index was used to present the dominance. Largest Patch Index represents largest contiguous patch and is a measure of 'Dominance' in the landscape (Turner et al., 2001; Herzog et al., 2001)

LPI = (AREA LARGEST PATCH/ AREA TOTAL) * 100

G. Neutral model

The simplest standard for landscape pattern is a random map, which lacks all factors that might organize structure the pattern (Gardner et al. 1987; Turner et al. 2001). Tests of observed landscapes against repeated random maps can then reveal the magnitude and significance of differences due to the formation of landscapes. Random maps are neutral landscape models.

Neutral model images with probability of 0 to 1, 0.1 intervals were created with the same extent as other images. The five landscape metrics were calculated on this neutral model. Programming code to create neutral model images is listed in the appendix B.

H. Change matrix

Change detection model was built in ERDAS Modeler using conditional statement listed in Appendix D. Table 2 showed area of changes from one entity to another in m^2. Change detection maps are also showed in Appendix D.

Table 2. Change matrix.

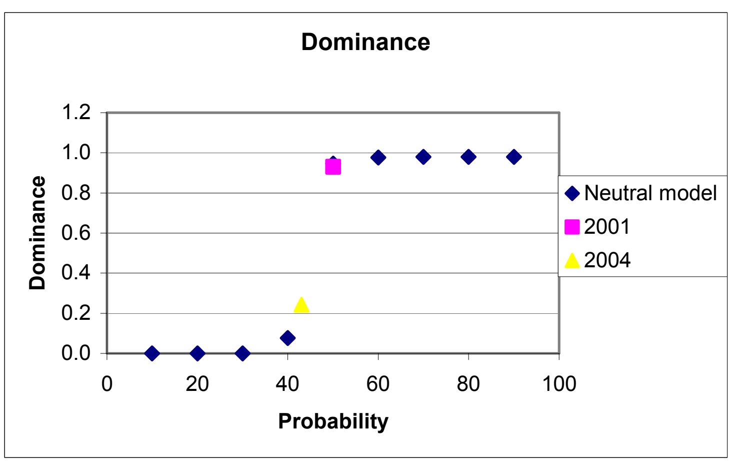
Class	Grassland	Standing Water	Tree	Cattail	Stump	Rock pile
Grassland	X	67056.16	55.68	918.88	101.12	50.4
Standing Water	1230.4	X	X	X	X	X
Tree	X	X	X	X	X	X
Cattail	X	X	X	X	X	X
Stump	X	X	X	X	X	X
Rock pile	36.8	X	X	X	X	X

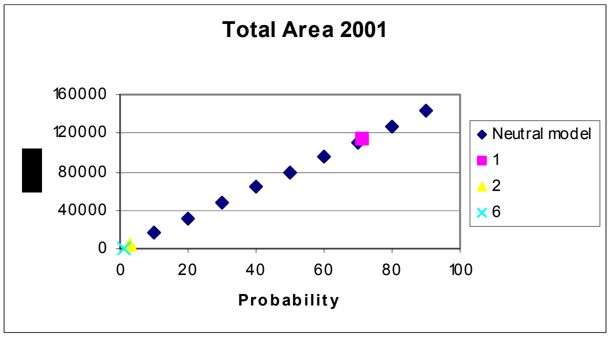
Results

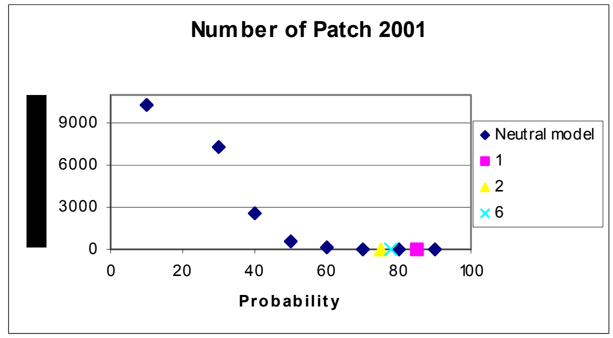
The resulting tables and graphs of images pattern metrics and neutral model are showed in the table 3.

