SPATIOTEMPORAL EXPLORATION OF URBAN AREA EXPANSION AND DEFORESTATION IN NORTHEAST DISTRICT OF FLORIDA

Abstract*:* The US population growth over the last centuries caused substantial LULC change, which drove fast urbanization by transforming vegetation, waterbodies, and barren ground into impervious surfaces like residential properties, roads, infrastructure, etc. Through the evaluation of LULC, it depicts the information of the change of landuse which is vital to ensure sustainable living environment. This study aims to explore the spatiotemporal change in urban area and vegetation coverage over the period between 2000 and 2022 using maximum likelihood classification of satellite imagery with moderate spatial resolution as it covers up larger area, northeast district of Florida comprised of 17 counties. The study demonstrated that vegetation was the most affected LULC class, dropping from 51.39%, 51.09%, and 45.82% of total areas in 2000, 2014, and 2022, respectively. Urban areas gradually increased over time, occupying 9.90%, 16.44%, and 22.04% of total areas in 2000, 2014, and 2022, respectively. The most LULC class transition was found between vegetation to vegetation as it was 10839 sq.km. Nassau County was found at bottom in urban growth rate and deforestation rate with -3.47 and -4.96 respectively whereas Dubal County was at the top among 17 counties in terms of urban growth rate with 32.50 and Madison County was experiencing extreme vegetation loss with deforestation rate of 24.74 over last 22 years. There was found a positive correlation between urban growth rate and deforestation rate though it was weak as the "R" value was 0.30. So, it should be a matter of concern for policymakers to make a balance between urban expansion and vegetation loss, otherwise it can bring more natural disasters in near future i.e., increase in Land surface temperature, droughts etc.

Keywords*:* Landuse Land Cover, Change detection, Satellite Data, Remote Sensing, Northeast District, Florida

Introduction

Population growth accelerates the rural-to-urban migration process, and as a consequence, urbanization is pervasive (Moss. and O'Neill 2012). By 2050, it is anticipated that 70 percent of the world's population would reside in urban areas (United Nations 2019). The expansion of urban area includes development in infrastructure, road, utilities which is key reasons of change in Landuse Landcover (LULC) with the passage of time (C.Estoque, Murayama and W.Myint 2017) (Alam, Bhat and Maheen 2020). The assessment of LULC change plays a vital role in correlating with natural environment and human activity (M.Foody 2002) (Herold, Scepan and Clarke 2002) (Ji, et al. 2006) (Diallo, Hu and Wen 2009) (Hegazy and Kaloop 2015) (Liu and Yang 2015). Rapid urban growth brings about massive change in LULC as it accelerates deforestation rate and wetland loss due to increase in impervious surface (Tariq, et al. 2022).

The United States has undergone an extensive urbanization process over the past two centuries, changing rural areas into urbanized ones (Bureau 2012). According to data from the U.S. Census Bureau, Florida is not lagging behind other states in terms of population growth, and between 2010 and 2020, its urban area and population will expand by around 3 million people. Florida ranks 8th among states of United states in terms of percentage of urban population (91.2%) by 2010 (Bureau 2012). Northeast Florida is experiencing prominent urban growth rate due to population growth.

Remote Sensing is distinguished for LULC change estimate due to its cost-effectiveness and alternative to ground-based surveying (Liu and Yang 2015). LULC estimation from satellite imagery is less time-consuming, and the spatial resolution of satellite imagery (30m) is sufficient for large area assessment in terms of accuracy, despite the fact that it is somewhat difficult to classify urban features due to their diversity (Guindon, Zhang and Dillabaugh 2004) (Herold, Goldstein and C.Clarke 2003).

In this study, Land use Land Cover change attempt to find out urban growth rate and deforestation rate among 17 counties of Northeast district of Florida including overall landuse land cover change from 2000 to 2022 using Landsat image.

Materials and Methods

Study Area

Northeast district is one of the largest districts of Florida based on land mass (Strong 2022). It is situated between $29^0$38'25''N and $81^0$26'20''W. This district encompasses with ample natural resources including several reivers i.e., St. Johns River, Suwannee, Santa Fe rivers etc and this region is also acknowledged as the first coast of Florida (NEFRC 2022). With the passage of time, urbanization is increasing which results in economic diversity in this region (NEFRC 2022). It comprises of 17 counties i.e., Alachua, Baker, Bradford, Clay, Columbia, Dixie, Duval, Gilchrist, Hamilton, Lafayette, Madison, Nassau, Putnam, St. Johns, Suwannee, Taylor, and Union counties.

