DETECTING URBAN LAND COVER CHANGES USING NEIGHBORHOOD-SCALE CLASSIFICATION IN CEBU CITY, CENTRAL PHILIPPINES USING LANDSAT IMAGERY

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ABSTRACT: The different configurations of urban growth result in varying land cover changes and differing landscape structure. An integrative approach was adopted to detect land cover changes and apply a neighborhood-scale land cover classification in Cebu City, Philippines. Landscape analysis using Landsat imagery was performed to classify the city from a spatially heterogeneous urban area into simplified and manageable units. The land cover classification was performed in Google Earth Engine using the random forest classifier from the year 2004 and 2018. It rendered an overall accuracy >80% for both years. Population data was then integrated to the resulting land classification data and Unweighted Paired-Group Method of Arithmetic Mean (UPGMA) algorithm was used to determine the neighborhood distance (Euclidean) of the 80 barangays in Cebu City. The analysis resulted in 6 unique classes that were interpreted based on the range of values from their respective data attributes. Results showed that the majority of the barangays (42.5%) belonged to Class 1 (urban core) covering an area of 1,652 ha. Other barangays belonged to Class 5 (densely vegetated uplands) 21.3%, Class 4 (urban periphery) 20%, and Class 6 (low vegetated uplands) 23.8%. They covered an area of 13,954.2, 4,252.9, and 9,170.8 ha respectively. Multiple correlation test resulted with urban and low vegetation cover having a negative correlation R^2=-88, and low vegetation and dense vegetation cover having a negative correlation coefficient of R^2=-71. The time-series analysis showed that urban areas encroached low vegetated areas in lowlands while low vegetated areas encroached the densely vegetated areas in the uplands. The diminishing dense vegetation cover was found to be the primary trade-off of urban growth and increasing area of agricultural parcels. This method of neighborhood-scale classification and detection of land cover changes using Landsat may be adopted by the local government and enhanced through addition of more variables, resulting to the development and implementation of effective sustainable urban management strategies.

1. INTRODUCTION

Nearly half of the global population resides in urban areas (United Nations, 2014) and it is forecasted to reach 60% by 2030 (McCarthy *et al*., 2001), driving changes and exceeding carrying capacities on city environments (Balica *et al*., 2012). The urban environment is now the most common area of congestion, pollution, poverty, and diseases (Nicholls *et al.*, 2007). Urbanization causes irreversible effects on ecosystems; and with the expected continuous resettlement of human population to urban areas, there is a need to transition to a more sustainable form of city living (Huang *et al*., 2010). To move towards urban sustainability, the present natural systems must be managed in a way that allows it to maintain its capacity to support the resident human population (Alberti and Susskind, 1996). Managing sustainability in cities entails setting priorities and assessment of options, which can be achieved with the development of strategies to classify urban landscapes into units of ecological significance at spatial scales (Steenberg *et al.*,2015). As the human population drives urbanization, its influence can define the processes and changes within the city environment (McPherson *et al.*, 2011). The human population then must be a novel component in the characterization of urban areas (Ancog and Ruzol, 2015). Classification of land cover changes in urban areas have previously focused on biophysical landscape attributes, but integration of other components from social and biophysical processes, such as built-up environments and human population data have then been consequently done, as with the study of Cadenasso *et al.* (2007) and Steenberg *et al.* (2015). The dynamics of land cover changes coupled with social and biophysical urban processes causes a high degree of spatial heterogeneity and high variability in the supply of urban ecosystem services (Escobedo and Nowak 2009). An integrative approach improves quantitative inputs needed for the implementation of urban management strategies (Steenberg *et al.*, 2015) (Fig. 1).

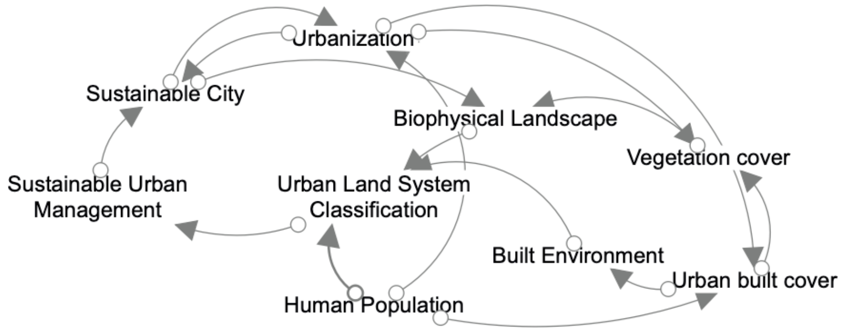

Figure 1. Causal loop diagram of sustainable urban management.

