GIS Analysis of Historical Changes in Urban Forest and Land-Cover in Scotlandville Louisiana, USA

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Abstract
Green infrastructure planning is emerging as an alternative approach to preserve vulnerable flora and fauna, and provide mitigation for climate change effects in urban areas. Cities are losing vulnerable ecosystems due to the ever expanding urban sprawl as city planners favor development of paved surfaces at the expense of conserving natural ecosystems. This study demonstrates how Geographic Information System and remote sensing can be applied in development of urban forestry plans. We analyzed the land use history of Scotlandville using GIS and remote sensing technologies in an effort to determine changes in urban forest development and the drivers of land cover change. Field studies and the spatial analysis of historical aerial photographs, topographic maps, and satellite images were used to create feature layers that were analyzed for changes in land cover using GIS algorithms as tools for decision criteria. There was a major change in land cover and land-use in Scotlandville in seven decades. The Scotlandville land-cover changed from predominantly farm land (68%) in 1941 to urban development (69%) in 2012. Forest cover reduced from 25% to 19% of the land-cover with increased fragmentation. Natural forests were cleared but land-use change from farmlands provided opportunities for development of street trees, riparian forests, urban forests, and open spaces for recreation.
Keywords: Conservation, Geographic information system, Land-cover, Land-use change, Urban forestry.

1.0 INTRODUCTION

Forest complexes and urban vegetation are increasingly being incorporated in climate change mitigation and adaptation strategies. The benefits derived from urban vegetation are numerous and of varying scales depending on the location, management and interests of the community. Urban vegetation not only sequesters atmospheric carbon dioxide but also ameliorates city climates, and plays a major role in protecting hydrological processes (Faulkner 2004). Environmental benefits of trees include improvement of air quality by removing pollutants, storm water management, noise mitigation, wildlife biodiversity conservation, and removal of pollutants from soils (Bolund & Hunhammar, 1999; Nowak & Dwyer, 2007; Nowak & Stevens 2006; Wu et al., 2010). Vegetation also provides a pervious ground layer while protecting the landscape from degradation. Therefore, the survival of a healthy urban hydrology depends on the existence of natural vegetation around the watershed. Replacing natural communities with impervious concrete layers in the form of roads, buildings, and parking lots deprives natural ecological complexes of a natural flow of surface and ground water.

Global urban population and the ever-expanding urban sprawl exert pressure on natural areas as cities expand to accommodate the needs of the growing population (Bhatta 2010). Development of infrastructure, industries, and housing are lead drivers for the diminishing vegetation cover (Seto et al., 2011). The depletion of natural communities in favor of infrastructure development deprives urban areas of a local natural heritage, native species of flora and fauna, and opportunities for recreation.

Urban ecosystems are unique, they have inbuilt manmade components within their structure (Nowak & Dwyer, 2007). Man-made structures such as transportation infrastructure, factories, buildings, and modified surfaces (parking lots and roof surfaces) present new challenges in the function of natural ecosystems and therefore require deliberate action to improve and preserve vulnerable ecosystems. Urban forestry is emerging as an alternative conservation effort that incorporates management of vegetation and natural systems in man-made concrete structures of the city environment (Nowak 1994). This approach opens opportunities to conserve vulnerable species and the ecosystems that rely on urban environments.

Urban ecosystems are critical functional units in the flow of energy and recycling of materials and nutrients (Erle & Emmett 2008). Cities depend on services from productive ecosystems within them and those beyond the city boundaries (Folke et al. 1997). For instance, water for the city population may come from neighboring forest ecosystem, or food for the population may come from agricultural lands several miles away from the city. Cities as points of convergence for human population bear the burden of assimilating artificially transported materials which come to the environment as industrial and domestic waste.