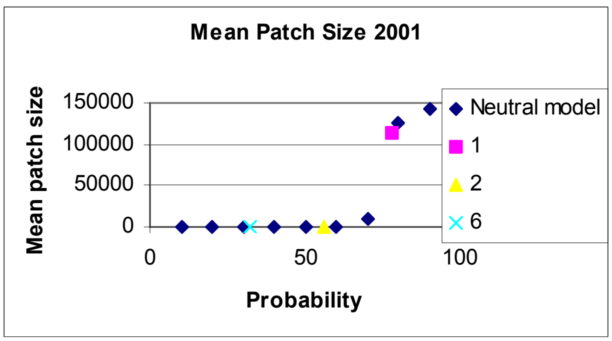
Table 3. The pattern metrics result

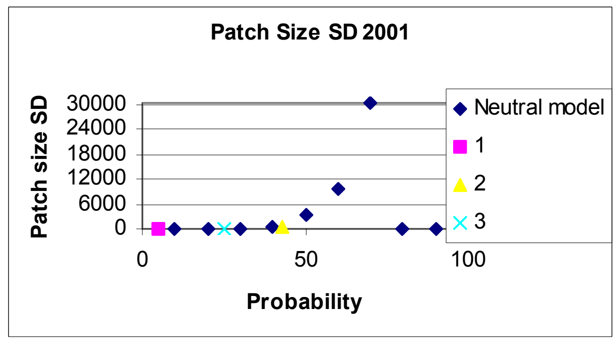
Class Name	Grassland	Standing Water	Tree	Cattail	Stump	Rock pile
Total area (square meter)						
2001	113400.83	4093.66	0	0	0	36.26
2004	46466.83	69949.53	55.44	919.25	101.53	51.35
Change	-66934	65855.87	55.44	919.25	101.53	15.09
Number of patches						
2001	1	8	0	0	0	4
2004	1	11	6	4	6	3
Change	0	3	6	4	6	-1
Mean patch size						
2001	113400	511.708	0	0	0	9.065
2004	46466.83	6359.04	9.24	229.813	16.9217	17.1167
Change	-66933.17	5847.332	9.24	229.813	16.9217	8.0517
Patch size STDV						
2001	0	650.797	0	0	0	3.99607
2004	0	14488.1	2.7191	48.138	4.33912	2.40592
Change	0	13837.303	2.7191	48.138	4.33912	-1.59015
Dominance	**All classes**					
2001	0.930991					
2004	0.243235					

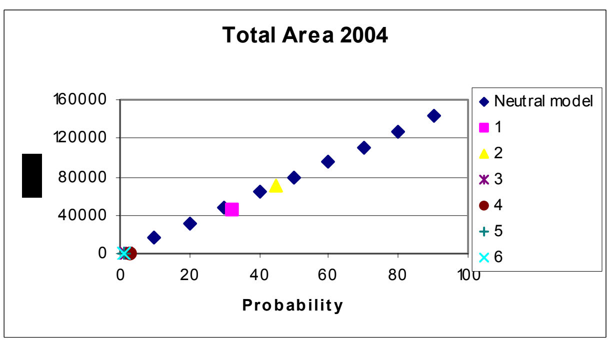


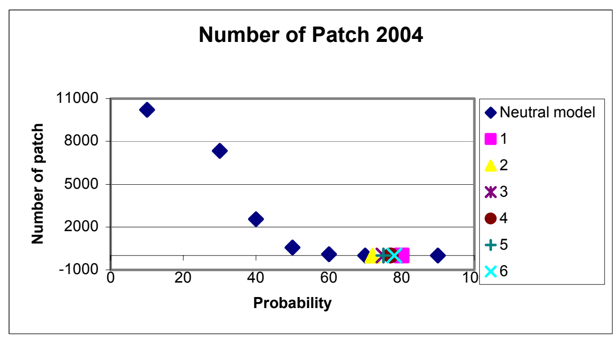

Total Area 2001
160000
120000
80000
40000
0
0
20
40
60
80
100
Probability
Neutral model
1
2
6

