# Detection of Land-Use and Land Cover Changes in Franklin, Gulf, and Liberty Counties, Florida, with Multitemporal Landsat Thematic Mapper Images

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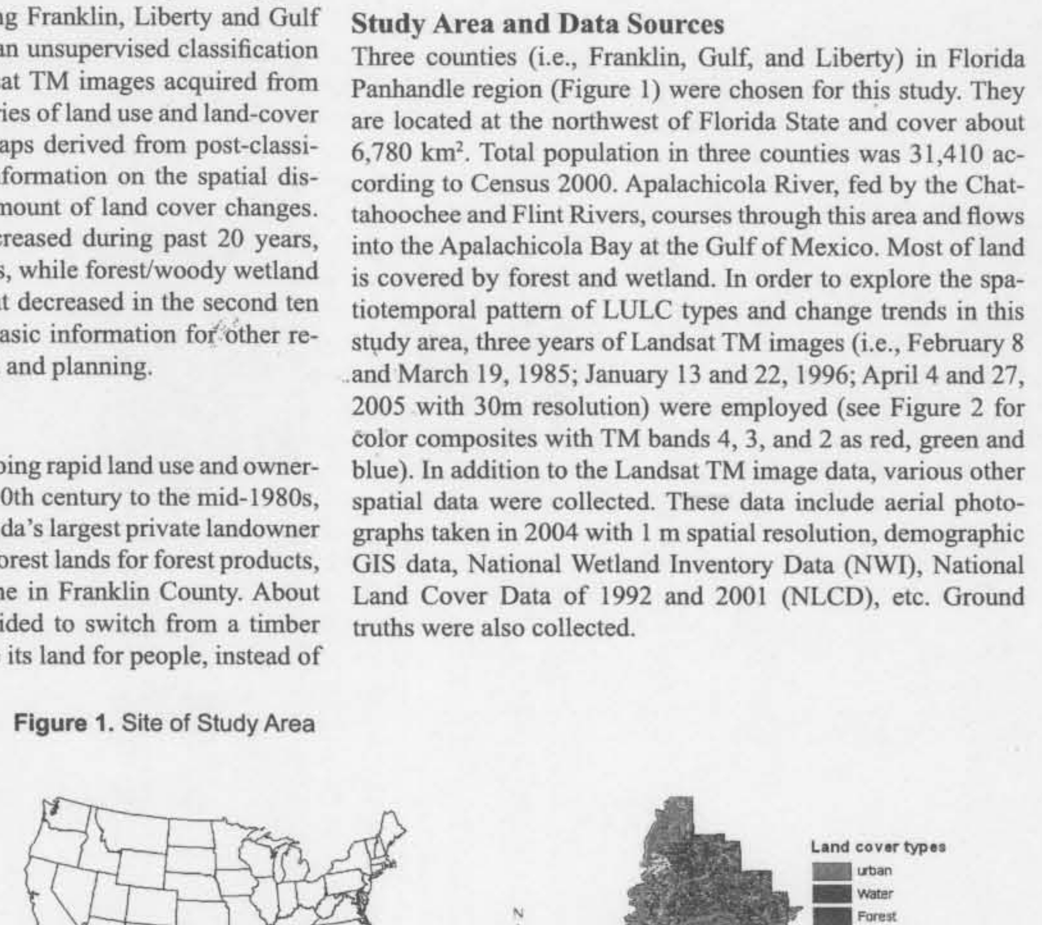
**Abstract**
Florida Panhandle region has been experiencing rapid land transformation in the recent decades. To quantify land use and land-cover (LULC) changes and other landscape changes in this area, three counties including Franklin, Liberty and Gulf were taken as a case study and an unsupervised classification approach implemented to Landsat TM images acquired from 1985 to 2005 provided a time-series of land use and land-cover data sets. Land-cover change maps derived from post-classification comparison provided information on the spatial distribution and types as well as amount of land cover changes. Results indicated that urban increased during past 20 years, especially in the second ten years, while forest/woody wetland increased in the first ten year but decreased in the second ten years. These data sets provide basic information for other research such as land management and planning.