The benefits of natural ecosystems can be enhanced through careful planning of green infrastructure (Benedict and McMahon 2002). Geographic Information System (GIS) and remote sensing technologies are increasingly becoming a necessary option in planning and management of natural resources. The capability for spatial analysis using geo-referenced data and non-spatial data enables managers to carry out continuous monitoring of land cover changes (Maantay & Ziegler, 2006, Namwamba, 2003), track wildlife demographics, and forestall land and resource use for conservation purposes. Technological applications provide platforms that record features on the earth surface over a long period of time. Such data repeated over the same area gives opportunity for monitoring changes on features with time.

In determining a remedy to the loss of urban forests in Scotlandville, we analyzed land-cover and land cover changes that occurred between 1940 and 2012 using GIS and RS technologies. Trends in forest cover, land cover and location of remnant close canopy urban forests were tracked from aerial photographs, satellite images, topographic maps and field studies. Previous studies in urban forestry have not emphasized the need for understanding historical trends in the development of current urban forestry programs.

1.1 Study Area

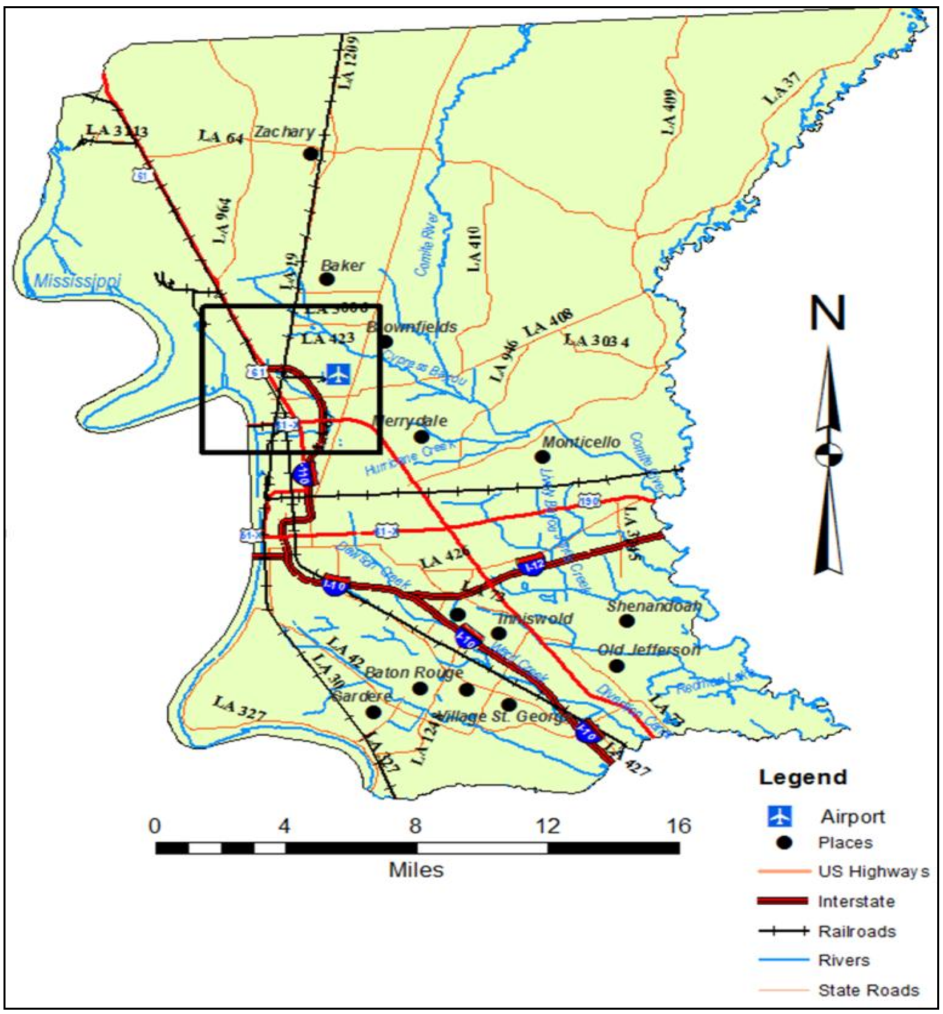

Figure 1 Study area in East Baton Rouge Parish, Louisiana

This study focused on the Scotlandville area of Baton Rouge City in East Baton Rouge Parish, Louisiana 30.522 N 91.186 W (Fig. 1). East Baton Rouge Parish and Baton Rouge city have experienced rapid increase in population in recent years (Fig. 2). The total area covered by the study was 5259 ha. The site overlaps Scotts Bluff, to the west is the Mississippi River, to the south is Airline Highway, to the east is Plank Road. Major features in the study area are Baton Rouge Metropolitan Airport, Southern University, Scotlandville town, petroleum tank farm and Interstate 110.

