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ORIGINAL ARTICLE

Color slices analysis of land use changes due to urbanization in a city environment of Miami Area, South Florida, USA

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Abstract

Land use maps are widely using all over the world for monitoring the usage of lands over a while when urbanization booms. The urban development of the city environment parallelly involves the quick change of landcover in a short time. This work aims to review the land cover changes in Miami which areone of a highly urbanized county in the USA in the twentieth century. The color patterns of land use maps were reviewed with a uniform temporal rate (5 years once) from 2001 to 2016. Based on the color code of the image, land use maps were visually interpreted and it was extended to the Statistical analysis. Unique formulas are derived from the linear statistical model for the changing rate of the land use type in 15 years. Urban built-up gave expeditious increment in land use (9.5%). In the meantime, agricultural land (5.97%) and water (4.21%) decreased at a rapid rate. At the end of the study, the regression model projects the land use change in the year 2021 in Miami Dade County. This study distinctly exhibits how urbanization affects the vegetation cover, water areas, and wetlands, in which land use classes playing a vital role in the ecosystem. This experiment gives a basic understanding of Miami Dade county development and its environmental impact.

Keywords Land use · Land cover · Urban changes · Miami · Florida

Introduction

Urbanization defines the increasing number of people that live in urban areas and it originated when the Industrial Revolution started (Chen et al. 2014), it mainly includes three dynamic variations, i.e., population, economy and urban building areas (Yi et al. 2014) and elevation (Dewan and Yamaguchi 2009). Several studies found that Economic development is the main factor of Urbanization and it yielded positive results when the urbanization increases (Birch and Wachter 2011; Shepherd et al. 2013). Even though urbanization brings about a variety of spatial, economic, social, demographic, and environmental changes, it leads to a decline in area under agriculture, forest, and wetlands (Nath and Agarwal 2007; Almamalachy et al. 2019). The green spaces had been converted into built-up areas due to Global urban expansion (Bagan and Yamagata 2014). Agricultural land disappeared when the urbanization began rapidly (Mundhe and Jaybhaye 2014; Khudair et al. 2019). It affects habitat quality through the infilling of low-lying areas and clearing of vegetation (Dewan and Yamaguchi 2009; Fadhil 2009). While the process of urbanization is unplanned and uncontrollable, then it can cause profound impacts on various environmental components, especially on land, water and air (Patraa et al. 2018; Almamalachy et al. 2019; Hana et al. 2014). In terms of ecological impact, urbanization is one of the most significant and long-lasting forms of land transformation and its extent of increase is proportional to population growth and economic development (Shepherd et al. 2013). Intrusion of urban areas towards natural habitats and increasing demands of growing urban populations on natural resources put direct and indirect pressures on ecosystems (Fadhil 2009).

To implement regulations and law in cities for protecting the environment and natural resources, monitoring

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of urbanization is very important (Mundhe and Jaybhaye 2014). Urbanization studies in cities have different factors including size and structure of the city, physical barriers such as mountains, layout and orientation of the road network, land tenure systems, land values, land use in the immediate periphery, etc. (Aguilar 2008). When the cities are getting more urbanized in the short term, it caused problems in climate changes concerning the surface temperature change (Kalnay and Cai 2003). Studies from China show that the environment has been polluted rigorously due to urbanization. The wealth and standard of living have been rapidly increased in many urbanized cities in China, meanwhile it is facing severe air pollution (Chan and Yao 2008; Huang et al. 2009).

The population lived in cities will increase by 70% from 2010 to 2050 due to urbanization (Birch and Watcher 2011). Populations of few cities are larger than many countries since urbanization focus is often on large cities (The 2007 Revision Population Database from World Urbanization Prospects). Coastal cities have resulted in intensive land use change (Liu et al. 2011). The cities in the United States of America with the highest populations and ISA (impervious surface area) are found in the South and West of the country. The density of population at the city-level inside the USA, on the east coast (e.g., New York, Miami) will reach higher than expected in the year of 2021 (Bounoua et al. 2018). According to the Census Bureau, Miami was No. 12 among cities for population growth in 2015 with a 2.23% rise from the prior year. Since 2010, yearly the population of Miami-Dade will increase by 1.4% (Cepero 2016). The previous studies resulted that Miami is growing rapidly but not in 360^{o} since the south and east parts are covered by the Atlantic Ocean so the population is increased only in a constrained space. Considering the above facts, the well-developed city 'Miami', which is located in the southern coastal part of the USA has taken for this experiment.