## Introduction

The Florida Panhandle is undergoing rapid land use and ownership changes. From the turn of 20th century to the mid-1980s, St. Joe's Lumber Company, Florida's largest private landowner managed over 800,000 acres of forest lands for forest products, also owned 20 miles of coastline in Franklin County. About 10 years ago, the company decided to switch from a timber company to a developer, and use its land for people, instead of trees. Now St. Joe Co. wants to develop much of hundreds of thousands of acres land in Panhandle region. It is predicted, the resulting LULC changes will significantly affect natural ecosystems, especially water quality, and economic conditions, including fishery. Actually, according the people living in coastal Franklin County, quality of water in Apalachicola bay is declining due to development (NPR News, Morning edition, April 30, 2007). Time-series of LULC data sets will be essential for monitoring these changes and evaluating the impact of these changes on natural and economic characteristics. The objective of this study is to provide some preliminary results related to LULC mapping and change detection based on multitemporal Landsat TM images from 1985 to 2005.

**Figure 1.** Site of Study Area



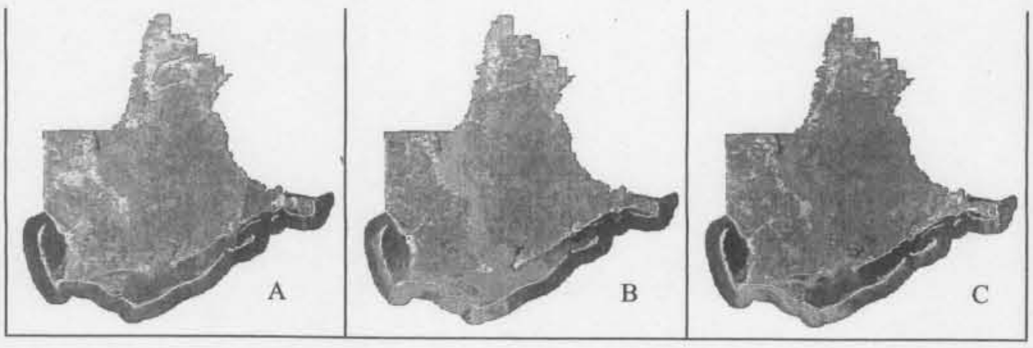

## Study Area and Data Sources

Three counties (i.e., Franklin, Gulf, and Liberty) in Florida Panhandle region (Figure 1) were chosen for this study. They are located at the northwest of Florida State and cover about 6,780 km$^2$. Total population in three counties was 31,410 according to Census 2000. Apalachicola River, fed by the Chattahoochee and Flint Rivers, courses through this area and flows into the Apalachicola Bay at the Gulf of Mexico. Most of land is covered by forest and wetland. In order to explore the spatiotemporal pattern of LULC types and change trends in this study area, three years of Landsat TM images (i.e., February 8 and March 19, 1985; January 13 and 22, 1996; April 4 and 27, 2005 with 30m resolution) were employed (see Figure 2 for color composites with TM bands 4, 3, and 2 as red, green and blue). In addition to the Landsat TM image data, various other spatial data were collected. These data include aerial photographs taken in 2004 with 1 m spatial resolution, demographic GIS data, National Wetland Inventory Data (NWI), National Land Cover Data of 1992 and 2001 (NLCD), etc. Ground truths were also collected.

## Methodology

The Landsat TM images were registered to UTM coordinate system with root mean square errors of less than 0.5 pixels. Because of the impacts of atmosphere on short wavelengths and high correlation between the visible bands, TM band 1 (blue band) was not used during image classification. Instead, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) derived from TM images were incorporated into the classification procedure in order to assist distinction of different vegetation types. The images were then stratified into urban and rural. An unsupervised classification was implemented for individual portions separately. According to the complexity of landscape of individual portions and their areas, diffident numbers of clusters were produced. For example, rural area generated 100 spectral clusters and urban portion generated 30-40 clusters. The spectral features of different LULC types were analyzed and aerial photographs and previous LULC thematic maps were used to assist the assignment of meaningful class for each cluster. 11 LULC types (i.e., urban, water, evergreen forest, deciduous forest, mixed forest, shrub, emergent herbaceous wetland, woody wetland, cropland, grass/pasture, and barren land) were identified. The whole land cover map for each year was merged by adding individual portions together. For the obliviously misclassified areas, post-refinement was conducted by manual corrections. Finally, six land-cover types were merged. Areas and percentages of each land-cover type were calculated.

**Figure 2.** Landsat Images, Color Composition with TM Bands 4, 3, 2 as Red, Green, and Blue. The study area is cross on two TM scenes. A. TM image was taken on February 8 and March 19, 1985; B. TM image was taken on January 13 and 22; C. TM image was taken on April 4 and 27, 2005.