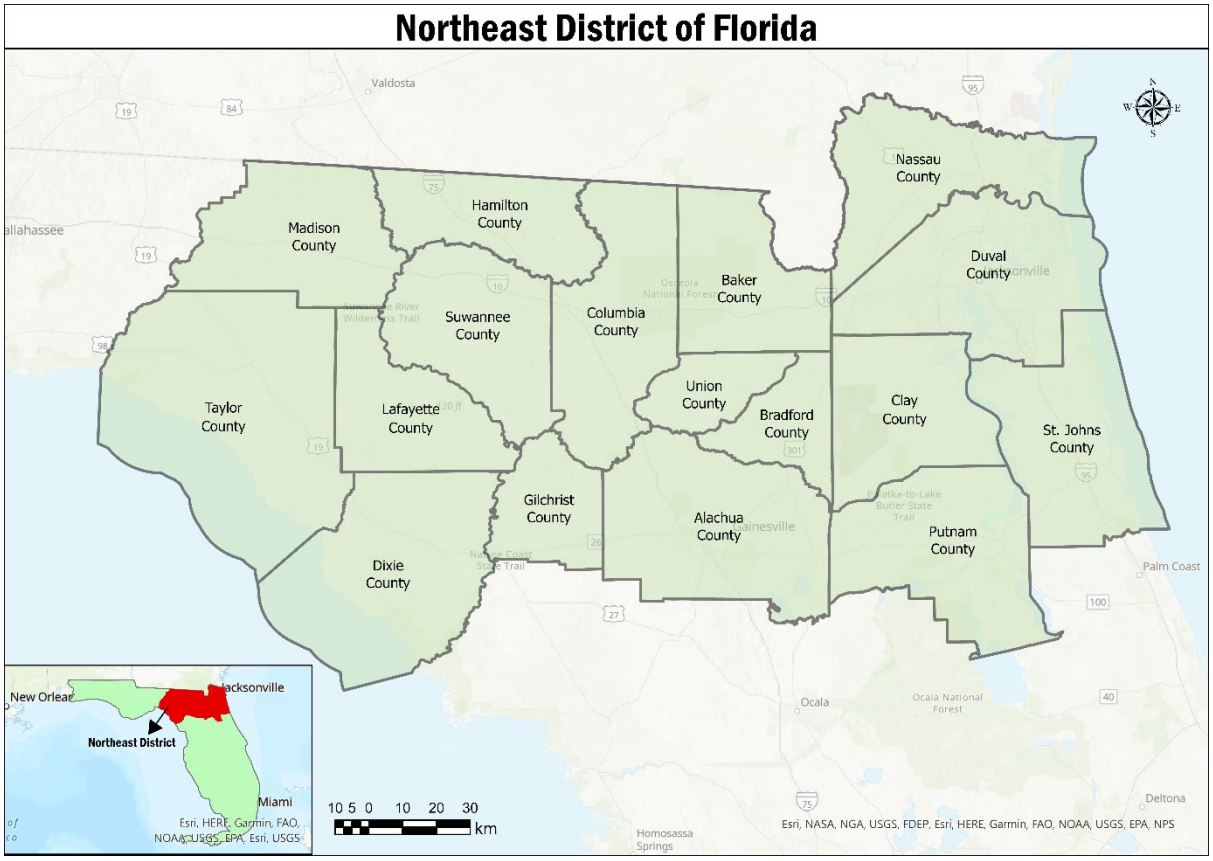


Figure 1 Study Area (Northeast District of Florida)

Data Sources

The spatial geodatabase was created to estimate LULC including urban growth rate and deforestation rate. Data was derived from different sources.

For LULC change assessment, Landsat 5 images was used for year 2000 and Landsat 8 & Landsat 9 images was used for year 2014 and year 2022. Near-infrared (NIR), Red, Green, and blue bands are used for generating natural color and false color image to ease the process of identification of different features. The classification process is run by ArcGIS Pro for clear visualization of satellite image after stacking different band combinations.

