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Mapping and Analysis of Land Use/Land Cover Change in Kelani Watershed, Sri Lanka

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Abstract - **The Kelani watershed is recognized as the second largest watershed in Sri Lanka. Kelaniriver is the main drinking water resource of people those who live in the Kelani catchment area. Kelani watershed is a productive eco-system which provides habitats for various inherent plant and animal species. But at present, it has been revealed that various human activities affect badly on the watershed of the Kelaniriver. Land Use/ Land Cover (LULC) change in the watershed can directly or indirectly impact on the natural balance of the terrestrial and aquatic eco-systems of the watershed area. In the present study, an attempt was made to detect the LULC change in the Kelani watershed during past nineteen years from year 2000 to 2019. Kelani watershed region which was the study area of the present research was delineated using SRTM DEMs. Satellite images of years 2000, 2010 and 2019 were classified according to the LULC types using Supervised Classification technique. The classified images were subjected to the analysis in order to determine the extent of each LULC type and their changes. In the present study, the quantities of LULC changes which have taken place in the Kelani watershed from year 2000 to 2019 were determined and mapped. Post classification change detection analysis was executed using cross classification technique on a pixel by pixel basis. It resulted in a two-way cross matrix containing different combinations of "from-to" change classes and a thematic layer representing them. The vegetation cover in year 2000 has been decreased by 333 km^2 during the 19 years' time period. Built-up areas have been increased by 367 km^2. Bare lands have been decreased by about 21 km^2. Water bodies have been decreased by 13 km^2. This study illustrated that the extent of the water bodies, bare land and vegetation which were present in year 2000 have been declined by around 41%, 17% and 17% respectively within the nineteen years' time period. Increment of built up areas was 208% during the same time period. Obtained results provided better evidences of deforestation and rapid urbanization in the study area.**
Keywords: **DEM, LULC, SRTM, Supervised Classification**

I. INTRODUCTION

Watershed is known as the basic planning unit of all hydrological analyses and designs (Bose *et al*., 2011). The Kelani River which starts from Sri Padamountain and flows into the Indian ocean at Colombo is the fourth longest river in Sri Lanka. Watershed of the Kelani river is recognized as the second largest watershed in Sri Lanka (Kottagoda andAbeysingha, 2017). Kelaniriver is the main drinking water resource of people those who live in the Kelani catchment area. Carriers of majority of people living in the watershed, such as transportation, fishery, agriculture and industries mainly depend on the Kelaniriver. And also there are various inherent plant and animal species found in the watershed.

It has been revealed that various human activities affect badly on water of the Kelaniriver. Rapid urbanization, sewage discharge without treatment, soil erosion and sand mining in the river impact badly on the quality of river water (Butt *et al*.,2015). Land cover refers to the surface cover of the Earth. It can be vegetation, water body or bare soil. Land use refers to, for what purpose or how the land is utilized by human whether for agricultural or development purposes (Oceanservice.noaa.gov, 2018).

Changes in Land Use/ Land cover (LULC) cause disturbances to the natural balance of the environment and bio-diversity of terrestrial and aquatic eco-systems (Rawatand Kumar, 2015).

However, LULC change is a major result of cutting down trees and conversion of forest land in to agricultural lands or human settlements. But conversion of large extents of forest lands into human settlements or agricultural purposes is not healthy for the natural balance of the terrestrial and aquatic eco-system.

Remote Sensing techniques are being applied hugely in the present world. Some of the applications are disaster management, weather forecasting, watershed analysis, determination of soil moisture content, flood analysis, land cover change detections, extraction of mineral deposits and underground water detection (GIS Geography, 2016).In order to achieve the objectives of the present research, satellite imageries which were captured using optical remote sensing techniques were used.

In optical remote sensing, wavelengths from the visible range (0.4 micrometers) up to the thermal infrared (15 micro meters) via near infrared are measured. However, interaction of electromagnetic radiation at these frequencies with the atmosphere and the clouds causes a limitation on the potential of observation of the Earth surface (Irea.cnr.it, 2014).