Urbanization results in land use/land cover changes. It is important to create a land use map for understanding the impact of urbanization (Bagan and Yamagata 2014). There is a need for developing a simple model for understanding and exploring the urbanization effects in landcover change (Eastman et al. 2019). Spatially explicit modeling of land use changes can be one of the good models (Serneels and Flambin 2001). The spatial approach is used in many studies for monitoring urban social landscapes both spatially and over the period of time (Liu and Cao 2017). Temporal change is an ambiance factor to investigate the land use change historically for a decade (Gidey et al. 2017). The previous studies have been clearly shown that urbanization in cities affected the topography, climate, land, air, and water. In this study, the impact of urbanization in land use of Miami is studied for the 15 years and its impacts are listed with the use of color patterns of pre-developed land use maps.

Study area

The most populous county in Florida, Miami-Dade County is home to 34 incorporated municipalities, cities, towns, and villages, as well as to unincorporated communities and neighborhoods (world atlas data). The northern, central, and eastern portions of the county are heavily urbanized with many high-rise buildings along the coastline. Southern Miami-Dade County makes up the agricultural economy of the region. According to the Florida census data in 2017, the population was 2,751,796. The average temperature of Miami is 77.05 $^{\circ}$F and the average annual rainfall is 61.93 inch.

In terms of land area, Miami is one of the smallest major cities in the United States. According to the US Census Bureau, the city encompasses a total area of 56.06 sq. mi (145.2 km^2). Of that area, 35.99 sq. mi (93.2 km^2) is land and 20.08 sq. mi (52.0 km^2) is water. That means Miami comprises over 400,000 people in 36 sq. mi (93 km^2), making it one of the most densely populated cities in the United States. According to the Florida geological survey, Miami Dade county base rock is Ordovician-Devonian sedimentary rocks and limestone.

From Fig. 1, it can be inferred that Miami Dade is the extreme southeastern part of Florida. The east and south boundaries are ocean hence the county can be extended in only the other two directions towards north and west. That is the main factor that Miami is easily populated and urbanized. Due to the human population increment, there are a lot of urban development was done. Land use change of Miami from 1998 to 2018 is very important to know about the impact of urbanization in this city.

Materials and methods

The land use maps are retrieved from the National Land Cover Database (NLCD) products and visually interpreted. Land use maps are the most common way of presenting land-based data. They show land uses by rendering them in different colors (Jeer 1997). The urban settlements maps are developed using colors of the satellite image (Afifi and Darwish 2018). The colors encoded in the maps are given the visual idea of information on the map. The quality of information is enhanced when we understand the dimension of the colors (Schloss et al. 2018). The colors of 4 years of land-use map taken into account for scrutinizing the land use change. The methodology adopted in this study has explained and illustrated in Fig. 2.