Table 1 Data Sources

Parameters	Data Source	Source Location
LULC	Landsat 5, Landsat 8 and Landsat 9	https://earthexplorer.usgs.gov/
Demographics	Administrative Boundary	https://www2.census.gov/geo/tiger/TIGER2016/COUSUB/tl_2016_12_cousub.zip

Land Use Land Cover Classification

Number of satellite images were downloaded with path/row to cover the study area.

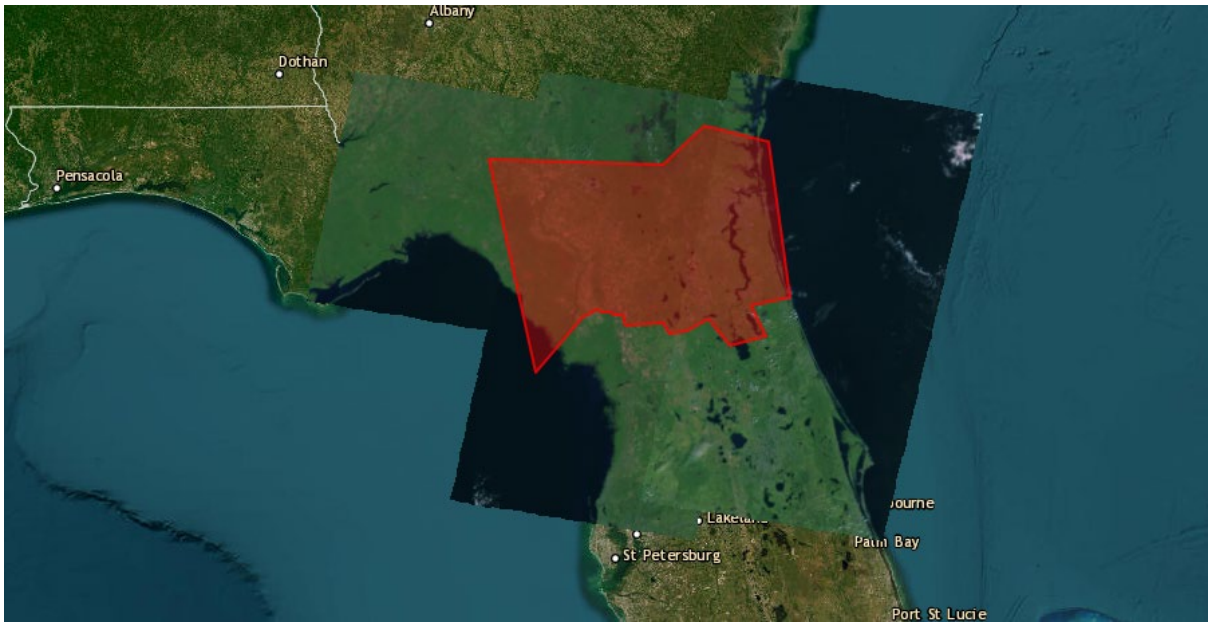


Figure 2 Satellite Images with different path row for study area; Source: USGS EarthExplorer

After downloading satellite images, images were stacked to generate a complete raster layer for study area. Then using pixel editor of ArcGIS pro, clouds were removed from satellite image using referenced image of same location. Characteristics of satellite images are provided in Table-2.

Table 2 Characteristics of Satellite Image

Landsat	Sensor	Resolution (m)	Range (µm)	Bands	Path/row	Acquisition
5	TM	30	0.45-0.90	1, 2, 3, 4	16-18/39-40	2000/02/04
8	OLI	30	0.452-0.879	2, 3, 4, 5	16-18/39-40	2014/02/10
9	OLI	30	0.43-0.88	2, 3, 4, 5	16-18/39-40	2022/03/27 2022/03/26

LULC classification was processed through image interpretation and classification using classification scheme (Table-3). Maximum likelihood classification was used to estimate LULC which basically performs based on two principles: the cells in each class sample in the multidimensional space being normally distributed and Bayes' theorem of decision making which evaluates the spectral response with algorithm (Liu and Yang 2015).

Table 3 Landuse landcover Classification Scheme

Class	Description
Waterbody	It includes waterbodies such as lakes, sea, river
Vegetation	It includes both dense and sparse vegetation i.e., green field, agriculture land, crop land, pastures
Urban	It includes development land, impervious features i.e., residential, industry, commercial, roads and other paved features
Barren	It includes vacant land near sea beach, open ground devoid of green surface

After finding out LULC of Northeast District of Florida for year 2000, year 2014, year 2022, the total coverage for each LULC class was calculated for abovementioned years using following formula:

> Area of each LULC class in square kilometres = count of pixels * 0.03 * 0.03 (as spatial resolution of satellite image is 30m).

