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Applying Geo-Spatial Techniques to Determine the Temporal Variation and Conversion Pattern of Land-Use Surrounding Negombo Lagoon

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ABSTRACT

Remote Sensing technology and Geographic Information Systems are the major partners in geospatial technology and they play a vital role in surface, subsurface and above earth's studies. It provides a better platform for researchers specially in the fields of regional planning, disaster management, natural resources management etc. Observing land-use patterns in a particular area forms a basis for decision making in these fields. The study has the purpose of applying geo-spatial techniques to determine the temporal variation and conversion pattern of land-use surrounding Negombo lagoon. For that, the study has used Landsat imageries of 2003, 2009, 2015 and 2021 from the United States Geological Survey. ISO Cluster Unsupervised Classification method and data conversion tools were used to create initial layers for analysing the land-use in selected four years by using Arc GIS 10.4. software. Intersect and field calculators were used to get a better understanding of the variation of land-use through classified Landsat imageries of respective years. The results will support for measuring area of the conversion of different land-use into another and / or within the same category in a particular area throughout the time. The study concluded that, the used techniques could measure only the temporal variation of major land use types; water bodies, vegetation, built-up areas and cultivations but the minor categories of land uses were unable to detect. However, the better spatial and temporal resolution data enables to improve results to avoid such issues.

1. Introduction

Remote Sensing Technology and Geographic Information Systems (GIS) are widely used to monitor the phenomenon on surface of earth as geo-spatial technologies. These technologies are advantageous for multi-disciplinary purposes such as land-use planning, urban planning, disaster management, environmental management and business management etc. Identifying temporal variation of land-use contributes to the development of these fields since the related findings support to decisions making in these sectors. Similarly, "Measuring land cover change helps to monitor the pressures on ecosystems and biodiversity. Advances in Earth observation and data processing improve measurement of land cover changes at the global scale" (Monitoring land cover change, 2018). Land-use changes affect the environment in a positive or negative manner in a particular area. Construction of buildings and other artificial surfaces contributes to the loss of sensitive ecosystems and fragmentation of natural habitats. Specially, land use changes cause land fragmentation and adversely affect wildlife and humans. As a result, wildlife-human conflicts are arising in different manners. Similarly, land use changes are caused by poor land management of humans like irregular agriculture, irrigation, dumping and unnecessary constructions that change the general morphology of land itself. "Poor land management has degraded vast amounts of land, reduced our ability to produce enough food, and is a major threat to rural livelihoods in many developing countries" (Maitima et al, 2010). Similarly, changing the natural environment into the built environment specially converting natural permeable surfaces into impermeable surfaces affects surface run-off, infiltration, ground water recharging like hydrological phenomena. Wu (2008) pointed out conversion of vegetation and agri lands into urbanized lands negatively affect food production and environmental productions. Establishment of ecological structures such as green infrastructures are the positive changes of land use. Remote sensing and GIS contribute as powerful tools of geospatial technology for studying such types of issues on the surface, and help decision making and management.