This study adopted the integrative approach to urban land classification of Steenberg *et al.* (2015). Quantified variables of land cover were acquired through remotely sensed data allowing a logical spatial analysis. The quantified results could then represent a sensible spatial scale for management (Steenberg *et al.*,2015). Classifying urban environments through clustering of variables and indicators, presenting consistent units of analysis, ecosystem likelihood and boundaries simplifies the area's heterogeneity, making it into manageable units of understanding. Sustainable urban management strategies may then be more effective as it broadens the focus from a single component to looking at the structure and functions of the ecosystem (Bailey, 2009).

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Cebu City is located in the central-eastern part of Cebu Province, an island in Central Visayas, Southern Philippines. It has the geographical coordinates 10°17' N and 123°54' E. It is bound by Mandaue City in the North and Talisay City in the South. On the East is Mactan Channel and on the west are the Municipalities of Balamban and Toledo City. Cebu City is the capital of Cebu Province with a total of 80 barangays, where a 'barangay' is defined as the smallest administrative division, designated between 2 legislative districts (north and south). It has an effective land area of 29,589 hectares (Cebu City Profile, 2008; Ejares *et al*., 2016).

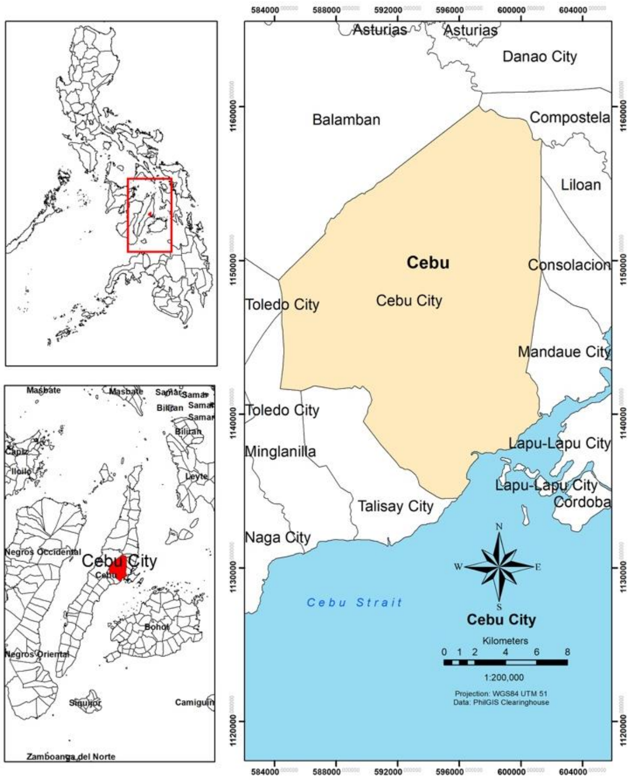

Figure 2. The map of Cebu City, the capital city of Cebu Province in Central Visayas, Philippines.

2.2 Pre-processing of Landsat Images

The data used in the study were from Landsat 5 and 8 for the year 2004 and 2018. Pre-processing of Landsat images was performed in Google Earth Engine (GEE). The processes included boundary selection and cloud masking (Fig. 3). Image composite for each year was generated and training points for each feature class were created with the aid of the supplementary data from Google Earth images. Training points for each feature class were selected based on the relative area of each class. Classes included water, urban (built-up), low vegetation and dense vegetation.

2.3 Image Classification and Accuracy Assessment

Image classification was carried out using the random forest classifier. Accuracy assessment was also conducted by randomly splitting the number of training points into 70% training and 30% testing data. Reclassification was performed when low accuracy was obtained. Classified images were then exported as object raster (*.tiff*) to ArcGIS 10.7 for further processing. Raster data were clipped per barangay boundary. Area of each feature class in every barangay were calculated using the "Calculate Geometry" in ArcGIS toolbox. Percentage cover of each class was also calculated and the result was the input for hierarchical cluster analysis (HCA) (Fig.3).

2.4 Statistical Analysis

The percent cover of each feature class was normalized by dividing each value to the maximum value within the dataset (Jongman, 1995). The values must range from 0 to 1. Classical hierarchical clustering was performed using the unweighted pair group method of the arithmetic mean algorithm (UPGMA). Similarity analysis was carried out using the Euclidean distance. Cluster analysis was performed in StatSoft Statistica software version 12.0. Each cluster was defined based on their quantified variables and spatial scaling was applied for urban land cover classification. Additionally, multiple correlation analysis was performed to determine the relationship among classes. The analysis is per barangay.