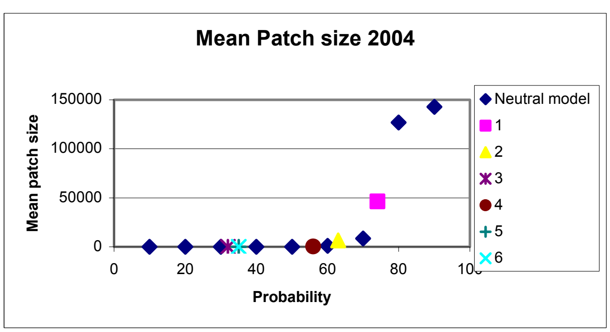

Number of Patch 2001
9000
6000
3000
0
0
20
40
60
80
100
Probability
Neutral model
1
2
6


Mean Patch Size 2001
Mean patch size
150000
100000
50000
0
0
50
100
Probability
Neutral model
1
2
6


Patch Size SD 2001
Patch size SD
30000
24000
18000
12000
6000
0
0
50
100
Probability
Neutral model
1
2
3


Total Area 2004
160000
120000
80000
40000
0
0
20
40
60
80
100
Probability
Neutral model
1
2
3
4
5
6


Number of Patch 2004
Number of patch
11000
8000
5000
2000
-1000
0
20
40
60
80
10
Probability
Neutral model
1
2
3
4
5
6


Mean Patch size 2004
Mean patch size
150000
100000
50000
0
0
20
40
60
80
100
Probability
Neutral model
1
2
3
4
5
6

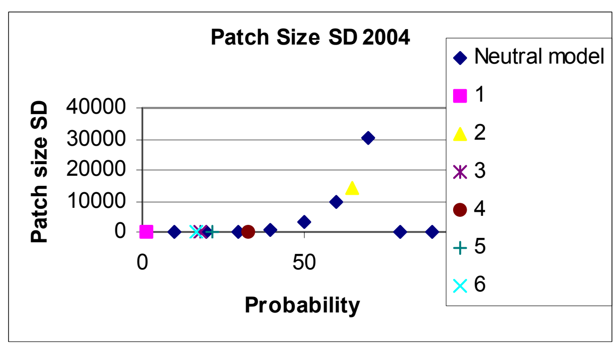

Patch Size SD 2004
Patch size SD
40000
30000
20000
10000
0
0
50
Probability
Neutral model
1
2
3
4
5
6

Table 4. Pattern metrics of the image compared to the neutral model

Pattern metrics result	Grassland	Standing Water	Tree	Cattail	Stump	Rock pile
Total area						
2001	71	3		0	0	1
2004	32	45	2	3	1	1
Number of patches						
2001	85	72		0	0	78
2004	80	75	75	77	75	78
Mean patch size						
2001	78	56		0	0	32
2004	74	63	32	56	35	35
Patch size STDV						
2001	5	43		0	0	25
2004	1	65	18	33	22	17
Dominance	**All classes**					
2001	50					
2004	43					

Discussion

Total area:

Total area of grassland decreased from 2001 (close to area of neutral model LE 71) to 2004 (close to area of neutral model LE 32) while that of standing water area increased. Rock pile maintained relatively the same area throughout 3 years. Stump and cattail were visible in 2004, but they were not in 2001. Tree class was not classified in 2001 as indicated earlier.

Number of patches:

The number of patches for grassland was slightly decreased from 2001 (close to area of neutral model LE 85) to 2004 (close to area of neutral model LE 80). The number of patches for standing water was slightly increased. The Rock pile was the same, and stump and cattail were first visible in 2004.