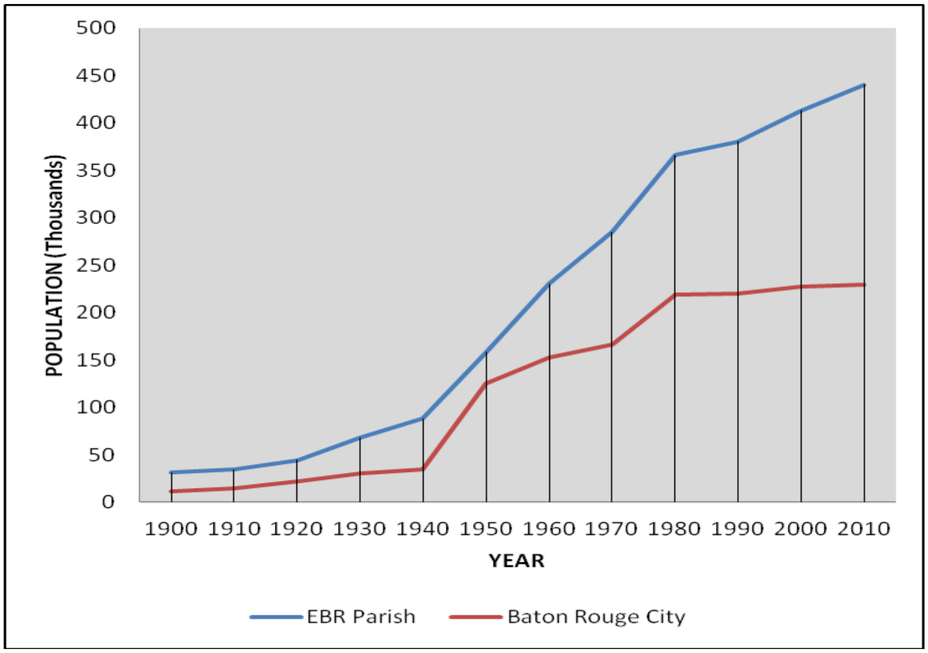

Figure 2 Population trends in East Baton Rouge Parish and Baton Rouge city from 1900 to 2010 (Source of data: Forstal 1995)