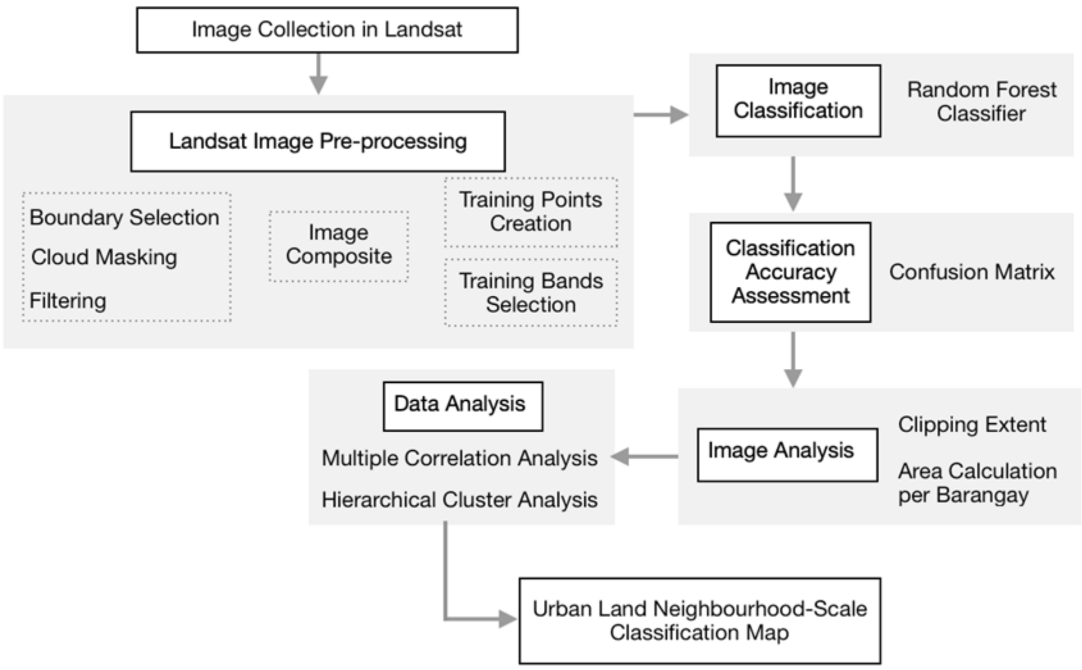

Figure 3. Methodological workflow performed in the study.

3. RESULTS AND DISCUSSION

About 93.5% of the total population of Cebu City (922,611 residents) live in urban barangays (50 out of 80 barangays), according to the data from the Philippine Statistics Authority in 2015. Under the 2005 Comprehensive Land Use Plan (CLUP), Cebu City is classified into four major districts: the protected zone (14,109 ha), the peripheral urban land use zone (9,810 ha), urban land use zone (4,166 ha), and inner-city or urban core (1,504 ha). Approximately, 76.3 % of its land is under the National Integrated Protected Areas System (NIPAS). These include the Mananga, Kotkot-Lusaran watersheds, the Central Cebu National Park, Sudlon National Park, and Cebu Buhisan Watershed. Approximately 28.50% (23 out of 80) of the barangays are totally or partially located in the four watershed areas, later declared as Central Cebu Protected Landscape (CCPL) (Cebu City Profile, 2008; Bagarinao, 2011).

3.1 Land Classification

Land classification map of Cebu City was generated using the composite images from the year 2004 and 2018. Classes included water, urban (built-up), low vegetation, and dense vegetation cover (Fig. 3). The overall accuracy of the analysis is >85% while Kappa Index of Agreement (KIA) is >80%. The accuracy assessment of each year's analysis is shown in Table 1.