A transition matrix was created to find out the transition among LULC classes using the coverage of each LULC classes between 2000 and 2022. Then, each raster layer was reclassified as value 1 for urban and value 0 for vegetation excluding water and barren land. Then each raster layer was converted into polygons to find out the total coverage for urban and vegetation coverage for years as mentioned. After converting the raster layers, they were clipped using each county to find out the county-wise coverage of urban area and vegetation area for year 2000, 2014, 2022 using modelbuilder in ArcGIS pro.

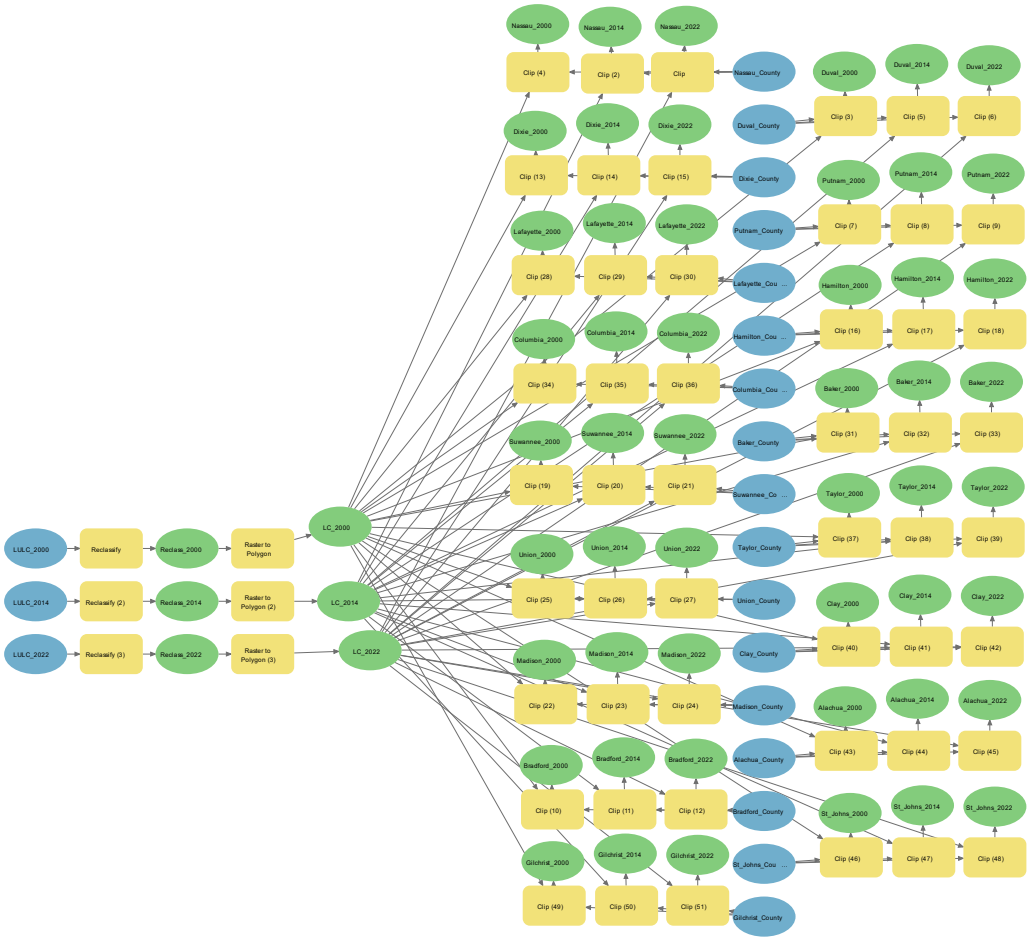


Figure 3 Modelbuilder of County-wise Urban and Vegetation Change Estimation for Northeast District of Florida

To find out the county-wise urban growth rate and deforestation rate over last 22 years, following formula is used:

Rate of change (Urban Growth or Deforestation Rate) = $\frac{Total\ Change\ in\ Urban\ area\ or\ Vegetation}{Number\ of\ Years}$