"Geospatial technologies are tools used to map and analyse Earth's surface and patterns in human societies. All environmental data refers to a specific location on Earth at a particular time, and geospatial mapping is critical to understanding where and when specific conditions exist" (Center for Environmental Policy, American University School of Public Affairs.(n.d.)) Accordingly the identification of temporal variation of land use provides the basis for environmental and social studies. "Timely and accurate detection of land use/land cover (LULC) change is important for the macro and micro level sustainable development of any region. For this purpose, geospatial techniques are the best tools for change-analysis as they supply timely, cheaper, precise and up-to-date information" (Kumar & Singh, 2021). Geo-spatial technology is powered by multi-sources of data, data processing and analysing methods to detect land-use variations. "Satellite images from USGS Earth Explorer are used to detect land use and land cover change through classification of original image or calculations of some indexes such as Normalized Difference Vegetation Index, Environmental Vegetation Index and etc." (Li et al, 2020). Integration of different methods of geo-spatial technology provides more benefits to the land-use studies. Obiefuna et al, 2013 have applied topographic maps for their study except to the satellite images because of lack of similar data sources for the selected time series of their study. Bawahidi, 2005 has acquired multi source data from LandSat and SPOTS satellites for analysis "Integrated land-use change analysis for soil erosion study in Ulu Kinta catchment". Kumar & Singh, 2021 have applied ERDAS 9.2 and ArcGIS 10.2 software for unsupervised classification and map creation respectively. In addition, Kumar & Singh, 2021 have used ENVI 5.3 software to do thematic changes to maps. Those are engaging with geospatial technology to provide the highest value for these studies. A study by Petja et al2014 to find out the agricultural potentiality used geospatial technologies; GIS, GPS and satellite images. Weighting techniques of Arc View software was used for the achievement of the objectives. Another study of Chaware et al, 2021 for the purpose of detecting spatio-temporal changes in land cover and land use has applied geo-spatial techniques combining with the other methods. In that study, Sentinel and Landsat satellite imageries and GPS data were used. Maximum likelihood of supervised classification has been used for the classification of satellite imageries and geometry calculation were used for the analysis of the study. Wijewardhana & Senevirathna(2021) have acquired spatial data from Google Earth Pro application to analyse "Development of urban green spaces for achieving ecological and social benefits of urban areas in Sri Lanka". KML tool in ArcMap 10.4 software was the major tool used to extract spatial data from Google Earth Pro in their study. "Detection of the changes of land use and land cover using remote sensing and GIS" by Wijesinghe et al, 2021 has used remote sensing and GIS techniques for analysing changes of land use in Thalawa Divisional Secretariat Division in Sri Lanka. Landsat images were the major source of data and they have classified the images using Maximum Livelihood method. The researchers applied both Erdas Imagine and ArcMap software for their study. This study used area calculations methods (geometric calculation) in GIS software to find the changes of different land-use types. "Land Use Land Cover Change Analysis using Geospatial Tools in Case of Asayita District, Zone one, Afar Region, Ethiopia" by Fantaye et al, 2017 has used the GIS, GPS and Remote Sensing techniques for achieving objectives. Both supervised and unsupervised classification methods have been used as image classification. For change-detection, the researchers have used geometric calculation in that study. Accordingly, geospatial technology has become an advanced option because many software applications and data sources are engaging with it.

Geo-spatial techniques are not only for analysing past and current situations of land-uses but also for predicting future situations by cooperating with other technologies. Nguyen et al, 2018 have done a study to predict urban expansion in a city in Vietnam. Land-use extracted from SPOT-5 satellite imageries of selected three years were used for this study. Markov Chain Model has been used to predict the future of urban expansion in the study area.

Web GIS, mobile GIS, 3D GIS visualizing and flythrough, open GIS are the recent improvements of GIS platform. Beaudreau et al, 2012 have studied how GeoWeb application is used for rural economic development. As per the study, this web based GIS technology is more effective than the other technologies because it reduces development cost, and strengthens the relationship among stakeholders.

1.1 Objective

Applying geo-spatial techniques to determine the temporal variation and conversion pattern of land-use in study area.

1.2 Research Question

What is the temporal variation and conversion pattern of land-use in study area?

2. Materials and Methods

The study selected the Negombo lagoon area of Sri Lanka as the study area (Figure 01) and has used secondary data to achieve the objectives. The researchers obtained land use data of Negombo lagoon area from remote sensing data for pre-defined 4 years. Accordingly, Landsat 8 OLI TIRS C2 L2 and

Landsat 7 ETM + C2 L1 have been applied to extract land use data (Buildings, Cultivation, water bodies and Vegetation) of Negombo lagoon area for 2021,2015,2009 and 2003 years respectively from United State Geological Survey (USGS). Thus 'ISO Cluster Unsupervised Classification' in ArcMap 10.4 software was applied to obtain data from Landsat images.

2.1 Extract land use data from Landsat 7, 8 images

Table 01 shows the band combinations that were used to extract land use data from Landsat images.