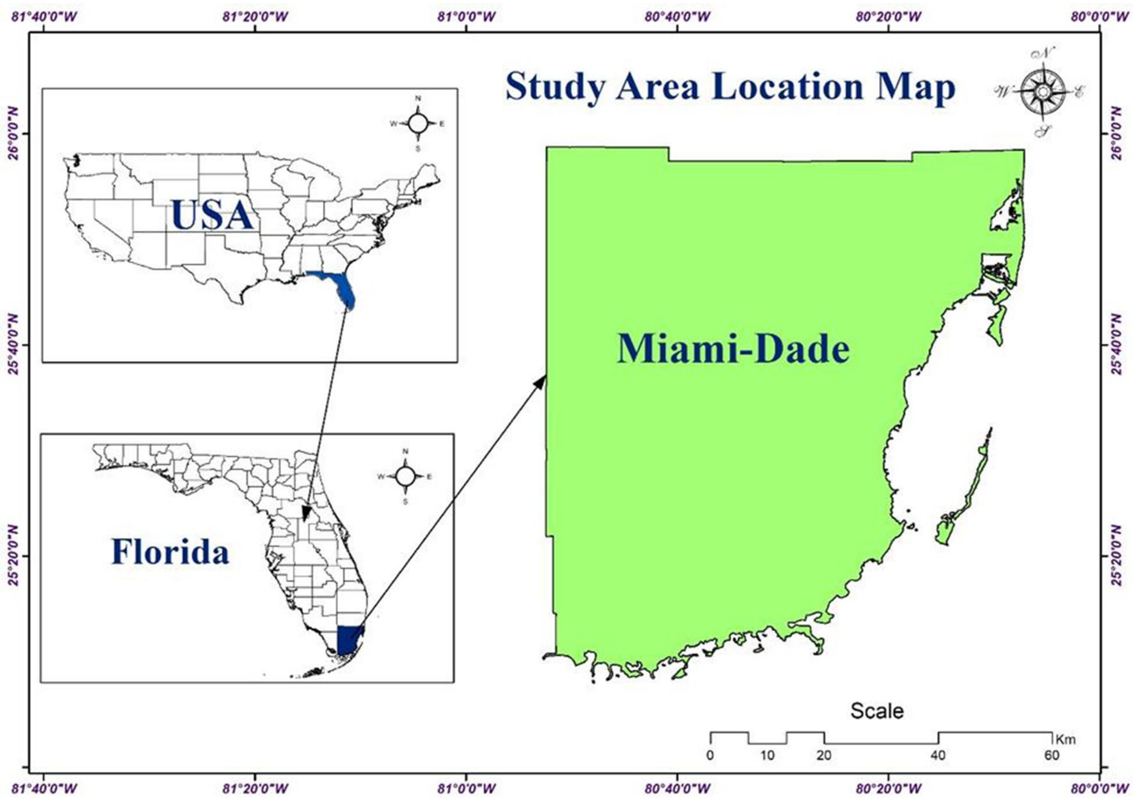


Fig. 1 Location map of Miami Dade County

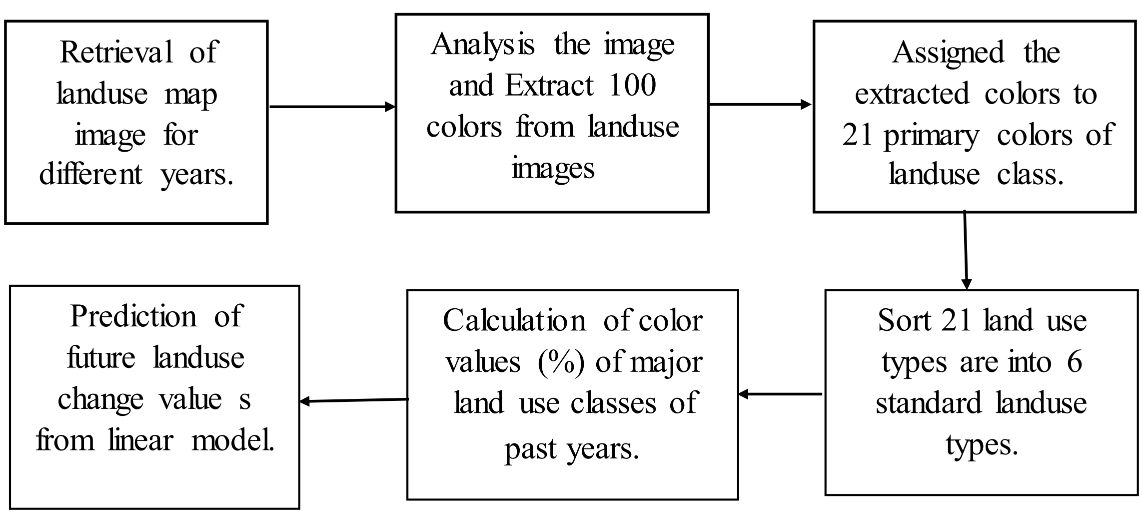


Fig. 2 Methods used for the study

Data collection

The National Land Cover Database (NLCD) products from the US Geological Survey (USGS) are used for this study. This database was created from Landsat imagery and geospatial ancillary datasets (Yang et al. 2018). The land sat image magnificently used to generate various land use change models (Nasehi et al. 2018). It has land cover information of the entire states in the United States. The land-cover data gives all urban development, vegetation cover, and other land use types. From the global map viewer of the NLCD database, the land use map of the Miami Dade

County had been extracted (Latitude: 25° 46′ 16.19″ N, Longitude: −80° 11′ 22.20″ W).

Data classification

The 4 years of land use map shown in Fig. 3. When the figures are visually perceived there is no abundant difference is distinguished but there are some differences perhapstruly found when it is seen by extreme zoom in the pixels. Single-pixel change in color from 1 year to another year map is a sign of a land use change. There is some color interpretation software that should need to quantify the pixel colors in each map automatically. As per the American Planning Association, LBCS Project, all the color shades are not acceptable by all software in all systems. The open-source color palette software named 'Image color extract tool' is used to analyze each picture of the land use map. The Image Color Extract PHP class pulls the most common colors out of an image file. The color values are in hexadecimal.