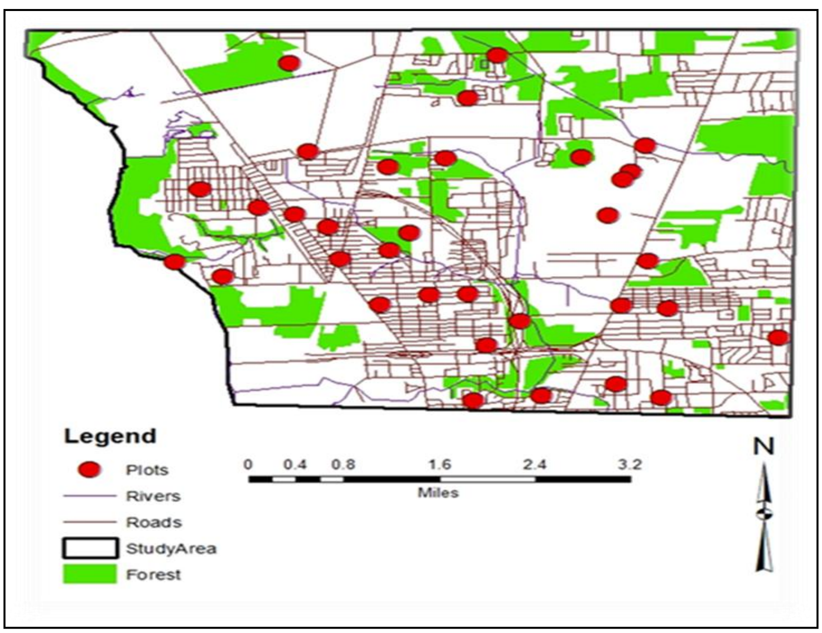

Figure 3 Plots within the study area in Scotlandville

2.0 METHODS

Aerial photographs from 1941, 1953, 1975, 1998, 2005 and 2012 were analyzed to determine the changes in vegetation, hydrology and land cover. These were complemented by georeferenced topographic maps and satellite images.

Field procedures involved the collection of ground-truthing data for the digital images. The features on aerial photographs, historical maps, and topographic-maps were verified on the ground to determine current status and also collect coordinates for use as ground control points to orient and project the images. Permanent buildings, road intersections and railway line intersections were noted to persist across all the images and were used as ground control points.

Changes that had not been captured on maps and images due to recent development such as new roads, buildings, concrete surfaces and open grounds were identified and updated. Randomly selected field plots measuring 400 m^2 were used (Fig 3). For each plot tree species, number of trees per plot and nature of surface cover were recorded.

The current study relied on spatial analysis and image analysis capabilities of ArcGIS 10.1 software (ESRI 2012). The image analysis extensions of Arc View required availability of imagery, data, and information in digital format and conversion of other data into digital format. Historical aerial photographs and topographic maps were applied as scanned images. Individual parameters in the study were therefore determined and selected based on availability of data for application in ArcGIS.

The changes in features on the aerial photographs were identified by locating features that were present in the current image but were not present in the old image. The features were then digitized, using the editor tools in ArcGIS 10.1 and saved as a new shape file. Overlays of DOQQs, topographic maps, and aerial photographs were generated for each set of analysis and the same were used to identify areas affected by changes. Forests, street trees, and green spaces were digitized from the overlays to identify the location and size of the features in all sets of data analyzed. Using GIS algorithms, the area covered by each feature layer was calculated. The areas that had had increase or reduction in land-use category were determined by comparing layers of the same feature for all the years covered.

The vegetation cover changes observed over the period of study were reexamined to determine the succeeding land uses. Current and historical topographical maps were also analyzed to track the land cover changes over time. The succeeding land changes were then classified as development (residential, commercial, and infrastructure e.g., roads), tree/forest or open space. This was then correlated with qualitative data and information from literature to establish the background for the succeeding land uses as compared to the initial ones.

3.0 RESULTS

Analysis of historical aerial photographs, topographic maps, and field survey demonstrated gradual and sudden changes in vegetation cover at Scotlandville. Gradual vegetation cover losses were observed in cases where forest patches converted to subdivisions for residential purposes. Sudden losses were observed in cases where forest and farmlands were converted to infrastructure development, such as the construction of airport (1945-1950) and construction of Interstate 110 (1970-1980).

Farmland was the dominant land-use in 1941 followed by forests (Fig 4). In 1953, the data reveals an increase in land conversion from agriculture to residential and commercial uses (Fig. 5 and Table 1). The same trend was observed in 1975 that showed increased residential and commercial land uses and a reduction in farmlands. Development, which comprised of infrastructure, commercial, residential land uses was the dominant land use within Scotlandville in 2012 (Fig 6).

Spatial analysis of forest changes between 1941 and 1975 showed continued fragmentation of existing forest blocks due to development of infrastructure. The period also experienced development of more forest patches as land-use changed from farmlands.

The spatial data analysis demonstrates that forest and tree cover in Scotlandville are on the decline (Table 2). The urban forest area reduced in all the years except 1975. There was 8% reduction in forest between 1941 and 1953, 8.4 % increase in forest area between 1953 and 1975, 18.8% reduction between 1975 and 1998, and a further 3.8% reduction in forest area between 1998 and 2005. The forest cover remained stable between 2005 and 2012.