Mean patch size:

Mean patch sizes of standing water and rock pile were slightly increased. Grassland was decreased. Some of the grassland area might have been flooded with water when fieldwork was constructed. It may be a permanent change or only seasonally because 2004 measurement was taken in spring season when water table was higher.

Patch size standard deviation:

Patch size standard deviation of grassland and rock pile were decreased suggesting a slightly increase in homogeneous of the entities. However, the numbers were not significant. Patch size SD of standing water increased a lot. There were more patches of water in 2004 than in 2001 and mean patch size increased significantly; therefore, SD of this entity appeared as expected.

Dominance:

Dominance of 2001 was closed to 1.0 indicated the landscape was dominate by one landscape feature/entity. Dominance decreased significantly in 2004 because the wetland was flooded so there were more scattered patches in the landscape.

Conclusion

Wetland ecosystems are very complicated. Direct relationships between entities are extremely difficult to determine. This research characterized the landscape and indicated that the wetland has changed during 2001 to 2004. Landscape pattern metrics for each class for both DOQQ and the landscape from GPS points were compared. The neutral models were examined. The result indicated that grassland was decreased and standing water was increased significantly. However number of patch for both classes did not change extensively. This means the area is not fragmented. This gives us a better understanding of the changes in landscape. The model developed for this research could easily be applied to any wetland restoration area. Furthermore, this result will guide more systematic and effective resource management and preservation plans for wetland.

Potential sources of error

1. Accuracy of the field survey method conducted in 2004 could be a potential problem. Point data were not actually sufficient to draw the boundaries of the landscape features.
2. The accuracy of GPS during the fieldwork could be an issue.
3. Conversion between vector and raster model could be another source of error although the processes had been carefully performed.
4. Classification of DOQQ image could have high error due to the lack of experience in aerial photo interpretation and local knowledge of the study in 2001.

Appendix A

For 2001 image

```
Pro doqq
image = make_array(4815,3501)
file = 'c:\classes\geo825\dig_doqq_tif.tif'
tiff = read_tiff(file,r,g,b)
image = tiff
help, image
;tvscl, image

class1 = image eq 1
class2 = image eq 2
class3 = image eq 3
class4 = image eq 4
class5 = image eq 5
class6 = image eq 6
;Print, 'Area of class1 =', total(class1)
;Print, 'Area of class2 =', total(class2)
;Print, 'Area of class3 =', total(class3)
;Print, 'Area of class4 =', total(class4)

patch_label1 = label_region(class1)
patch_label2 = label_region(class2)
patch_label3 = label_region(class3)
patch_label4 = label_region(class4)
patch_label5 = label_region(class5)
patch_label6 = label_region(class6)
;Print, 'Number of patch class1', max(patch_label1)
;Print, 'Number of patch class2', max(patch_label2)
;Print, 'Number of patch class3', max(patch_label3)
;Print, 'Number of patch class4', max(patch_label4)

reg = label_region(class1)
numreg = max(reg)
outreg = make_array(numreg, /float)
j=1
   repeat begin
   cells= n_elements(where(patch_label1 eq j))
   area = cells
   ;Print, 'Area of patch',j, '=', area
   outreg[j-1]=area
   j=j+1
   endrep until j GT numreg
   Print, 'Mean Area patch class1 =', mean(outreg)
```

```
   IF (numreg NE 1) THEN sdv = stddev(outreg) ELSE sdv = 0
   Print, 'St. dev. of patch class1 =', sdv
   Print, 'Number of patch class2 =', numreg

k=1
   reg2 = label_region(class2)
   numreg2 = max(reg2)
   outreg2 = make_array(numreg2, /float)
   repeat begin

   cells= n_elements(where(patch_label2 eq k))
   area = cells
   outreg2[k-1]=area
   k=k+1
   endrep until k GT numreg2
   Print, 'Mean Area patch class2 =', mean(outreg2)
   Print, 'St. dev. of patch class2 =', stddev(outreg2)
   Print, 'Number of patch class2 =', numreg2

l=1
   reg6 = label_region(class6)
   numreg6 = max(reg6)
   outreg6 = make_array(numreg6, /float)
   repeat begin

   cells= n_elements(where(patch_label6 eq l))
   area = cells
   outreg6[l-1]=area
   l=l+1
   endrep until l GT numreg6
   Print, 'Mean Area patch class6 =', mean(outreg6)
   Print, 'St. dev. of patch class6 =', stddev(outreg6)
   Print, 'Number of patch class6 =', numreg6
end
```