It presented every color value in terms of percentage. There are 100 different color shades are extracted after the color PHP tool process (Table 1). This tool can identify 98.53% of colors on the map. The tiny transformation in the color also calculated and shown in Fig. 4.

More color shades will result in complex land use categories (Sanjay 1997). Hence for better understanding, these 100 color shades are assigned into 21 colors as depicted in legends of the map based on the color by visual interpretation.

There are 21 categories of land cover classes were derived from the land use maps. These classes are fallen under the six major (Table 1) categories. (1) Urban/built-up land. (2) Agricultural lands. (3) Forests. (4) Water. (5) Wastelands/barren land and. (6) Wetlands.

This land classification system was referred from NRSA 1995 classification scheme, the similar land use classes were used in another research (Johnson et al. 2002) also. The color values extracted from the land use map image provide 21 land classification system (Fig. 4), these categories are further divided and grouped into the standard 6 categories of landcover. To assign colors to the land use divisions with the use of basic RGB colors is important in land use change analysis. It is the standard approach to depict the land use map in an interactive way (James et al. 1976).

Results

The land cover comparison results for 4 years (2001, 2006, 2011, and 2016) has been shown in Table 2 after examining the color values (%).

It can be inferred that the land use changing drastically year by year (Table 2). In 15 years, urban built-up area percentage increases by 9.5%, barren land increases by 1.88%.