The main objective of the present research was to map and analyze the LULC change in Kelani watershed during past nineteen years' time period from year 2000 to year 2019. There were several sub-objectives.
They are,

1. To delineate the Kelani watershed region.
2. To create LULC classified maps of the Kelani watershed in the years 2000, 2010 and 2019.
3. To detect and analyze the changes of LULC types from each other classes from year 2000 to 2010 and from 2010 to 2019.

Watershed of the Kelaniriver was delineated using freely available Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM). Satellite images of the Kelani watershed in years 2000, 2010 and 2019 were downloaded and classified into classes according to LULC type, using Supervised Classification.

In Supervised classification, the image analyst specifies various pixel values or spectral signatures in order to classify them into different classes. Using the spectral signatures of the trained samples, the computer classifies the whole image into particular classes (Gsp.humboldt.edu, 2020).After the classification, extents of each LULC class was determined through the analysis.

Transformation of each LULC class into another class, from year 2000 to 2010, 2010 to 2019 and 2000 to 2019 were determined through cross classification analysis on a pixel by pixel basis.

The present study would provide a clear understanding about the changes of LULC in the Kelani watershed during around last two decades.

II. METHODOLOGY

A. Data Requirement

In the present research, DEM data of Sri Lanka were used to delineate the watershed area of Kelaniriver, because the study area of the present research was the watershed of the Kelani river. For that, SRTM 30 m DEMs were freely downloaded from USGS Earth Explorer website.

Optical images which were captured using satellites of the Landsat program, covering the study area in years 2000, 2010 and 2019 were downloaded. These satellite images were also freely available in USGS Earth Explorer website. Therefore it was very convenient to download and use the images.

1. Year 2000 (2000.01.23) - Landsat 7
2. Year 2010 (2010.01.26) - Landsat 5
3. Year 2019 (2019.02.20) - Landsat 8

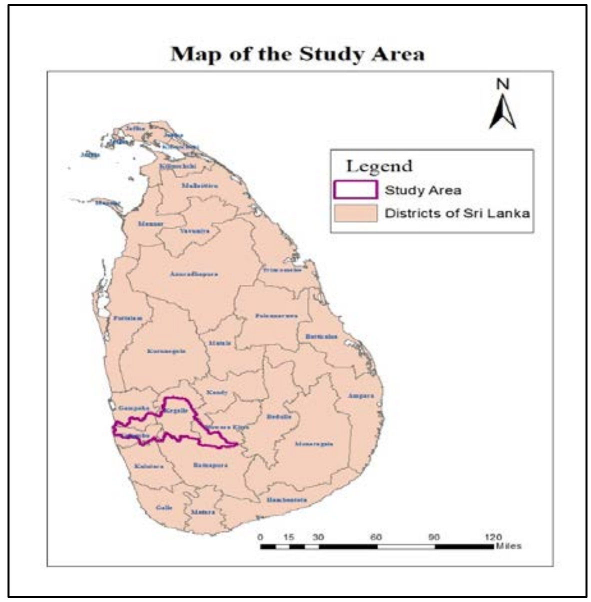

Fig.1 Map of the Kelani watershed, Sri Lanka

B.Study Area

The study area of the present research is the watershed area of the Kelaniriver, Sri Lanka.Areas of Gampaha, Kegalle, Ratnapura, Colombo and NuwaraEliya districts mainly falls in the Kelani watershed area. The Kelani catchment area is about 2284.168 km^2 in extent.