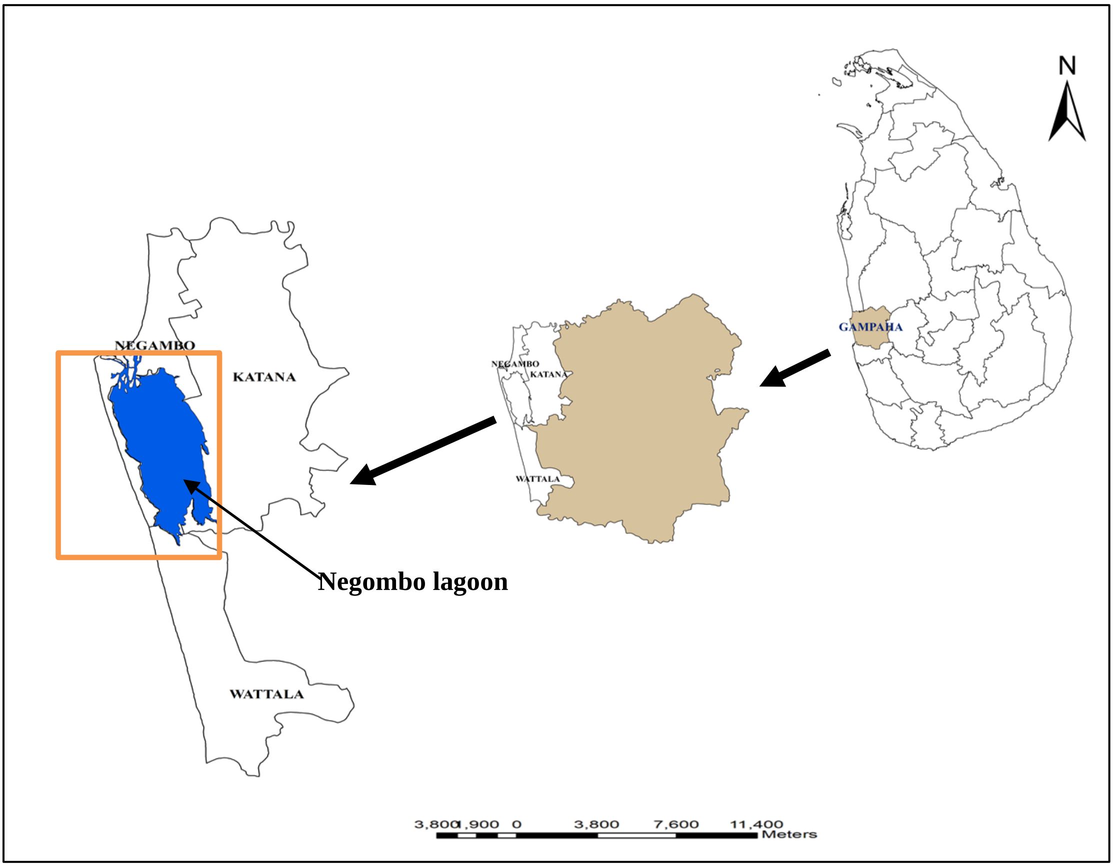

Figure 1. Study area (Source: Survey Department of Sri Lanka).

Table 1. Band combinations for extracting land use data from Landsat images

Land use type	Band combination
Water bodies	564
Buildings/Urbanized area	764
Agro lands/ Home Garden	652
Vegetation	562

Source: United State Geological Survey (USGS)

The study created composite layers for above all band combinations using 'composite band' tool in ArcMap 10.4 Next, each composite layer was classified in to 4 classes separately using 'ISO Cluster Unsupervised Classification' method. After that, each classified layer was reclassified in to 2 numbers of classes as 0 and 1 by using 'Reclass' tool. For instance, classified 564 composite layer is given value '1' for water bodies and given value '0' for other extra 3 classes to identify only the water bodies. Finally, reclassified raster data (classified layers) is converted into vector data by using 'Raster to Polygon' tool in ArcMap 10.4 and exported only the value '1' layer of each land use layer (reclassified layers).

These vector features of each year have been merged according to land use type using "Dissolved" tool. Since these processed layers (dissolved vector layers) have been used for the analysis of the study, the researchers have decided to do accuracy assessments for these output layers (pg. 06-10). Then dissolved layers were intersected as 2009 and 2003, 2015 and 2009, 2021 and 2015 separately by using "intersect" tool. To identify the temporal variation of land use from 2003 to 2021 (figure 02) "field calculator" was used.