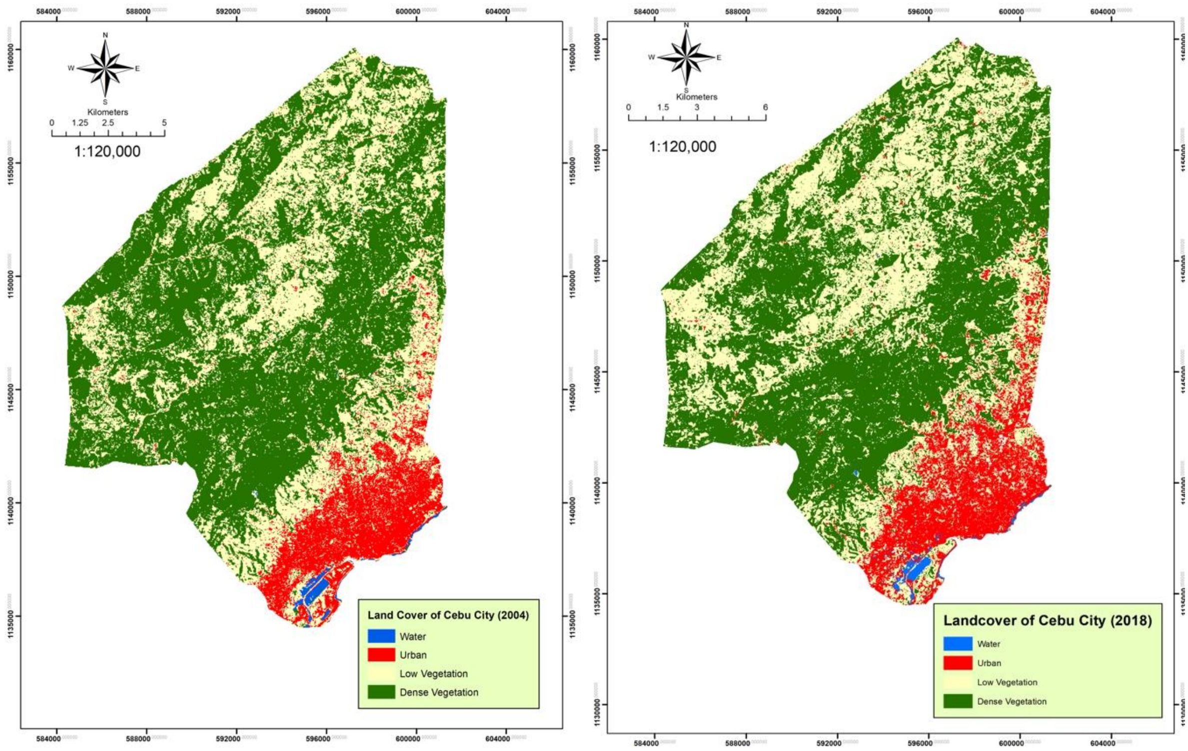

Figure 3. The land classification map of Cebu City for 2004 and 2018.

Table 1. The accuracy assessment of the analysis for 2004 and 2018.

	Year	
	2004	**2018**
Overall Accuracy	87.3	90.9
Kappa	81.1	86.6

Table 2. The calculated area (in hectares) of each feature class showing the increase of urban and low vegetation cover while a decreasing dense vegetation cover. This trend is accompanied by the increasing city population.

Year	Population	Water	Urban	Low Vegetation	Dense Vegetation	Total
2004	718,821	162.20	3,053.90	10,130.30	17,096.20	30,442.59
2018	922,611	202.30	3,395.90	11,858.60	14,985.70	30,442.59

The land classification of Cebu City showed the sprawling of urban areas from the southeast spreading to the north. This equates to a 10% increase of urban cover between 2004 and 2018 and a 1.12% increase relative to the total land area of Cebu City (Table 2). Barangays with rapid change in urban cover included Bacayan, Pit-os, and Banilad with 22%, 21%, and 15% increase from 2004 to 2018. The increased urbanization of these barangays can also be attributed by the impact of the adjacent Mandaue City, a highly urbanized area in the eastern part of Cebu City.

In contrast, there was an observed increase in low vegetation cover, particularly in the northwestern part of the city (Fig. 3). These included bare lands, grasslands, agricultural farmlands, and natural parks and playgrounds. The change accounted for about 15% from 2004 to 2018 and 5.67% relative to the total land area. Field validation (visual inspection) found that most of the low vegetation areas were agricultural farmlands. Notable barangays with the largest change in low vegetation cover were Barangays Sudlon 2, Sudlon 1, and Tabunan; all with a 14% increase. Further, Barangays Bacayan, Banilad, and Lahug had the largest decrease in low vegetation cover with 21%, 19%, and 18% respectively. These same barangays had the highest built-up increase from 2004 to 2018. The trend reflects the conversion of low vegetated areas into built-up, which could be attributed to the rapid economic development of Cebu City over the years (Table 2). According to the PSA report in 2015, most of the development in the city included real estates, business process outsourcing (BPO) companies, schools, and micro-enterprises.

The conversion of more lands to built-up is expected to continue as Cebu city is the major hub of BPO industries in the Philippines. It ranked 8th worldwide in the "Top 100 BPO Destinations Report" in 2013 as reported by a global advisory firm Tholons. The growth of BPO industries contributed to $484 million in revenue in 2012. The major hub for BPO industries is located in the IT Park, in Barangay Lahug; whereas above-mentioned was one of the areas with a significant decrease in low vegetation cover (Cebu City Profile, 2008).