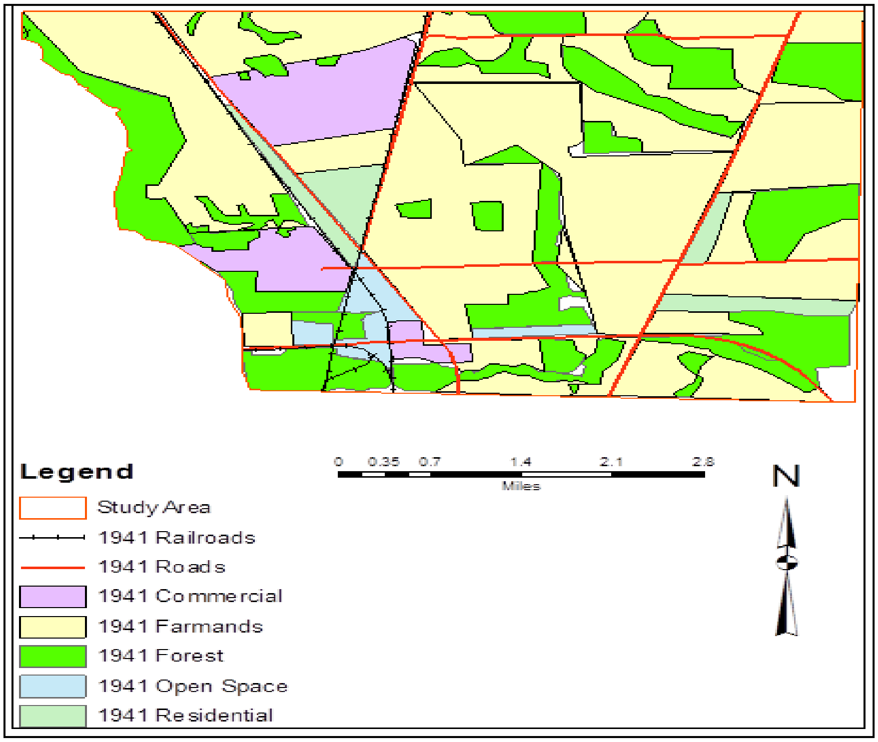

Figure 4 Dominant Land Uses in Scotlandville in 1941

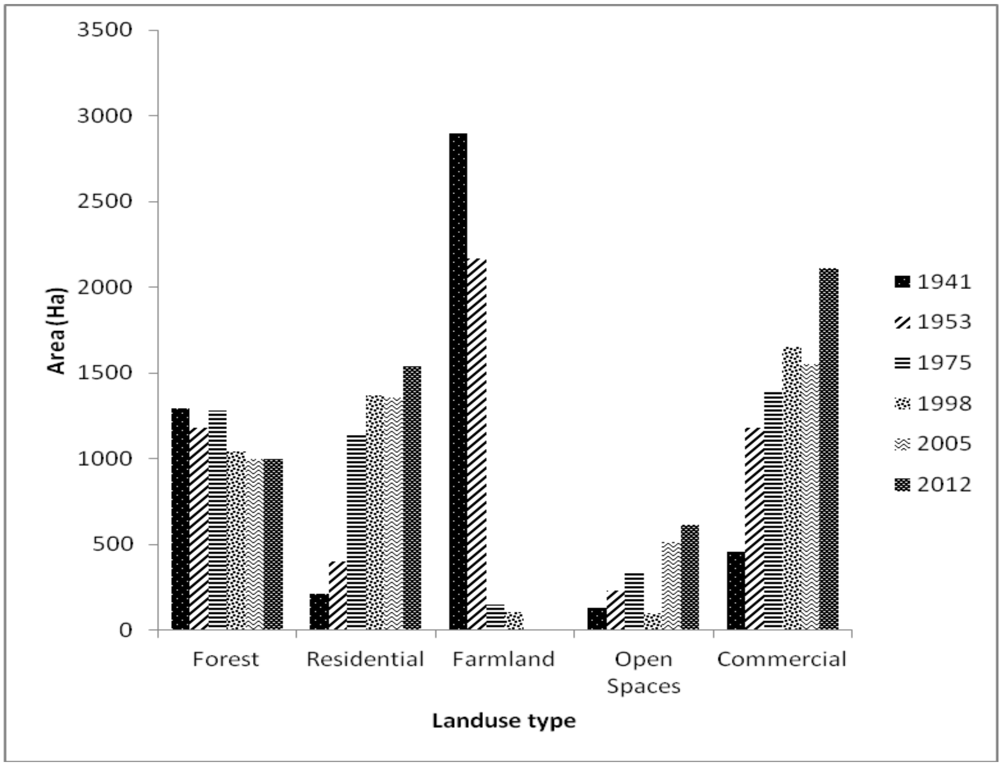

Figure 5 Land-use Changes Between 1941 and 2012 in Scotlandville

Table 1 Extent of Land Uses in Hectares in Scotlandville Between 1941 and 2013

	LANDUSE AREA (Ha)				
YEAR	Forest	Residential	Farmland	Open Spaces	Commercial
1941	1289.90	304.37	2897.50	218.27	548.97
1953	1181.00	435.00	2164.10	263.54	1215.36
1975	1280.50	1467.76	146.96	652.77	1711.01
1998	1040.40	1701.47	103.50	432.07	1981.56
2005	1000.30	1633.00	10.40	789.40	1825.90
2012	997.00	1539.00	-	613.00	2110.00

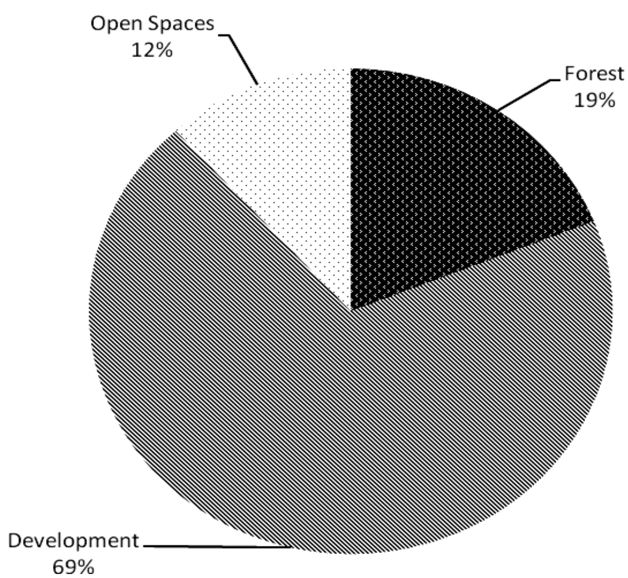

Figure 6 Land-use types in Scotlandville in 2012

Examining sampled plots showed that, 30% of the plots were developed areas and therefore did not have trees. Seventy percent of the plots had trees and were used for tree cover verification. Chinese tallow (*Sapium sebiferum*) was observed to dominate open spaces and edges of forests. In some plots the species was noted to have dominated both understory and overstory (Figure 7). This is an indication of its aggressive invasive characteristics that enable it to out-compete native species.

Table 2 Percentage Change in Urban Forest Cover Between 1941 and 2012 in Scotlandville

Year	Forest (ha)	% change
1941	1289.9	-
1953	1181.0	- 8.4
1975	1280.5	8.4
1998	1040.4	-18.8
2005	1000.3	-3.8
2012	997	-0.3

Figure 7 Chinese tallow tree (*Sapium sebiferum*) is dominating the landscape in Scotlandville, June 2013

4.0 DISCUSSION

Human factors were major drivers of changes in land cover and land use patterns recorded over a long period of time in the study area. These influences include urban expansion, residential and commercial development, population growth and introduction of exotic species. The land uses changed with increased economic activity occasioned by the economic boom that followed World War II and the rapid population growth in that period (Fig 2). In 1953, the data analysis reveals an increase in land conversion from forest and farmlands to residential and commercial uses (Fig. 4). The development of commercial and residential areas reduced the farmlands, but it had little effect on forest land. There was also an emergence of clear land subdivisions that enabled adequate analysis to separate residential from other built up areas.