The post-classification comparison approach was used to detect LULC changes. Change matrixes were produced by comprising LULC maps between two years. LULC change areas were calculated and spatial distribution and trajectories of changes were analyzed.

## Results

The classification results (see Figure 3) indicate that forest/ woody wetland cover over half of the study area (from 57% to 63%) and the developed areas are very limited (see Figure 4) in these three counties. Table 1 provides areas of LULC types and their percentage over the study area.

Comparison and change detection results show that urban areas increased from 1.09% in 1985 to 1.95% in 2005, and large change occurred during 1995 to 2005 with growth rate of 74.05%, in other words, the urbanization rate during 1996–2005 is faster than that during 1985–1996 (see Table 1). Urban expansion usually occurred along highways converted from forest/woody wetland. From 1985 to 1996, forest /woody wetland increased, while the shrub/young forest and barren land decreased due to regeneration. Figure 6A gives an example of changes from clear out barren land to forest. However, overall forest /woody wetland decreased during 1996—2005, although some areas of shrub/ young forest grew to mature forest (Figure 6B). Comparing 1996 and 2005 TM images, we found, there are large patches where deforestation happened in Franklin County resulting in increase of grass/pasture. Another contributor to forest/woody wetland declination is the urbanization. The change matrix (Table 2) shows, during the period of 1996–2005 about 6000 ha of forest/woody wetland converted to urban. Figure 5 gives distribution of land cover transformation between major types.

## Discussion

In this study initially 11 land cover types were identified. However, LULC classification and change detection in the subtropical landscape is especially difficult due to overlap of spectral signature between land-cover types and impacts of complex environmental conditions on the land surface reflectance. There is much confusion on spectral signature between woody wetland and forest, among forest types (especially leaf-on images), between pasture, grass and crop, even scrubs, between urban and barren land, which limit accuracy in mapping with satellite images. That is why we merged 11 types to 6 coarse categories based on similarities of their spectral response. Environmental conditions also influence the spectral response of land surface features. For example, fluctuating water content is an important factor, which changes the spectral reflectance of vegetation and other land-cover types, leading difficulties to separate different vegetation types, and urban and barren lands (Ozesmi and Bauer, 2002). More moist under the vegetated areas often reduces the vegetation reflectance, especially in the near and shortwave infrared wavelengths, which bands are critical for separation of vegetation classes. Urban areas often have relatively low reflectance because of the dark color construction materials and shadows cast from building or tall trees, and urban areas are often mixed with trees and grass. Therefore, land-cover classification based on pure spectral signatures in the wetland environment often results in poor classification performance. In order to separate wetland from upland vegetation, using image data acquired when the wetlands are at their highest water levels are optimal. Multi-seasonal images acquired at diffident phenological seasons like leaf-on and leaf-off will be helpful for separation of diffident forest types ((Bolstad and Lillesand, 1992; Boyer et al. 1988; Miller et al. 1991; Shriever and Congalton 1993). Hence, more ancillary information such as hydrological data, soil, elevation and census data are needed to improve the classification performance. For example, hydrological data may be useful for better separation of upland forest and wetland forest, and use of population distribution for separation of barren lands from urban residential areas. The low spatial resolution is also an important factor resulting in misclassification because of the mixed pixels inherent in the remote sensing data. Higher spatial resolution data, such as SPOT and IKONOS, will be helpful, especially for the urban landscape. Higher spatial resolution data with advanced classification algorithms will be explored in this study area in our research. More ground truth data will be collected for assisting the land cover classification and for assessment of the classification results.

The performance of post-classification comparison approach is especially influenced by the accuracies of individual classification images, thus, this approach may be not suitable for the land cover change detection in the wetland environments. We will explore some advanced or new change detection approaches for improving land cover change detection in this study area.