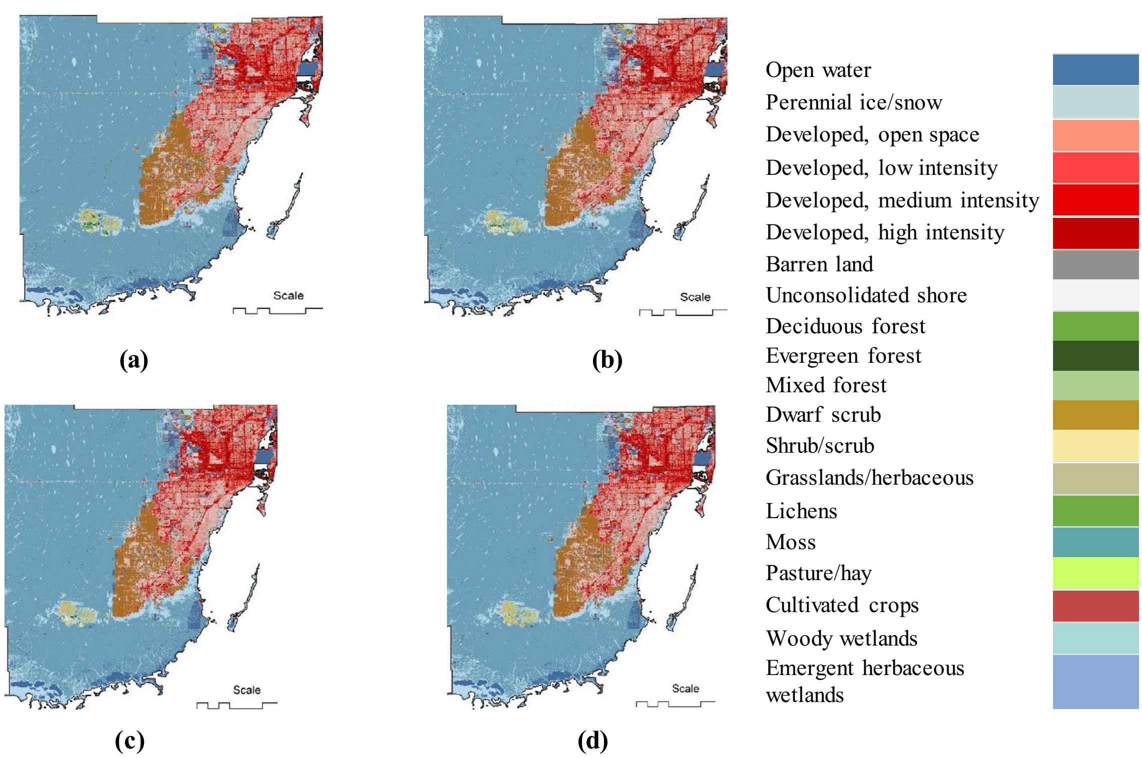


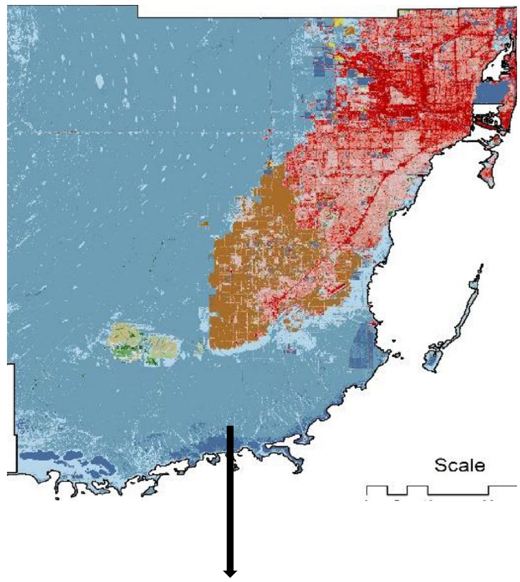
Fig. 3 Land use map of Miami Dade county for the year **a** 2001, **b** 2006, **c** 2011, **d** 2016

Table 1 Major land use categories extracted from the land use map

S.no	Land type in the map	Category of major land cover type
1.	Open water	Open water
2.	Snow	
3.	Developed, open space	Urban development
4.	Developed, low intensity	
5.	Developed, medium intensity	
6.	Developed, high intensity	
7.	Deciduous forest	Forest area
8.	Evergreen forest	
9.	Mixed forest	
10.	Dwarf scrub	Agricultural land
11.	Shrub	
12.	Grasslands	
13.	Sedge	
14.	Lichens	
15.	Moss	
16.	Pasture	
17.	Cultivated crops	
18.	Barren land	Barren land
19.	Unconsolidated shore	Wetlands
20.	Woody wetlands	
21.	Open water	

Open water is decreased by 4.21%, agricultural land is reduced by 5.97%, wetlands are decreased by 0.63%, and the forest area is reduced by 0.58%. According to the results of land use map color change percentage values, the urban built-up is rapidly increased the vice versa the agricultural land areas are rapidly decreased. Next to agricultural land, the water area is decreased rapidly. The other land use classes show gradual changes. Figure 5 depicts graphically about these facts.

The linear regression model is developed for each land use class discretely. Linear regression provides the outcomes eternally and it can able to predict the near future values (Teeboom 2019) likewise any number of variables can be examined. The linear regression model can be able



0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269
0.2326	0.0087	0.0055	0.0046	0.0034	0.0022	0.0016	0.0012	0.0009	0.0007
0.1507	0.0086	0.0054	0.0045	0.0034	0.0021	0.0016	0.0012	0.0009	0.0007
0.0137	0.0082	0.0053	0.0045	0.0033	0.0021	0.0014	0.0011	0.0008	0.0006
0.0135	0.008	0.0053	0.0045	0.0032	0.002	0.0014	0.0011	0.0008	0.0006
0.0122	0.0078	0.0052	0.0042	0.0028	0.0019	0.0013	0.0011	0.0008	0.0006
0.0102	0.0075	0.005	0.0042	0.0027	0.0019	0.0013	0.0011	0.0008	0.0006
0.01	0.0073	0.0049	0.0038	0.0025	0.0019	0.0013	0.001	0.0008	0.0006
0.0099	0.0073	0.0048	0.0038	0.0024	0.0019	0.0012	0.001	0.0008	0.0006
0.0007	0.0068	0.0047	0.0038	0.0024	0.0019	0.0012	0.001	0.0007	0.0005

Fig. 4 Percentage of colors (X100) perceived from the 2001 land use map

Table 2 Land use area comparison of the years from 2001 to 2016

S. no	Name	Total landcover area in different years (%)			
		2001	2006	2011	2016
1	Urban buildup	12.30	14.25	17.35	21.81
2	Forest	1.64	1.49	1.42	1.06
3	Agricultural land	12.13	11.65	8.93	6.16
4	Water	62.24	59.6	59.22	58.03
5	Wetlands	7.28	7.18	6.77	6.65
6	Barren land	4.41	5.83	6.30	6.29

to give a qualitative result in environmental studies (Divya and Gopinathan 2019). The quantitative transformation of land cover area (%) versus temporal change (2001, 2006, 2011, and 2016) is predicted by the linear regression model, shows in Fig. 6. The model clearly shows that the formulas and R^2 value in a unique way of all land cover categories. From the R^2 values, it can be inferred that urban built up land use shown the highest value, following by wetlands and agricultural land. Area covered by these land use classes in the future can be predicted with good accuracy based on this color pattern model for the study area.