Nevertheless, despite the commercialization from BPO industries and general urban development, a significant portion of the city, approximately 50%, was still classified as dense vegetation. This is, however, lower in contrast to 76.3% declared protected areas in Cebu City. A 12.3% decline of dense vegetation was observed from 2004 to 2018, decreasing the total dense vegetation land area by 6.9%. Dense vegetation cover includes dense shrublands and forest lands. Notable barangays with the rapid decrease of dense vegetation cover from 2004 to 2018 are Barangay Pit-os, Sudlon 1, and Sudlon 2 with 16.6%, 15%, and 14.7% respectively. This trend shows that dense vegetation is converted into either urban or low vegetation class depending on its proximity to urban development. Barangays with a slight increase in dense vegetation cover includes Bulacao, Pardo, and Quiot Pardo with 11.5%, 8.3%, and 8.2% respectively (Table 3).

3.2 Neighborhood-scale Classification

Neighborhood-scale classification determined the likelihood of the 80 barangays in Cebu City based from their respective population density, urban (built-up) cover, low vegetation cover, and dense vegetation cover data. In consideration of the image utilized in the study, acquired from Landsat, the components mentioned excluding population, are limited to the resolution. As such Urban (built-up) cover includes mostly houses and buildings but does not include other infrastructures such as bridges and railroad infrastructures. Low vegetation cover refers to bare lands, grasslands, agricultural farmlands, and open grounds of natural parks. Dense vegetation cover encompasses both forest and shrubland. Field validation was conducted confirming acquired image results.

Hierarchical cluster analysis was then conducted resulting in 6 unique classes from data acquired in 2004 and 2018. The classes were named with reference to existing Land Use terminologies used for Cebu City, and are as follows: Urban Core 1 (Urban Center), Urban Core 2 (High built-up cover), Urban Core 3 (High population density), Urban Periphery, Low Vegetated Uplands and Densely Vegetated Uplands (Cebu City Profile, 2008). Each unique class was described and interpreted based on the range of values from their data attributes (Fig. 4). The classification supports an inverse relationship trend between vegetation cover and built-up cover and a direct relationship between the latter and population density.

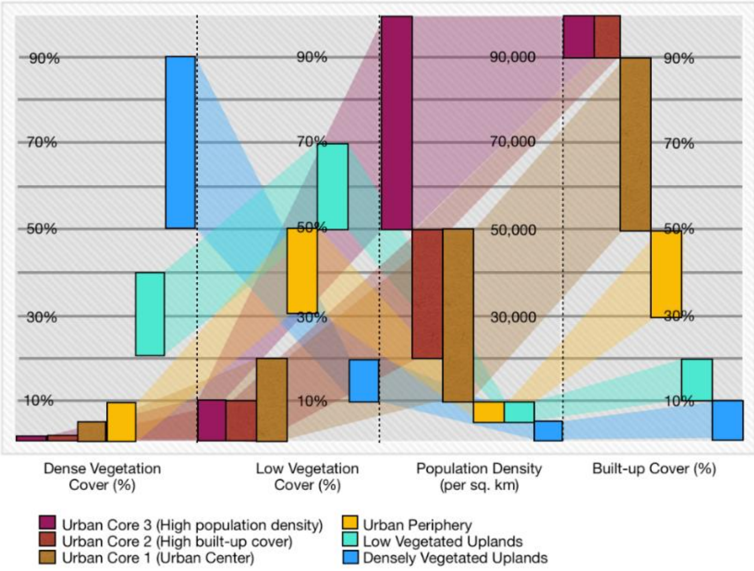

Figure 4. Neighborhood-scale land classification based on the results of Hierarchical Cluster Analysis.

Table 3. Neighborhood-scale land classification by barangays in Cebu City

Land Class		2004 Area (ha.)	2004 No. of Barang-ays	2004 Land Coverage (%)	2018 Area (ha.)	2018 No. of Barang-ays	2018 Land Coverage (%)	Change (%)
1	Urban Core 1	1,403.44	31	4.83	1,651.72	34	5.68	17.60
2	Urban Core 2	49.04	2	0.17	0.00	0	0.00	-100.00
3	Urban Core 3	29.24	1	0.10	29.24	1	0.10	0.00
4	Urban Periphery	4,305.92	16	14.82	4,252.92	16	14.64	-1.23
5	Low Vegetated Uplands	4,327.93	7	14.89	9,170.80	12	31.56	111.90
6	Densely Vegetated Uplands	18,943.31	23	65.19	13,954.20	17	48.02	-26.34
	Total	29,058.88	80	100.00	29,058,88	80	100.00	