**Figure 3.** Land Cover Pattern Derived from Landsat TM Data

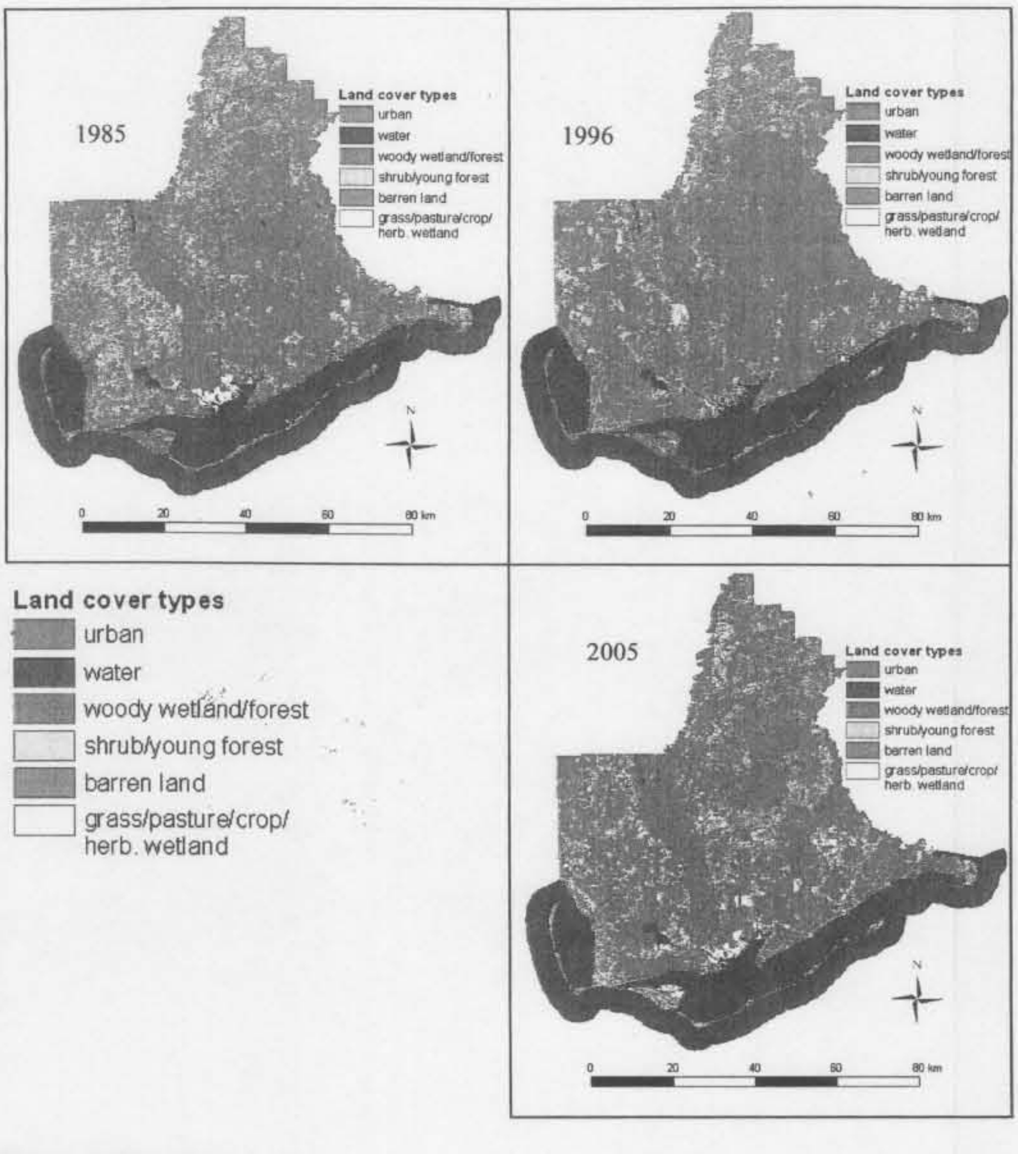



**Figure 4.** Urban Area


## Conclusions

Landsat TM images are still the primary data sources for LULC classification and change detection in a large area. The preliminary results in this study indicate the important LULC change trends in this study area and can be used as a basis for land management and planning. More research is planned for improving LULC classification and change detection through a combinative use of higher spatial resolution images and ancillary data with more advanced algorithms in this study area.