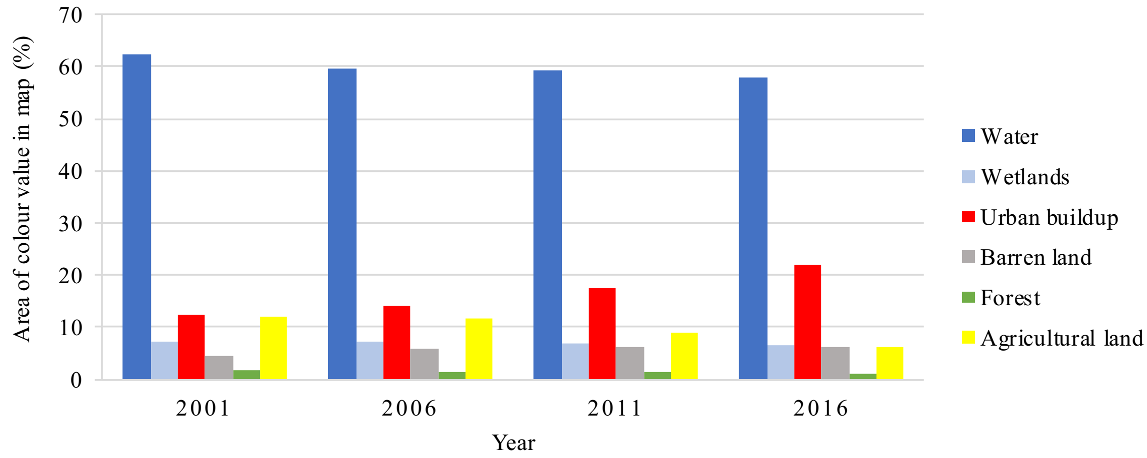


Fig. 5 Percentage of land area covered in time series of 2001, 2006, 2011 and 2016 in Miami Dade County

Discussion for future prediction

As per Environmentally endangered lands program management plan part 1 (2007) report, the population dramatically jumped into 400 times higher rates in the Miami Dade county nineteenth to twentieth century and it unpredictably affects ecosystems. The ecosystem is directly related to forests. Built-up land incline towards the human population, close to roads, and on plain land with good access to the water (Suparno Ghosh and Amba Shetty 2017) hence the urban development is negatively affecting the forest cover over the period (Escobedo et al. 2011). There is a need to develop a simple regression model to predict the land use values particularly urban built-up and vegetation areas (Forest and agricultural land). The formulas derived from the linear models of this study can be used for future land use prediction value in Miami Dade county. The linear model projected to the year 2021 and values are listed in Table 3.

The final results have shown that when the city size is developed, it negatively influences the vegetation areas, water, and wetlands. The future prediction value from Table 3 gives an alarming value in urban development. From 2001 to 2021, the urban development approximately increased by 200%. The other land use change values may look very small or negligible but it will show the greater impact when we apply to the large-scale region, Miami Dade County.

Conclusions

The second-largest tourist spot of Miami (global public transit index 2017) is increased by its human population day by day and it positively helping for the development of the city in both financial ways and cultural ways. All the land cover types have been occupied by human urban activities at a great rate. This paper is investigated the land cover changes in recent years (2001–2016), and it is predicted the future land cover change values using color patterns and a linear regression model. The results of the study shown that there is a need to take special care of vegetation, water, and wetlands in the county when it is developing by the socio-economic ways.

The future (2021) land use change values are predicted with decent accuracy using a simple linear regression model in this study. There may be a chance to develop this study with other statistical models using different classification systems and software. The vegetation cover may alter to some extentdue to the seasonal change in a year, considering this fact also the future studies can be performed (Tafesse and Suryabhagavan 2019). The linear model developed by this study is simple and the formula extracted from the regression model is easy to apply to predict significant land use change near future. It may be guided for further environmental studies in Miami Dade County.