For 2004 image

```
Pro gps
image = make_array(4815,3501)
file = 'c:\classes\geo825\dig_gps_tif.tif'
tiff = read_tiff(file,r,g,b)
image = tiff
help, image
;tvscl, image

class1 = image eq 1
```

```
class2 = image eq 2
class3 = image eq 3
class4 = image eq 4
class5 = image eq 5
class6 = image eq 6
;Print, 'Area of class1 =', total(class1)
;Print, 'Area of class2 =', total(class2)
;Print, 'Area of class3 =', total(class3)
;Print, 'Area of class4 =', total(class4)

patch_label1 = label_region(class1)
patch_label2 = label_region(class2)
patch_label3 = label_region(class3)
patch_label4 = label_region(class4)
patch_label5 = label_region(class5)
patch_label6 = label_region(class6)
;Print, 'Number of patch class1', max(patch_label1)
;Print, 'Number of patch class2', max(patch_label2)
;Print, 'Number of patch class3', max(patch_label3)
;Print, 'Number of patch class4', max(patch_label4)

j=1
   reg1 = label_region(class1)
   numreg1 = max(reg1)
   outreg1 = make_array(numreg1, /float)
   repeat begin

   cells= n_elements(where(patch_label1 eq j))
   area = cells
   outreg1[j-1]=area
   j=j+1
   endrep until j GT numreg1
   Print, 'Mean Area patch class1 =', mean(outreg1)
   Print, 'St. dev. of patch class1 =', stddev(outreg1)
   Print, 'Number of patch class1 =', numreg1

k=1
   reg2 = label_region(class2)
   numreg2 = max(reg2)
   outreg2 = make_array(numreg2, /float)
   repeat begin

   cells= n_elements(where(patch_label2 eq k))
   area = cells
   outreg2[k-1]=area
   k=k+1
```

```
   endrep until k GT numreg2
   Print, 'Mean Area patch class2 =', mean(outreg2)
   Print, 'St. dev. of patch class2 =', stddev(outreg2)
   Print, 'Number of patch class2 =', numreg2

l=1
   reg3 = label_region(class3)
   numreg3 = max(reg3)
   outreg3 = make_array(numreg3, /float)
   repeat begin

   cells= n_elements(where(patch_label3 eq l))
   area = cells
   outreg3[l-1]=area
   l=l+1
   endrep until l GT numreg3
   Print, 'Mean Area patch class3 =', mean(outreg3)
   Print, 'St. dev. of patch class3 =', stddev(outreg3)
   Print, 'Number of patch class3 =', numreg3

m=1
   reg4 = label_region(class4)
   numreg4 = max(reg4)
   outreg4 = make_array(numreg4, /float)
   repeat begin

   cells= n_elements(where(patch_label4 eq m))
   area = cells
   outreg4[m-1]=area
   m=m+1
   endrep until m GT numreg4
   Print, 'Mean Area patch class4 =', mean(outreg4)
   Print, 'St. dev. of patch class42 =', stddev(outreg4)
   Print, 'Number of patch class4 =', numreg4

n=1
   reg5 = label_region(class5)
   numreg5 = max(reg5)
   outreg5 = make_array(numreg5, /float)
   repeat begin

   cells= n_elements(where(patch_label5 eq n))
   area = cells
   outreg5[n-1]=area
   n=n+1
   endrep until n GT numreg5
```

```
    Print, 'Mean Area patch class5 =', mean(outreg5)
    Print, 'St. dev. of patch class5 =', stddev(outreg5)
    Print, 'Number of patch class5 =', numreg5

o=1
    reg6 = label_region(class6)
    numreg6 = max(reg6)
    outreg6 = make_array(numreg6, /float)
    repeat begin

    cells= n_elements(where(patch_label6 eq o))
    area = cells
    outreg6[o-1]=area
    o=o+1
    endrep until o GT numreg6
    Print, 'Mean Area patch class6 =', mean(outreg6)
    Print, 'St. dev. of patch class6 =', stddev(outreg6)
    Print, 'Number of patch class6 =', numreg6

End
```