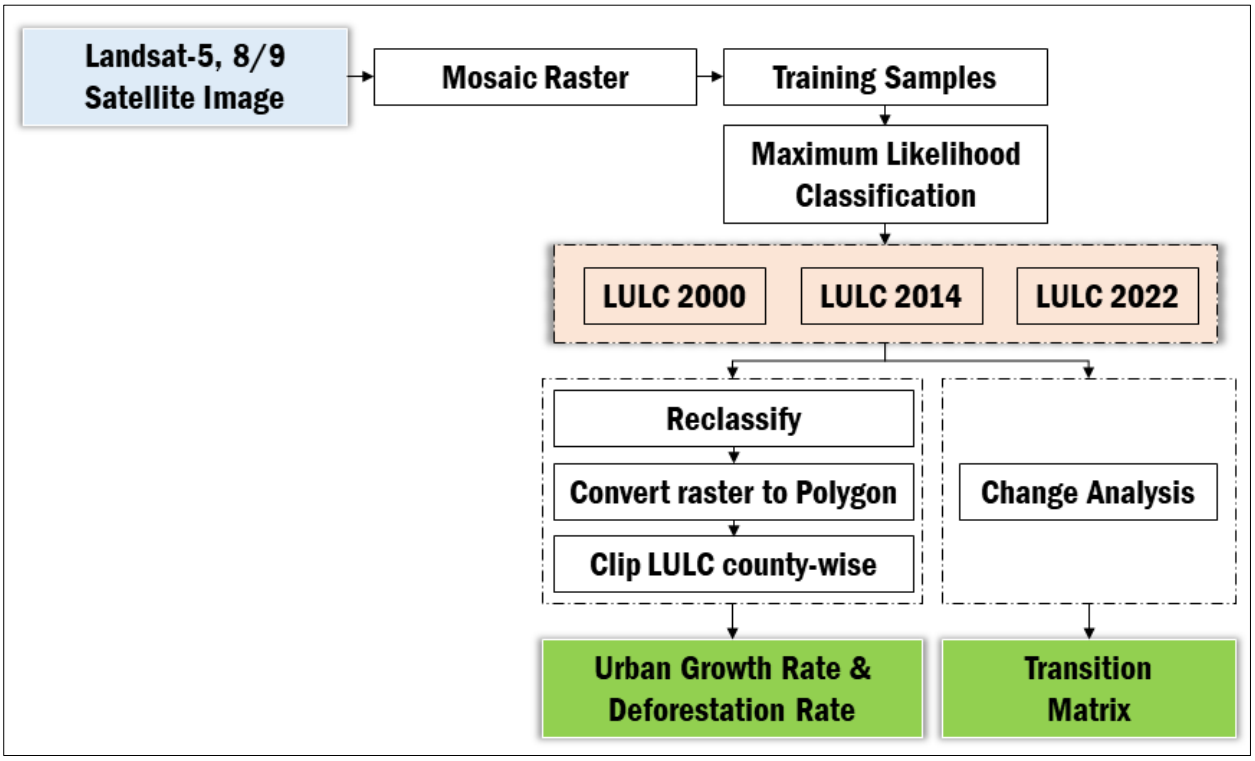


Figure 4 Methodology for Landuse Landcover classification

Results

In last 22 years, the study area went through massive land change from 2000 to 2022. Vegetation loss and barren land were transformed into urban area which was found the root cause of expansion of urban area.