2.3 Accuracy Assessment of the Data

This study has done an accuracy assessment by using "create accuracy assessment points" tool in ArcMap 10.4 software. According to the simple random sampling method, sixty (60) numbers of points per year were selected due to the inconvenience of getting large sample size for the follow up method (pg. 7) of the accuracy assessment. Researchers have overlaid 60 points onto relevant Google Earth Pro image in 2003, 2009, 2015 and 2021 respectively to recognize the correctly classified points. The correctly classified points out of 60 (Table 02, 03, 04 and 05) have been marked manually by the researchers comparing classified images with the relevant Google Earth Images Then, accuracy of the data was calculated by using following formula;

$$\text{Overall Accuracy} = \frac{\text{Total number of correctly classified points (diagonal)}}{\text{Total number of reference points}} \times 100$$

The highlighted numbers in table 02, 03, 04 and 05 are the correctly classified points of the processed layers (classified images) after comparing with the Google Earth Pro images. The summation of correctly classified points of each year has been divided by total number of reference points (60) to measure the accuracy of the image classification of selected years.

Table 2. Accuracy assessment table for classified map of year 2021

	Water body	Vegetation	Built-up area	Others	Cultivation	Total (User)
Water body	11	0	0	1	0	12
Vegetation	2	10	0	0	0	12
Built-up area	0	2	9	0	0	11
Others	0	0	2	8	3	13
Cultivation	1	2	0	0	9	12
Total (Producer)	14	14	11	9	12	60

Source: Evaluate the accuracy by using Google Earth Pro and ArcMap 10.4 software

$$Overall\ Accuracy\ (2021) = \frac{Total\ number\ of\ correctly\ classified\ points\ (diagonal)}{Total\ number\ of\ reference\ points} \times 100$$

$$Overall\ Accuracy = \frac{47}{60} \times 100$$

= 78.33

Table 3. Accuracy assessment table for classified map of year 2015

	Water body	**Vegetation**	**Built-up area**	**Others**	**Cultivation**	**Total (User)**
Water body	10	0	0	0	1	11
Vegetation	2	8	0	0	1	11
Built-up area	0	1	13	2	0	16
Others	0	0	1	9	0	10
Cultivation	1	4	0	0	7	12
Total (Producer)	13	13	14	11	9	60

Source: Evaluate the accuracy by using Google Earth Pro and ArcMap 10.4 software

$$Overall\ Accuracy\ (2015) = \frac{Total\ number\ of\ correctly\ classified\ points\ (diagonal)}{Total\ number\ of\ reference\ points} \times 100$$

$$Overall\ Accuracy = \frac{47}{60} \times 100$$

= 78.33

Table 4. Accuracy assessment table for classified map of year 2009

	Water body	**Vegetation**	**Built-up area**	**Others**	**Total (User)**
Water body	8	3	0	2	13
Vegetation	4	11	0	2	17
Built-up area	0	1	10	3	14
Others	2	1	4	9	16
Total (Producer)	14	16	14	16	60

$$Overall\ Accuracy\ (2009) = \frac{Total\ number\ of\ correctly\ classified\ points\ (diagonal)}{Total\ number\ of\ reference\ points} \times 100$$

$$Overall\ Accuracy = \frac{38}{60} \times 100$$

= 63.3

Table 5. Accuracy assessment table for classified map of year 2003

	Water body	Vegetation	Built-up area	Others	Cultivation	Total (User)
Water body	10	2	0	0	1	13
Vegetation	3	8	1	0	2	14
Built-up area	0	0	10	4	0	14
Others	0	1	2	6	1	10
Cultivation	1	0	0	0	8	9
Total (Producer)	14	11	13	10	12	60

Source: Evaluate the accuracy by using Google Earth Pro and ArcMap 10.4 software

$$Overall\ Accuracy\ (2003) = \frac{\text{Total number of correctly classified points (diagonal)}}{\text{Total number of reference points}} \times 100$$

$$Overall\ Accuracy = \frac{42}{60} \times 100$$

$$= \underline{70}$$

3. Results and Discussion

Tables 06 to 09 show the area calculations of major types of land use respective to the selected years.