Appendix B

```
Pro LPI_fi
file = 'C:\classes\geo825\dig_gps_tif.tif'
image = read_tiff(file)
count = bytarr(4815,3501)
count = image
; Find the largest patch for the forest class
reg = label_region(count eq 1,/all_neighbors,/ulong)
numreg = max(reg)
total_area = total(count)
area_array = make_array(n_elements(reg), /float)

vec_ps = MAKE_ARRAY(numreg, /float, VALUE = 0.0)
 k = 1

;Start loop finding the largest patch
   while (k LE numreg) do begin

     index = where(reg EQ k)
     p_area = n_elements(index)
     vec_ps[k-1] = p_area
      k = k+1

   endwhile

;Find the max area
   largest = max(vec_ps)
;Calculate dominance value
   dominance = largest/total_area
print,'Largest patch area = ', largest
print, ' Dominance =',dominance
end
```

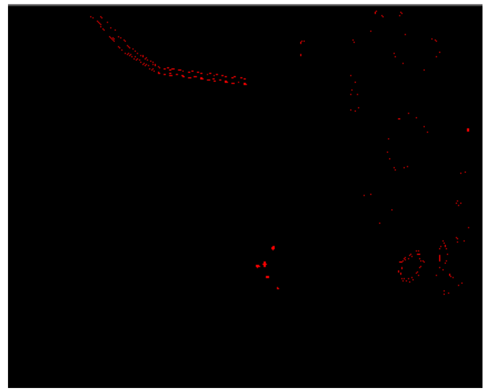
Appendix C

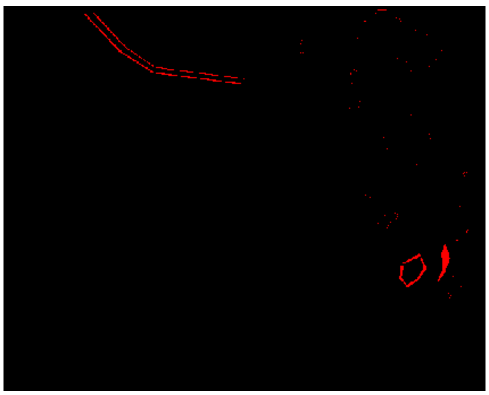
```
pro neutral
array_area = make_array(10, /float)
array_max = make_array(10, /long)
array_mean = make_array(10,/long)
x=0.1
y = 1
WHILE x lt 1.1 do begin

random = randomu(seed, 4815, 3501)
img1 = random lt x
x = x + 0.1
total_area = total(img1)
array_area[y] = total_area

label = label_region(img1,/all_neighbors,/ulong)
;number of patches
num_patch = max(label)
array_max[y] = num_patch
mean_size = total_area/num_patch
array_mean[y] = mean_size

print, 'area =', array_area[y]
print, 'number of patches = ',array_max[y]

outreg = make_array(num_patch, /float)
j=1
   repeat begin

   cells= n_elements(where(label eq j))
   area = cells
   outreg[j-1]=area
   j=j+1
   endrep until j GT num_patch
   Print, 'Mean Area patch type', mean(outreg)
   if n_elements(outreg) gt 1 then begin
   Print, 'St. dev. of patch type', stddev(outreg)
   endif else begin
   Print, 'St. dev. of patch type',': 0'
   endelse

endwhile
end
```