Urban core classes (Class 1 – 3) were identified in about 42.50% (34 out of 80) of the Barangays in 2004 with a slight increase to 43.75% (35 out of 80) by 2018. Almost all of the identified Urban core barangays fall in Class 1, Urban Center. These barangays are situated within an area with high urban cover, high population density and sparse vegetation cover (Table 3) (Steenberg *et al*., 2015). According to PSA (2015) data, these classes are the center of commerce and trade of the city. Major ports, schools, provincial terminals, BPO industries, and government offices are located in this area.

Additionally, 16 barangays fell into the urban periphery class (Class 4). In 2018, an additional 1 barangay was added to the class which was previously classified as low vegetated uplands (Class 5) while one barangay was reclassified as urban core (Class 1). Urban periphery is the boundary between the highly urbanized center and the rural upland community or sometimes referred to as the second urban core (Steenberg *et al*. 2015). Majority of the areas in this class are residential mixed with micro-enterprise, commercial establishments, and real-estate developers. This area also is directly impacted by the spillover effect of development from the urban center.

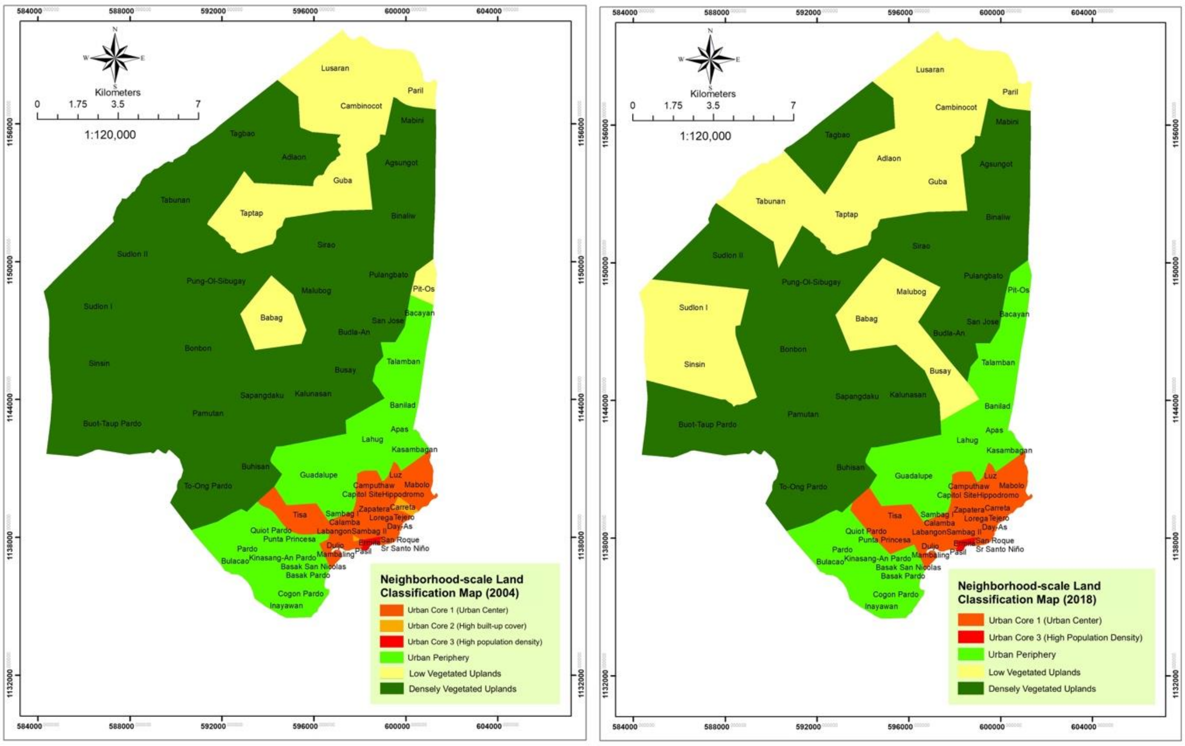

Figure 5. The neighborhood-scale classification maps of Cebu City in 2004 and 2018.