Table 6. Land use 2003

Type	Area (hec)
O	40.28
B	6052.76
V	4867.19
W	3803.78

Table 06 indicates the total area of water bodies (W), vegetation (V), built-up areas (B) and other land uses (O) in the study area as approximately 3803.78, 4867.19, 6052.76 and 40.28 hectare respectively in 2003.

Table 07 indicates the total area of water bodies (W), vegetation (V), built-up areas (B) and other land uses (O) in the study area as approximately 3743.78, 7967.39, 3034.42 and 52.13 hectare respectively in 2009. Table 08 indicates the total area of water bodies (W), vegetation (V), built-up areas (B) and cultivation land uses (C) in the study area as approximately 3443.20, 4794.32, 5307.61 and 1208.26 hectare respectively in 2015.

Table 7. Land use 2009

Type	Area (hec)
O	52.13
B	3034.42
V	7967.39
W	3743.78

Table 8. Land use 2015

Type	Area (hec)
B	5307.61
W	3443.20
C	1208.26
V	4794.32

Table 09 indicates the total area of water bodies (W), vegetation (V), built-up areas (B) and other land uses (O) in the study area as approximately 3178.24, 5392.08, 4725.05 and 1412.67 hectare respectively in 2021.

Table 9. Land use 2021

Type	Area (hec)
O	1412.67
B	4725.05
V	5392.08
W	3178.24

The following tables show how much land use has changed from 2003 to 2021 (Table 10 – 12). Accordingly the land use types in the study area has shown quantitative variations within the same type during the selected time period and some land use types change from one type to another.

Table 10. Classification of changes 2003-2009

Type	Area (hec)	Type	Area (hec)
O-O	40.022403	V-O	3.3459
O-B	0.011784	V-B	240.566797
O-V	0.231472	V-V	4559.016968
O-W	0.249583	V-W	64.26616
B-O	8.516178	W-B	105.870697
B-B	2681.928181	W-V	119.301203
B-V	3288.829895	W-W	3576.39078
B-W	72.414048		

Table 11. Classification of changes 2009-2015

Type	Area(hec)	Type	Area(hec)
O - C	6.519999	V-C	456.448961
O- B	30.528738	V-W	17.72258
O-V	5.633029	V-B	0.272115
B-C	478.590618	V-V	4486.797255
B-W	23.37047	W-C	258.28579
B-V	244.812996	W-W	3393.831952
W-V	57.078619		

Table 12. Classification of changes 2015-2021

Type	Area (hec)	Type	Area (hec)
C-O	531.65272	B-O	30.585244
C-B	474.839075	B-B	0.022112
C-V	190.609089	B-V	0.193497
C-W	9.701969	V-O	380.519959
W-O	171.45089	V-B	324.984194
W-V	5.24495	V-V	4040.425061
W-W	3151.51	W-B	104.536076

W = Water bodies V= Vegetation B= Buildings C= Cultivation O=Others

*Example to read the tables 09 to 12; V-B = Change vegetation into buildings

The study has found some changes according to the change detection area calculations of the study area. As shown in Table 10, 11 and 12, changes can be seen in same categories of land use as well as some land use categories have been converted into another. In 2003, the built-up area is covered by approximately 6052 hectares from total land area. In 2009 the same category is covered by approximately 3034 hectares from total land area. (Table 06 and 07). Table 10 shows the reason behind that situation. Accordingly, the conversion of built-up area into another category is approximately 3369 hectares (Table 10).

As well as the conversion of other different categories into built-up areas is approximately 357 hectares (Table 10). And 2682 hectares of built-up area has not been changed into another within 2003 to 2009. In 2003 and 2009, the study could detect vegetation, built-up area and water bodies only. Rest of the land uses are mentioned as others. In 2015, there is another category; cultivation lands, except vegetation, built-up area and water bodies. The cultivation lands are approximately 1208 hectares (Table 08). Vegetation and water bodies are approximately 4794 and 3443 hectares respectively (Table 08). "Other" land uses in 2009 have been recognised in 2015 as cultivation (approximately 7 hectares), built-up areas (approximately 31 hectares), vegetation (approximately 6 hectares) (Table 11).