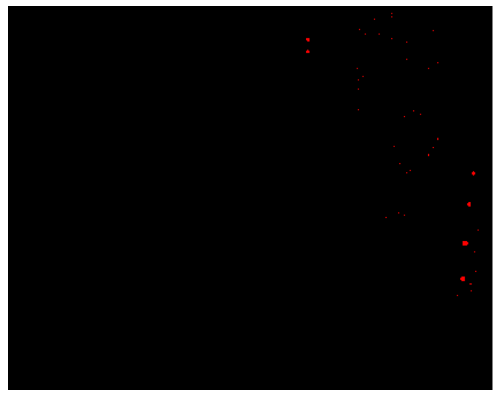
Appendix D

```
CONDITIONAL { ($n4_dig_doqq_gr == 1.0 AND $n1_dig_gps_gr == 1.0) 11 ,
              ($n4_dig_doqq_gr == 1.0 AND $n1_dig_gps_gr == 2.0) 12 ,
              ($n4_dig_doqq_gr == 1.0 AND $n1_dig_gps_gr == 3.0) 13 ,
              ($n4_dig_doqq_gr == 1.0 AND $n1_dig_gps_gr == 4.0) 14 ,
              ($n4_dig_doqq_gr == 1.0 AND $n1_dig_gps_gr == 5.0) 15 ,
              ($n4_dig_doqq_gr == 1.0 AND $n1_dig_gps_gr == 6.0) 16 ,
              ($n4_dig_doqq_gr == 2.0 AND $n1_dig_gps_gr == 1.0) 21 ,
              ($n4_dig_doqq_gr == 2.0 AND $n1_dig_gps_gr == 2.0) 22 ,
              ($n4_dig_doqq_gr == 2.0 AND $n1_dig_gps_gr == 3.0) 23 ,
              ($n4_dig_doqq_gr == 2.0 AND $n1_dig_gps_gr == 4.0) 24 ,
              ($n4_dig_doqq_gr == 2.0 AND $n1_dig_gps_gr == 5.0) 25 ,
              ($n4_dig_doqq_gr == 2.0 AND $n1_dig_gps_gr == 6.0) 26 ,
              ($n4_dig_doqq_gr == 6.0 AND $n1_dig_gps_gr == 1.0) 61 ,
              ($n4_dig_doqq_gr == 6.0 AND $n1_dig_gps_gr == 2.0) 62 ,
              ($n4_dig_doqq_gr == 6.0 AND $n1_dig_gps_gr == 3.0) 63 ,
              ($n4_dig_doqq_gr == 6.0 AND $n1_dig_gps_gr == 4.0) 64 ,
              ($n4_dig_doqq_gr == 6.0 AND $n1_dig_gps_gr == 5.0) 65 ,
              ($n4_dig_doqq_gr == 6.0 AND $n1_dig_gps_gr == 6.0) 66 }
```

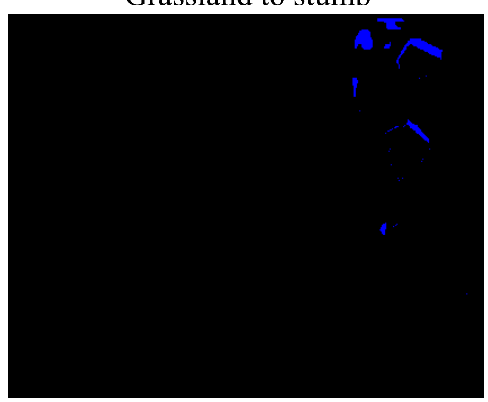

Grassland to standing water


Grassland to tree


Grassland to cattail


Grassland to stump


Grassland to rock pile


Water to grassland


Rock pile to grassland

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