A more notable increase was observed in the barangays classified as Low Vegetated Uplands (Class 5) as the number of barangays grew from 7 to 12 by 2018, causing a change of 111.90%. This is due to the reclassification from Densely Vegetated Uplands (Class 6) of 6 barangays to Class 5, while a previous Class 5 Barangay, Pit-os, was reclassified into Urban Periphery (Class 4). The Densely Vegetated Uplands decreased from 23 to 17 barangays, having a -26.34% change from 2004 to 2018. It is generally observed that the classification of barangays tended to move upward a class towards a highly urban area (Fig. 5).

The changing classes over time are impacted by the increasing population and land cover changes. The increasing urban cover has a negative correlation to low vegetation cover (R^2=-0.88). This scenario is apparent in urban centers and urban periphery where any available open space is heavily converted into built-ups. On the other hand, low vegetation is negatively correlated (R^2=-0.71) to dense vegetation cover. This is also apparent in mountainous uplands where forest patches are heavily converted into farmlands. This case can be observed in Barangay Sudlon 1, Sudlon 2, and Tabunan. Google Earth images showed an expanding agricultural land within these barangays. Thus, farming becomes the primary driver of deforestation. This claim is also reported in the study of Adams *et al*., (2013) and Nugroho *et al*., (2018).

4. CONCLUSION AND RECOMMENDATIONS

Urban land classification should continually advance to include more quantitative indicators and drivers of land cover changes. As was attempted in this study, an integrative approach helped to better comprehend the changes that occurred in Cebu city. Despite a majority of its area declared as protected under the Republic Act 7586 NIPAS Act of 1992, Cebu city's land cover showed that a significant portion of the barangays in the uplands have been converted to agricultural farmlands. The urban core is concentrated in the southeast portion of the city and results showed a general trend for barangays to move towards an increased urbanized class over time.

The utilization of Landsat imagery allowed detection of urban land cover changes without exhausting high financial and human resources. This aspect is important to consider in the Philippines, where these said resources may be limited. Landsat spatial resolution may not be as detailed to fully assess urban sprawl, but its imagery still served well for the purpose of this study. It is recommended that more variables be included in the classification to allow further comprehension of the complexity of the urban landscape. Variables that may be considered include income, water and energy consumption, road networks, ethnical groups, and even crime rate. This method of classification and detection of land cover changes may further be adopted and enhanced by the local government towards development and implementation of effective sustainable urban management strategies.

5. LITERATURE CITED

Achtert, E., Böhm, C., Kröger, P., 2006. "DeLi-Clu: Boosting Robustness, Completeness, Usability, and Efficiency of Hierarchical Clustering by a Closest Pair Ranking". LNCS: Advances in Knowledge Discovery and Data Mining. Lecture Notes in Computer Science. 3918: 119–128.

Adams, C., Chamlian Munari, L., Vliet, N., Sereni, Murrieta R., Piperata, B., Futemma, C., Spressola-Prado, V., (2013) Diversifying incomes and losing landscape complexity in Quilombola shifting cultivation communities of the Atlantic rainforest (Brazil). Hum Ecol 41(1):119–137. doi: 10.1007/s10745-012-9529-9

Alberti, M., and Susskind, L. (1996). Managing urban sustainability: An introduction to the special issue. Environmental Impact Assessment Review, 16(4-6), 213–221. doi: 10.1016/s0195-9255(96)00070-4

Alberti, M., Marzluff, J.M., Shulenberger, E., Bradley, G., Ryan, C., Zumbrunnen, C., 2003. Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. BioScience. 53: 1169-1179.

Ancog, R., Ruzol, C., 2015. Urbanization adjacent to a wetland of international importance: The case of Olango Island Wildlife Sanctuary, Metro Cebu, Philippines. Habitat International. 49:325-332.

Bagarinao, R., 2011. Patch richness and shape complexity in Central Cebu Protected Landscape, Cebu Island, Philippines: Implications in Environmental Management. Asia life sciences 20(1):25-35.

Bailey, R.G., 2009. Ecosystem Geography - From Ecoregions to Sites. 2nd ed. Springer, New York, NY.

Cadenasso, M.L., Pickett, S.T.A., Schwarz, K., 2007. Spatial heterogeneity in urban ecosystems: re-conceptualizing land cover and a framework for classification. Front. Ecol. Environ. 5: 80-88.

Cebu City Profile, 2008. City Planning and Development Office. Cebu City. Available at: https://www.cebucity.gov.ph

Costanza, R., d'Arge, R., de Groot, R., Farberk, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.J., Suttonkk, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature. 387: 253-260.

Conway, T.M., Bourne, K.S., 2013. A comparison of neighborhood characteristics related to canopy cover, stem density, and species richness in an urban forest. Landsc. Urban Plan. 113: 10-18.