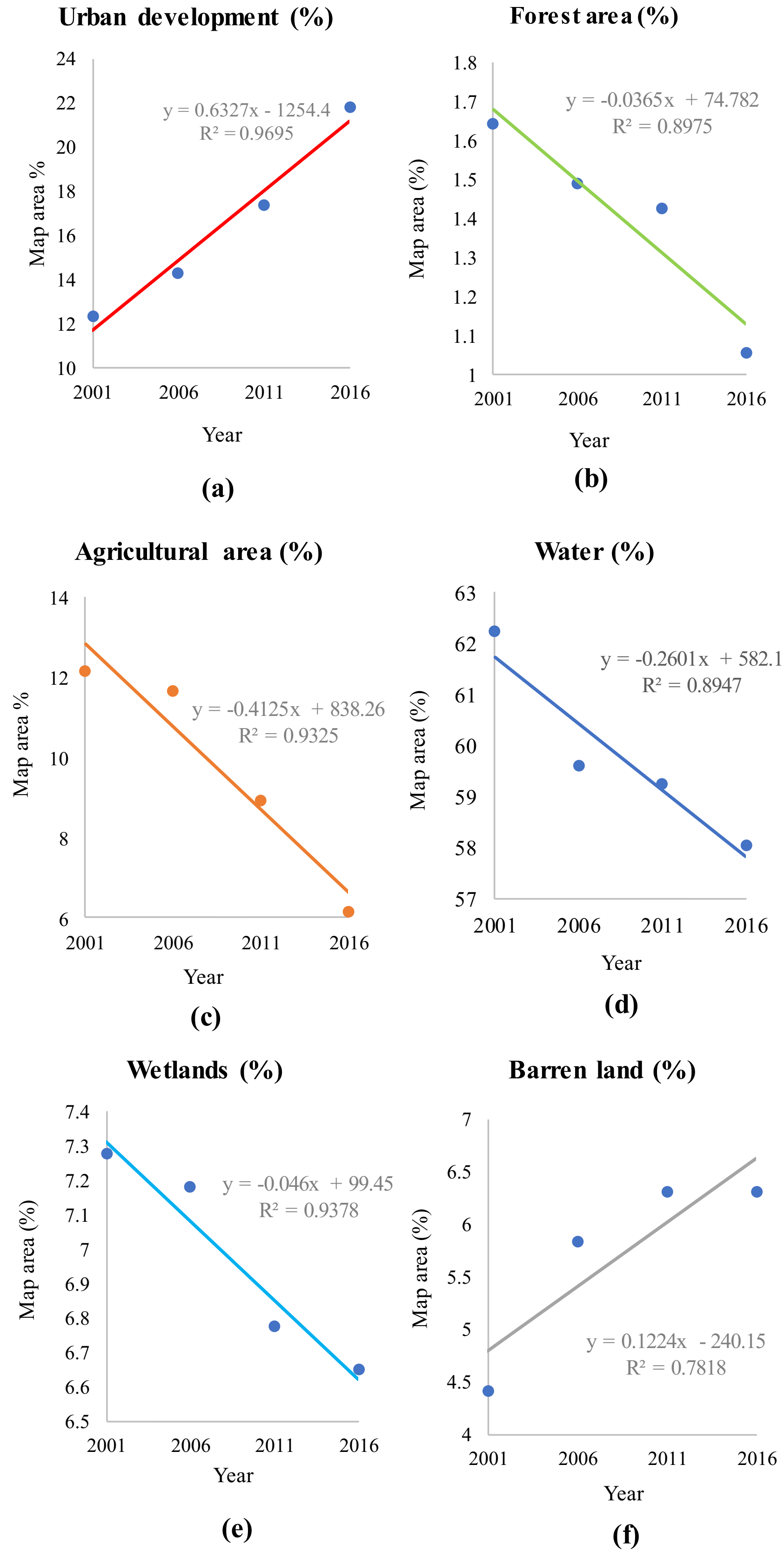


Fig. 6 Percentage change of major land use classes from 2001 to 2016 from linear regression analysis

Table 3 Projected land use (%) values in 2021

Type of land cover	Year 2001 (%)	Year 2006 (%)	Year 2011 (%)	Year 2016 (%)	Year 2021 (%)
Urban buildup	12.30	14.25	17.35	21.81	24.29
Forest	1.64	1.49	1.42	1.06	1.02
Agricultural land	12.13	11.65	8.93	6.16	4.60
Open water	62.24	59.6	59.22	58.03	56.44
Wetlands	7.28	7.18	6.77	6.65	6.48
Barren lands	4.41	5.83	6.30	6.29	7.22

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