In addition to this, built-up areas in 2009 have been converted into different land uses; approximately 745 hectares in 2015 (Table 11). Vegetation in 2009 has been converted into different land use with approximately 473.3 hectares in 2015. Water bodies in 2009 have been converted into different land use with approximately 322 hectares in 2015 (Table 11). Approximately 3151 hectares of water bodies and 4487 hectares of vegetation land area in 2009 only exist as it is in 2015 (Table 11).

Some lands belonging to 4 number of land use categories in 2015 appear as 'others' in 2021. This is approximately 1112 hectares (Table 12). Only three types of lands exist as it is in 2021 when compared with 2015; water bodies, built-up areas and vegetation lands with approximately 3151, 0.5 and 4040 hectares from total land area (Table 12).

According to table 10, vegetation-cover in 2003 has changed as built up areas with approximately 240 hectares and into water bodies as approximately 64 hectares in 2009. Vegetation has changed again into built-up areas with approximately 0.2 hectares, cultivation 456 hectares in 2015(Table 11). Approximately 4794 hectares of other land use area has been recognized as vegetation lands in 2015 (Table 08). In 2021, vegetation-cover, as it existed in 2015, has changed into built-up area with approximately 325 hectares.

Approximately 4040 hectares of vegetation land exists as it is same as in 2015. Approximately 380 hectares of vegetation in 2015 has been recognised as others in 2021. Cultivations, water bodies and built-up areas in 2015 have been changed into vegetation area in 2021 with approximately 190, 5 and 1 hectares respectively (Table 12).

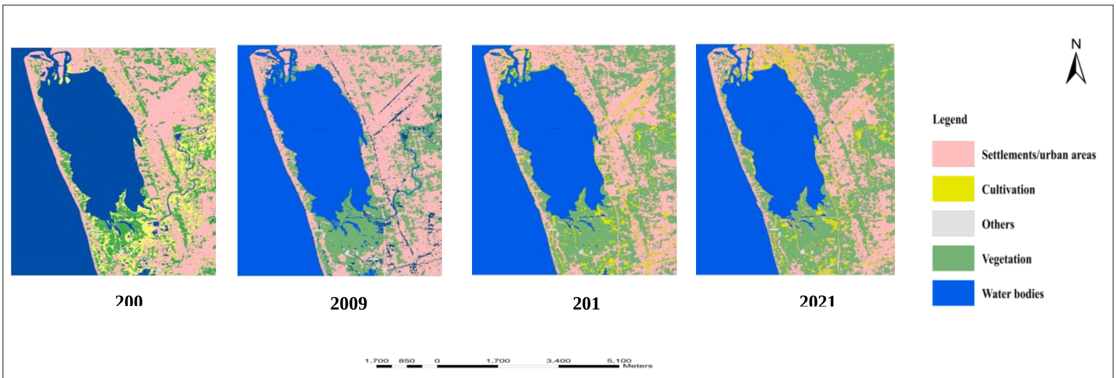

Figure 2. Temporal variation of land use in study area – 2003 to 2021 (Source data: United State Geological Survey data have been processed by authors)

4. Conclusion and Recommendations

The study has used 4 number of LandSat imageries to identify the land use types of Negombo lagoon area for the selected four years; 2003, 2009, 2015 and 2021. Study has found major land use types but detecting the minor categories of land uses was not possible. The study has found the major categories of land use as water bodies, built-up areas, vegetation and other land uses. When going through the land uses in the selected four years from 2003 to 2021, variation of temporal distribution of land uses in the study area can be seen. The study has used geographic information system and Remote sensing techniques to find out the temporal variation of different types of major land use categories by using mainly the intersect tool of Arc Map 10.4 software. Through this model, it can be identified how the area of land-use changed over the period of time and which type of land use replaced. When taking couple of years for an instance, it has shown some area of land replaced by another land use in second year when compared with the first year. Geometry calculation is a famous way to determine the size of a feature. But this study has used overlaying techniques to filter the variations and their sizes of variation of different land uses. There are three types of variation of land use that has been found through the study; variant within same category of land use, converting one land use in to another, and un-recognition conversion. Area of each land use under these categories has been calculated by the study. Accordingly, the method which has been used by this study makes it easy to identify the temporal variation of land use in terms of how, and to what extent over the period of time.

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