Duinker, P.N., Ordónez, C., Steenberg, J.W.N., Miller, K.H., Toni, S.A., Nitoslawski, S.A., 2015. Trees in Canadian cities: indispensable life form for urban sustainability. Sustainability. 7: 7379-7396.

Ejares, J.A., Violanda, R.R., Diola, A.G., Dy, D.T., Otadoy, J.B., Otadoy, R.E.S., 2016. Tree canopy cover mapping using LiDAR in urban barangays of Cebu City, Central Philippines. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XLI-B8: 611-615.

Escobedo, F., Nowak., D.J., 2009. Spatial heterogeneity and air pollution removal by an urban forest. Landscape and Urban Planning. 90(3): 102-110.

Gonzales, G.R., 2004. Metro Cebu: A metropolitan area in need of coordinative body. Philippine Institute for Development Studies. Discussion Paper Series No. 2004-09.

Grove, J.M., Locke, D.H., O'Neil-Dunne, J.P.M., 2014. An ecology of prestige in New York City: examining the relationships among population density, socioeconomic status, group identity, and residential canopy cover. Environ. Manag. 54: 402-419.

Jiang, B., Larsen, L., Deal, B., Sullivan, W.C., 2015. A dose–response curve describing the relationship between tree cover density and landscape preference. Landscape and Urban Planning. 139: 16–25.

Jongman, R.H.G., Ter Braak, C.J.F., Van Tongeren, O.F.R., 1995. Data Analysis in Community and Landscape Ecology. Cambridge University Press, Cambridge, UK.

Huang Shu-Li, Chia-Tsung Yeh, Li-Fang Chang., 2010. The transition to an urbanizing world and the demand for natural resources. Current Opinion in Environmental Sustainability. 2:136-143.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.S., White, K.S., 2001. Intergovernmental Panel for Climate Change. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Eds., Cambridge University Press, Cambridge. 1032.

McNab, W.H., Browning, S.A., Simon, S.A., Fouts, P.E., 1999. An unconventional approach to ecosystem unit classification in western North Carolina, USA. For. Ecol. Manag. 114: 405-420.

McPherson, E.G., Simpson, J.R., Peper, P.J., Xiao, Q., Wu, C., 2008. Los Angeles 1-Million tree Canopy Cover Assessment (No. PSW-207). USDA Forest Service Pacific Southwest Research Station, Albany, CA.

McPherson, E.G., Simpson, J.R., Xiao, Q., Wu, C., 2011. Million trees Los Angeles canopy cover and benefit assessment. Landsc. Urban Plan. 99: 40–50.

Nicholls, R.J., Wong, P.P., Burkett, V.R., Codignotto, J.O., Hay, J.E., McLean, R.F., Ragoonaden, S., Woodroffe, C.D., 2007. Coastal systems and low-lying areas. Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. Eds., Cambridge University Press, Cambridge, UK. 315-356.

Nugroho, H.Y.S.H., van der Veen, A., Skidmore, A.K. et al. J. For. Res. 2018. 29: 495. https://doi.org/10.1007/s11676-017-0449-9.

Nowak, D.J., Dwyer, J.F., 2007. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J.E. (Ed.), Urban and Community Forestry in the Northeast. Springer, New Brunswick, NJ. 25-46.

Philippine Statistics Authority (PSA)., 2010. The Cebu City barangays https://psa.gov.ph/content/urban-barangays-philippines-based-2010-cph

Philippine Statistics Authority (PSA). 2015. The Philippines in figures. Available at: https://psa.gov.ph/content/psa-releases-2015-philippines-figures

Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., Boone, C.G., Groffman, P.M., Irwin, E., Kaushal, S.S., Marshall, V., McGrath, B.P., Nilon, C.H., Pouyat, R.V., Szlavecz, K., Troy, A., Warren, P., 2011. Urban ecological systems: scientific foundations and a decade of progress. J. Environ. Manag. 92: 331-362.

Steenberg, J.W.N., Millward, A.A., Duinker, P.N., Nowak, D.J., Robinson, P.J., 2015. Neighbourhood-scale urban forest ecosystem classification. J. Environ. Manag. 163: 134-145.

Tratalos, J., Fuller, R.A., Warren, P.H., Davies, R.G., Gatson, K.J., 2007. Urban form, biodiversity potential, and ecosystem services. Landscape and Urban Planning. 83: 308-317.

United Nations, 2014. Millennium Development Goals Report. Department of Economic and Social Affairs.

Young, R.F., McPherson, E.G., 2013. Governing metropolitan green infrastructure in the United States. Landscape and Urban Plan. 109 (1), 67-75.