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**Table 1.** Areas, Percentages, and Overall Amount of Changes in LULC (unit: hectare)

| Land cover types | 1985 | | 1996 | | Changes | |
|---|---|---|---|---|---|---|
| | Area | Percentage | Area | Percentage | Area | Percentage |
| Urban | 7412 | 1.09 | 7641 | 1.12 | 229 | 3.09 |
| Water | 174642 | 25.66 | 176768 | 25.97 | 2126 | 1.22 |
| Forest/woody wetland | 391191 | 57.47 | 430411 | 63.23 | 39220 | 10.03 |
| Herb. wetland/grass/ crop/pasture | 47359 | 6.96 | 28700 | 4.22 | -18659 | -39.40 |
| Shrubs/young forest | 39587 | 5.82 | 31441 | 4.62 | -8146 | -20.58 |
| Barren land | 20530 | 3.02 | 5737 | 0.84 | -14793 | -72.06 |
| Total | 680721 | 100.00 | 680698 | 100.00 | | |
| **Land cover types** | **1996** | | **2005** | | **Changes** | |
| | Area | Percentage | Area | Percentage | Area | Percentage |
| Urban | 7641 | 1.12 | 13299 | 1.95 | 5658 | 74.05 |
| Water | 176768 | 25.97 | 177847 | 26.13 | 1079 | 0.61 |
| Forest/woody wetland | 430411 | 63.23 | 408477 | 60.01 | -21934 | -5.10 |
| Herb. wetland/grass/ crop/pasture | 28700 | 4.22 | 67845 | 9.97 | 39146 | 136.40 |
| Shrubs/young forest | 31441 | 4.62 | 8152 | 1.20 | -23289 | -74.07 |
| Barren land | 5737 | 0.84 | 5076 | 0.75 | -660 | -11.51 |
| Total | 680698 | 100.00 | 680697 | 100.00 | | |
| **Land cover types** | **1985** | | **2005** | | **Changes** | |
| | Area | Percentage | Area | Percentage | Area | Percentage |
| Urban | 7412 | 1.09 | 13299 | 1.95 | 5887 | 79.42 |
| Water | 174642 | 25.66 | 177847 | 26.13 | 3205 | 1.84 |
| Forest/woody wetland | 391191 | 57.47 | 408477 | 60.01 | 17286 | 4.42 |
| Herb. wetland/grass/ crop/pasture | 47359 | 6.96 | 67845 | 9.97 | 20487 | 43.26 |
| Shrubs/young forest | 39587 | 5.82 | 8152 | 1.20 | -31435 | -79.41 |
| Barren land | 20530 | 3.02 | 5076 | 0.75 | -15453 | -75.27 |
| Total | 680721 | 100.00 | 680697 | 100.00 | -24 | |