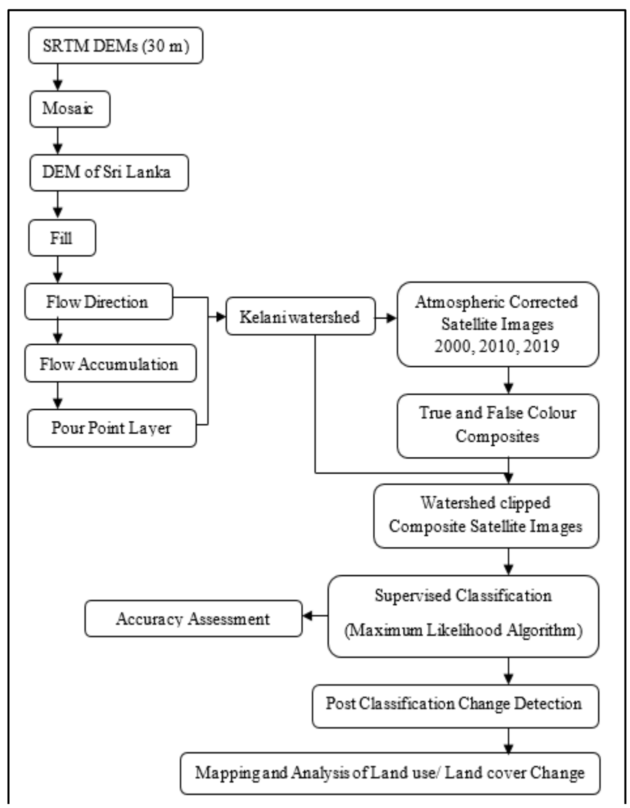

Fig.2 Methodology of the Research

III. RESULTS

A. Watershed Delineation

First step to be conducted in the present research was to delineate the Kelani watershed because the study area of the present research is the watershed region of the Kelaniriver. Using SRTM 30 m DEMs, the watershed of the Kelaniriverwas delineated in ArcMap 10.7 software using its tools inside the Hydrology toolbox.

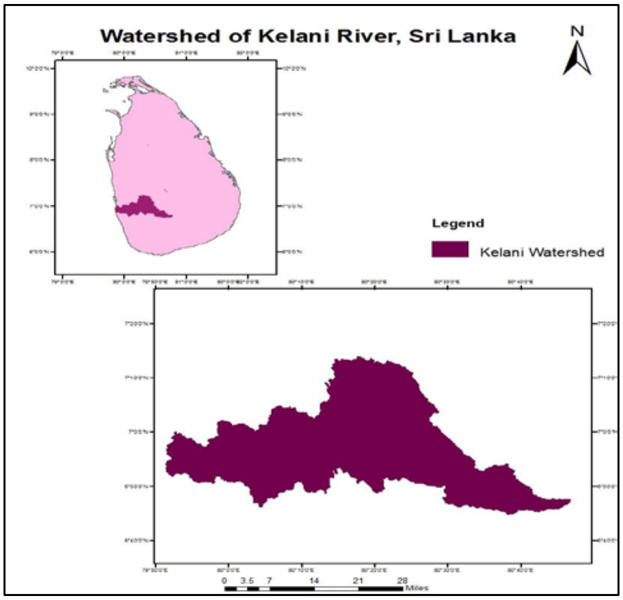

Fig. 3 Watershed region of the Kelaniriver

B. Band Combinations

The true colour composite image and two false colour composite images for each year were created. True colour composite images were created by combining Visible Red, Visible Green and Visible Blue bands. One false colour composite was created by combining Near Infrared, Visible Red and Visible Green bands. The other false colour composite was created by combining Shortwave Infrared 2, Near Infrared and Visible Green bands.

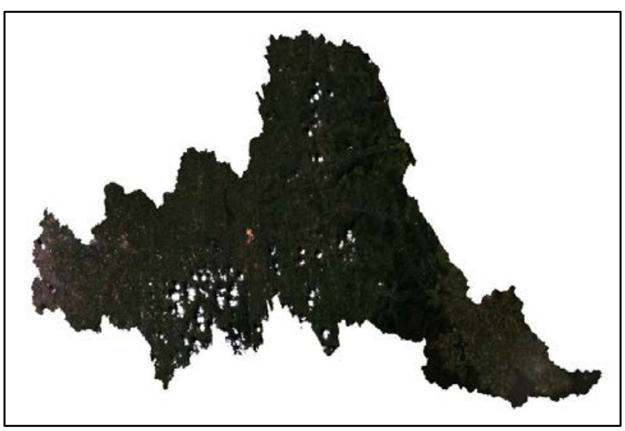

Fig. 4 Visible Red, Visible Green and Visible Blue band combination of year 2000

C. Supervised Classification

Figure 5, Figure 6 and Figure 7 represent the supervised classification results of satellite images of the years 2000, 2010 and 2019 respectively according to the LULC type. The images were classified into five classes such as vegetation, bare land, built up area, water bodies, clouds and shadows using the supervised classification maximum likelihood algorithm.