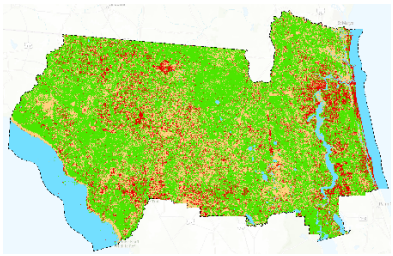


Figure 5 Landuse Landcover of Northeast District, Florida, 2000

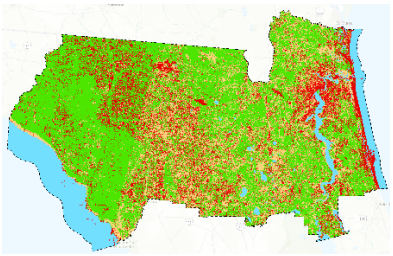


Figure 6 Landuse Landcover of Northeast District, Florida, 2014

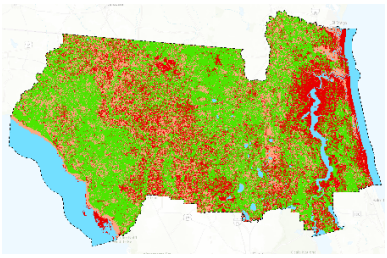
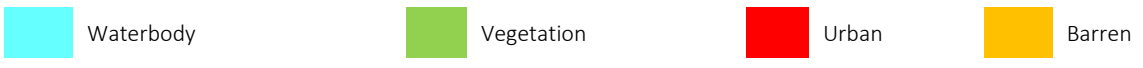


Figure 7 Landuse Landcover of Northeast District, Florida, 2022



Vegetation is most coverage area found in northeast district of Florida, but it is gradually declining over the study period with the expansion of urban area. Vegetation occupies about 51.39%, 51.09% and 45.82% of total areas in 2000, 2014, 2022 respectively as it was seen that there was massive vegetation loss in last 8 years. In response to vegetation, urban area occupies about 9.90%, 16.44% and 22.04% of total areas in 2000, 2014, 2022 respectively. From Figure 9 it is evident that from 2014 to 2022, there was massive decline in vegetation and expansion of urban area

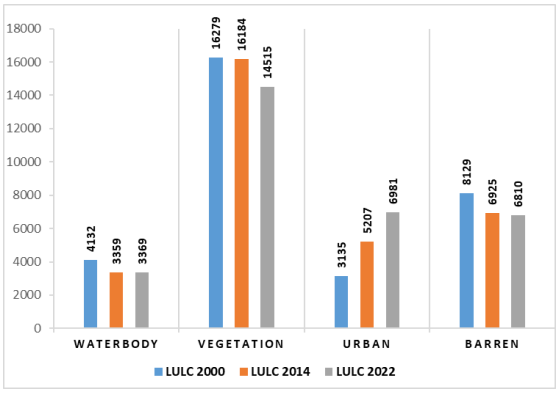


Figure 8 Area(sq.km) of LULC class for 2000, 2014, 2022

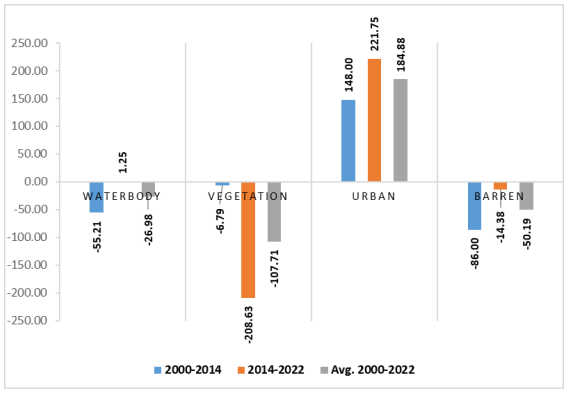


Figure 9 Rate of Change in LULC class for 2000, 2014, 2022

From the transition matrix table 4, it is found that most transition was between vegetation to vegetation. Then, 2467 sq.km. of barren land, 2479 sq.km. of vegetation area and 503 sq.km. of waterbody area was transformed into urban area in last 22 years.

Table 4 Transition Matrix of LULC from 2000-2022 for Northeast District, Florida

2000 LULC	2022 LULC				2022 Total
	Barren	Urban	Vegetation	Water	
Barren	2945	2467	2680	38	8130
Urban	680	1532	861	62	3135
Vegetation	2876	2479	10839	85	16279
Water	310	503	135	3184	4132
2000 Total	6811	6981	14515	3369	31676

During the study period, almost all counties of northeast district of Florida gained gradual urban growth rate whereas urban growth rate of some counties was not linear. Among 17 counties, Dubal County was found with most average urban growth rate (32.50), next to Putnam County (25.52) and Nassau was lagging with the urban growth rate next to Taylor County (0.99) in comparison of growth rate other counties. St. Jones county, Clay County and Alachua County were almost similar growth rate with little fluctuations as 17.80, 18.77 and 19.72.