**Figure 5.** Major Land Cover Changes During 20 Years

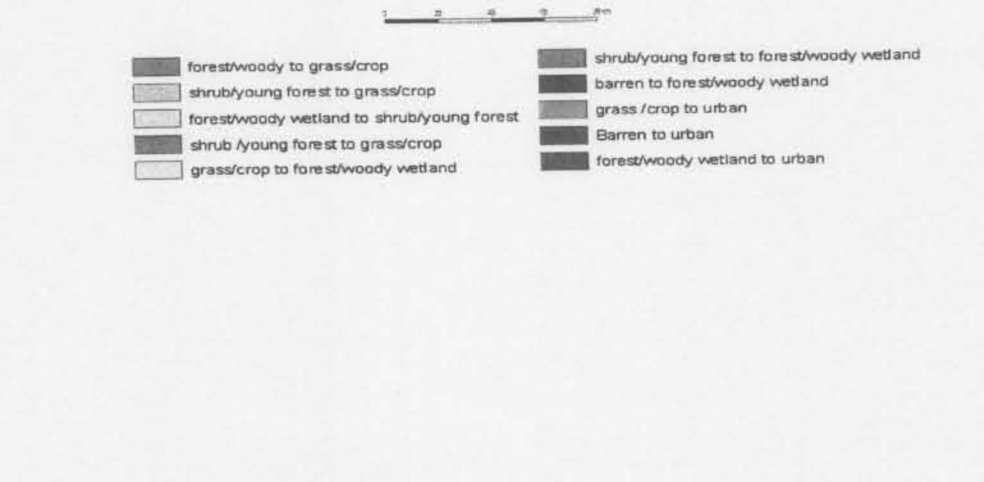


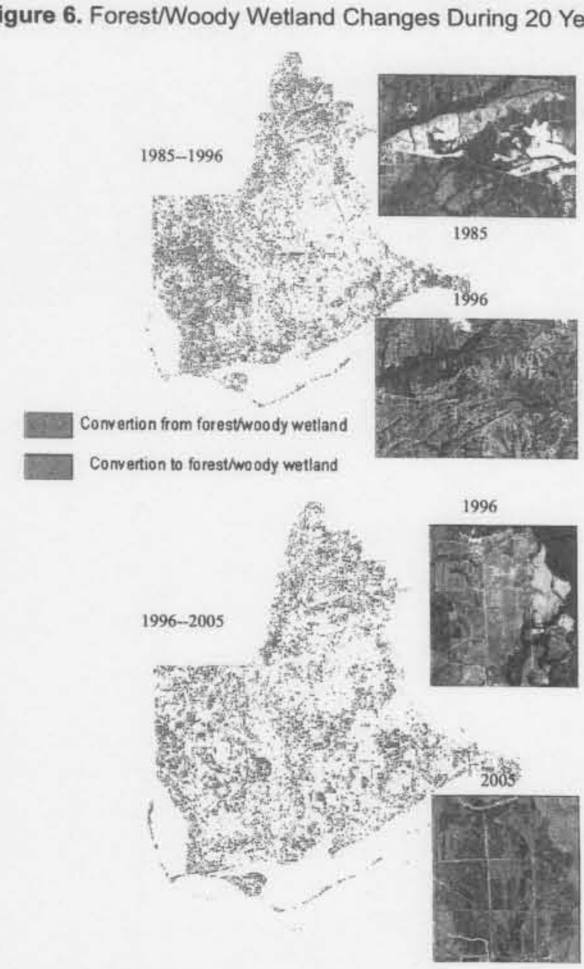
**Table 2.** Land Cover Change Matrix During 20 Years (unit: hectare)

| 1985 / 1996 | Water | Forest/ Woody wetland | Shrub/ young forest | Urban | Grass/pasture/crop/ herbaceous wetland | Barren land | Total |
|---|---|---|---|---|---|---|---|
| Water | 172399 | 1647 | 56 | 83 | 1636 | 808 | 176629 |
| Forest/woody wetland | 785 | 350129 | 30379 | 3220 | 34256 | 11577 | 430346 |
| Shrub/young forest | 11 | 19359 | 5913 | 576 | 3133 | 2436 | 31428 |
| Urban | 80 | 2483 | 494 | 2443 | 1091 | 1048 | 7640 |
| Grass/pasture/crop/ herbaceous wetland | 766 | 15986 | 2507 | 691 | 6671 | 2064 | 28686 |
| Barren land | 420 | 1541 | 231 | 398 | 554 | 2592 | 5736 |
| Total | 174460 | 391145 | 39581 | 7412 | 47341 | 20526 | 680466 |

| 1996 / 2005 | Water | Forest/ Woody wetland | Shrub/ young forest | Urban | Grass/pasture/crop/ herbaceous wetland | Barren land | Total |
|---|---|---|---|---|---|---|---|
| Water | 173848 | 780 | 80 | 147 | 1435 | 1437 | 177727 |
| Forest/woody wetland | 1006 | 369701 | 19685 | 2088 | 15151 | 770 | 408402 |
| Shrub/young forest | 4 | 4982 | 2074 | 164 | 740 | 187 | 8150 |
| Urban | 113 | 5961 | 1957 | 2758 | 1556 | 953 | 13297 |
| Grass/pasture/crop/ herbaceous wetland | 1379 | 47443 | 7328 | 1677 | 9376 | 623 | 67826 |
| Barren land | 246 | 1519 | 316 | 807 | 425 | 1763 | 5076 |
| Total | 176596 | 430386 | 31440 | 7641 | 28684 | 5733 | 680478 |

| 1985 / 2005 | Water | Forest/ Woody wetland | Shrub/ young forest | Urban | Grass/pasture/crop/ herbaceous wetland | Barren land | Total |
|---|---|---|---|---|---|---|---|
| Water | 172429 | 1474 | 83 | 74 | 1862 | 1698 | 177621 |
| Forest/woody wetland | 545 | 337446 | 27662 | 3024 | 28969 | 10786 | 408432 |
| Shrub/young forest | 1 | 4267 | 2200 | 177 | 579 | 925 | 8150 |
| Urban | 117 | 6412 | 1545 | 2234 | 1516 | 1474 | 13298 |
| Grass/pasture/crop/ herbaceous wetland | 1090 | 40123 | 7706 | 1485 | 13844 | 3566 | 67814 |
| Barren land | 273 | 1383 | 371 | 412 | 564 | 2073 | 5076 |
| Total | 174454 | 391105 | 39568 | 7407 | 47334 | 20523 | 680391 |

**Figure 6.** Forest/Woody Wetland Changes During 20 Years



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