The area under forest cover was observed to have dropped between 1941 and 1953. This is attributed to the emergence of commercial land uses in which forests were cleared to establish commercial interests. There was an increase in the area under forest cover between 1953 and 1975 to match the initial forest area observed in 1941. This is attributed to conversion of farmlands to other land uses, and some land remained fallow leading to forest regrowth. There was also increased fragmentation of forest blocks, such that though total forest area increased in this period, the sizes of individual forest patches were much smaller. The reduction in total area under forest between 1975 and 2012 is attributed to losses due to infrastructural development and expansion of residential and commercial land uses. There were land use changes that led to increase in urban forests or open spaces such as the closure of a military base and decommissioning of oil tanks.

Chinese tallow (*Sapium sebiferum*) was noted to dominate open spaces and edges of forest patches (Figure 7). Introduced species in urban areas often have unintended consequences like invasiveness. They can alter the landscape by replacing native species. Urban areas generally have a mix of native and nonnative plant species that have been selected naturally or by human action. Studies have shown that urban areas are becoming dominated by invasive nonnative species (Burton et al., 2005) due to their ability to outcompete native species in the natural environment. Expansion of built up environments in urban areas is often accompanied with a decline in composition and abundance in local native species (Faulkner 2004). According to Hardman (2011), the increase in non-native species in urban areas may be due to importation into the city by residents and the existence of a favorable habitat for non-native species in the city. Generally, there is wide variability in responses to urban environments in terms of species composition and diversity by the ecosystems due to varying local conditions. Increases in urban plant species may also be caused by presence of different habitats at small scale which support a wide variety of species and the importation of water and nutrients which are necessary for primary productivity (Hardman, 2011).

Open spaces, urban forests, and street trees were the dominant components of green infrastructure identified. Urban forests were mapped as isolated blocks in the study area. Street trees were present, most of them being remnants of cleared natural forests. In planning for green infrastructure, there is need to create opportunities for development of an interconnected network of vegetation (Benedict & McMahon, 2002). The planning and construction of new roads and other infrastructure need to include urban trees in the planning stage. The interconnection between forests can be enhanced by links such as open spaces and rivers with riparian forest buffers. Streets in residential subdivisions were relatively high in tree density, being an indicator of the value attached to the street trees by residents.

Open spaces have multiple uses and provide multiple benefits if planned properly (McConnel and Walls, 2005). Open spaces play an important role in improving the quality of the environment, storm water management, and recreation, providing economic values, aesthetic values, noise reduction, agricultural preservation, cultural and historic preservation, and sense of community. Managing open spaces as part of the green infrastructure could enhance their role in providing benefits to the community.

The urban forests in Scotlandville consist of forest patches on both public and private land. The forest patches are remnants of native blocks of forest and natural areas that have been conserved. Street trees are planted along roads and highways for many functions which include pollution removal, screening houses, aesthetics, and shade. Trees are designed to accommodate many functions and services concurrently without interfering with other city plans (Boniarz and Ryan 1993).

5.0 CONCLUSION

The historical land use in Scotlandville during the period covered by this study was dominated by farmlands in 1941 comprising 58% of the land. In 2012 development, comprising of infrastructure, commercial and residential land uses accounted for 69% of the total land in Scotlandville. The forest cover reduced from 25% to 19% between 1941 and 2012. Observed historical changes in urban forest development demonstrated that there was fragmentation and reduced forest cover due to land use change in favor of development. These developments brought about high population pressure driving the urban sprawl. The natural ecosystems of the study area are increasingly becoming fragmented and isolated due to development. Green infrastructure plan is proposed to create linkages between isolated forest blocks (hubs) and natural ecosystem cores in order to protect wildlife and hydrological processes.

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