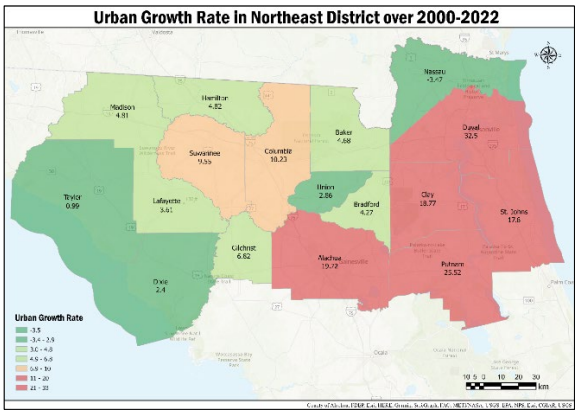


Figure 10 Urban Growth rate in Northeast District, Florida

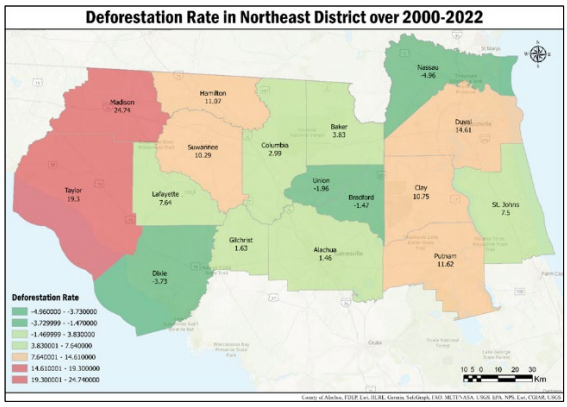


Figure 11 Deforestation rate in Northeast District, Florida

On the other hand, almost all counties of northeast district of Florida were going through vegetation loss during the study period. Among 17 counties, Madison County was found with most average deforestation rate (24.74), next to Taylor County (19.30). Some counties weren't experiencing extreme vegetation loss due to low expansion of urban area as Nassau County is with negative value (-4.96) indicated that it wasn't going extremely through the process of expanding urban area by transforming vegetation into impervious surface, next to Union County (-1.96) and Bradford County (-1.47).

Suwannee county, Hamilton County and Putnam County were almost similar deforestation rate with little fluctuations as 10.29, 11.07 and 11.62.

From both analysis of urban growth rate and deforestation rate, it was found that there was a positive correlation between urban growth rate and deforestation rate though the value of "R" was 0.30, near to zero as there are several factors and land classes influencing the expansion of urban area excluding vegetation.

Table 5 Correlation between Urban Growth Rate and Deforestation Rate

	Urban Growth Rate	Deforestation Rate
Urban Growth Rate	1	
Deforestation Rate	0.30	1

Discussion and Conclusion

Landuse landcover serves as an indicator of the change in the earth's surface caused by natural or human forces. The transformation in LULC can be evaluated using satellite imaging for wider areas to portray information on the spatiotemporal transition of landuse, which is difficult to cover by physical survey as it requires time, labor, and equipment. This study was conducted using Landsat images on the remote sensing platform (ArcGIS Pro) to determine the LULC change of the northeast district of Florida over the past 22 years, including urban growth rate in relation to deforestation rate for each county of the northeast district, Florida based on the LULC classification scheme (vegetation, waterbody, urban, and barren land). In 2000, 2014, and 2022, the area of the northeast district's vegetation was 16279 sq. km., 16184 sq. km., and 14515 sq. km., respectively. This study revealed that the northeast district has experienced an extreme trend of vegetation loss over the years, as the area of its vegetation was 16279 sq. km., 16184 sq. In contrast, as a result of the reduction of vegetation, urban area expanded dramatically over time, reaching 3,135 sq.km. in 2000, 5,207 sq.km. in 2014, and 6,981 sq.km. in 2022. This study clearly demonstrated the gradual growth of urban areas in the northeast district of Florida, where Duval County led other counties in terms of urban growth rate over the past 22 years, with an urban growth rate of 32.50, while Nassau County lagged behind, with an urban growth rate of -3.47. In comparison to the urban growth rate, Nassau County experienced less vegetation loss, as its deforestation rate was -4.96, while Madison County had the highest rate of deforestation among 17 counties, at 24.74. This study could aid policymakers and urban planners in the future planning of counties to provide a sustainable living environment with a balance between greenery and urban expansion.

References

Alam, Akhtar, M. Sultan Bhat, and M. Maheen. 2020. "Using Landsat satellite data for assessing the land use and land cover change in Kashmir valley." *GeoJournal* 85: 1529-1543. doi:https://doi.org/10.1007/s10708-019-10037-x.

Bay, NWS Tampa. 2022. *Urbanization and Our Climate.* 6 February. https://storymaps.arcgis.com/stories/21ff8cc0406548668f8fe3f131b96025.

Bureau, U.S. Census. 2012. *United Stated Summary: 2010.* U.S. Government Printing Office, Washington, DC: U.S. Census Bureau, 20-26.

C.Estoque, Ronald, Yuji Murayama, and Soe W.Myint. 2017. "Effects of landscape composition and pattern on land surface temperature: An urban heat island study in the megacities of Southeast Asia." *Science of The Total Environment* 577: 349-359. doi:https://doi.org/10.1016/j.scitotenv.2016.10.195.

Diallo, Yacouba, Guangdao Hu, and Xingping Wen. 2009. "Applications of Remote Sensing in Land Use/Land Cover Change Detection in Puer and Simao Counties, Yunnan Province." *Journal of American Science* 5 (4): 157-166.

Foster, Bruce. 1983. "Some urban measurements from Landsat data (Sydney, Australia)." *Photogrammetric Engineering & Remote Sensing* 49 (12): 1693-1707.

Guindon, Bert, Ying Zhang, and Craig Dillabaugh. 2004. "Landsat urban mapping based on a combined spectral–spatial methodology." *Remote Sensing of Environment* 92 (2): 218-232. doi:https://doi.org/10.1016/j.rse.2004.06.015.

Hegazy, Ibrahim Rizk, and Mosbeh Rashed Kaloop. 2015. "Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt." *International Journal of Sustainable Built Environment* 4 (1): 117-124. doi:https://doi.org/10.1016/j.ijsbe.2015.02.005.

Herold, M., J. Scepan, and K. Clarke. 2002. "The Use of Remote Sensing and Landscape Metrics to Describe Structures and Changes in Urban Land Uses." *Environment and Planning* 34 (8): 1443-1458. doi:https://doi.org/10.1068/a3496.

Herold, Martin, Noah C. Goldstein, and Keith C.Clarke. 2003. "The spatiotemporal form of urban growth: measurement, analysis and modeling." *Remote Sensing of Environment* 86 (3): 286-302. doi:https://doi.org/10.1016/S0034-4257(03)00075-0.

Ji, Wei, Jia Ma, Rima Wahab Twibel, and Karen Underhill. 2006. "Characterizing urban sprawl using multi-stage remote sensing images and landscape metrics." *Computers, Environment and Urban Systems* 30 (6): 861-879.

Liu, Ting, and Xiaojun Yang. 2015. "Monitoring land changes in an urban area using satellite imagery, GIS and landscape metrics." *Applied Geography* 56: 42-54. doi:https://doi.org/10.1016/j.apgeog.2014.10.002.

M.Foody, Giles. 2002. "Status of land cover classification accuracy assessment." *Remote Sensing of Environment* 80 (1): 185-201. doi:https://doi.org/10.1016/S0034-4257(01)00295-4.

Moss., Mitchell L., and Hugh O'Neill. 2012. *Urban Mobility in the 21st Century.* NYU Rudin Center for Transportation Policy.

NEFRC. 2022. *Northeast Florida Regional Council.* https://www.nefrc.org/regional-information.

Strong, Greg. 2022. *Florida Department of Environmental Protection.* https://floridadep.gov/northeast#:~:text=Jurisdiction%3A%20Alachua%2C%20Baker%2C%20Bradford,Suwannee%2C%20Taylor%20and%20Union%20counties.

Tariq, Aqil, Faisal Mumtaz, Xing Zeng, Muhammad Yousuf Jat Baloch, and Muhammad Farhan Ul Moazzam. 2022. "Spatio-temporal variation of seasonal heat islands mapping of Pakistan during 2000–2019, using day-time and night-time land surface temperatures MODIS and meteorological stations data." *Remote Sensing Applications: Society and Environment* 27. doi:https://doi.org/10.1016/j.rsase.2022.100779.

United Nations. 2019. *World Urbanization Prospects: the 2018 Revision (ST/ESA/SER.A/420).* New York: Department of Economic and Social Affairs, Population Division.