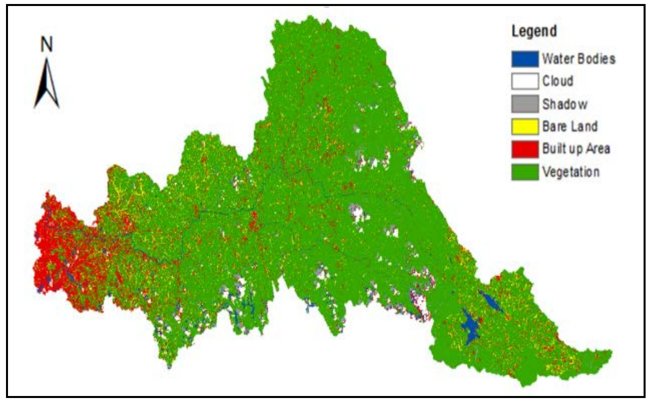

Fig.5 LULC classified map of Kelani watershed in year 2000

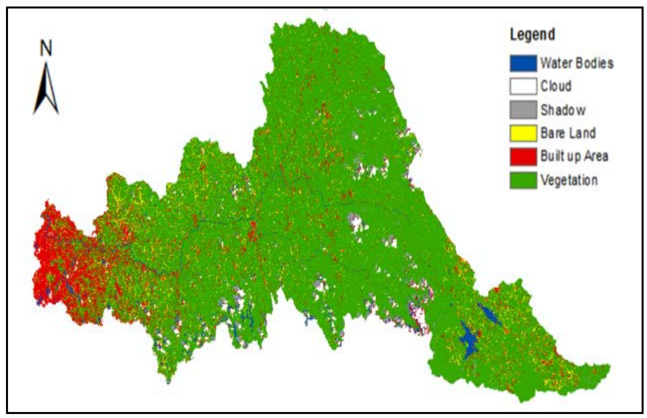

Fig. 6 LULC classified map of Kelani watershed in year 2010

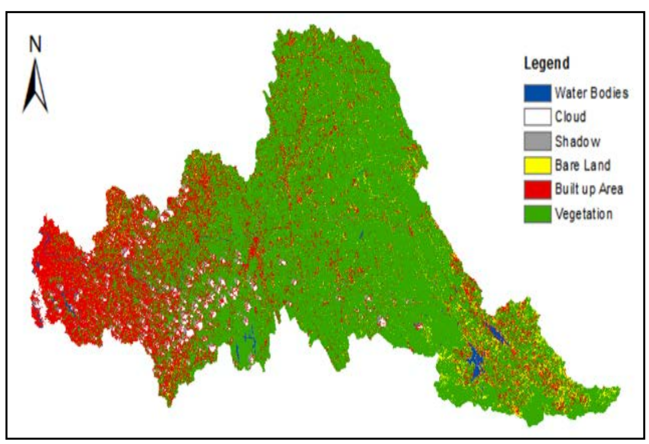

Fig.7 LULC classified map of Kelani watershed in year 2019

D. Accuracy Assessment

Accuracy assessment for each classified raster was performed by creating 100 accuracy assessment points for each classified raster. Stratified random sampling strategy was applied for this. The confusion matrices provided the overall accuracies of 81%, 81% and 84% for the classified images of 2000, 2010 and 2019 years respectively.

E. LULC Scenario of Kelani Watershed

In order to enhance the results of the present study about the actual extent of different LULC types, the pixel count of the clouds and shadows were distributed among the other four classes. This was done by assigning different percentages to the number of pixels which were classified as cloud and shadow, to the other four LULC classes by visual interpretation.

TABLE I AREA (SQ.KM) OF EACH LULC TYPE IN YEARS 2000, 2010 AND 2019

LULC Type	2000	2010	2019
Water Bodies	32.1408	48.366	18.9864
Bare Land	117.8775	105.82	97.2792
Built up Area	176.391	241.264	542.7909
Vegetation	1957.7898	1888.76	1625.039

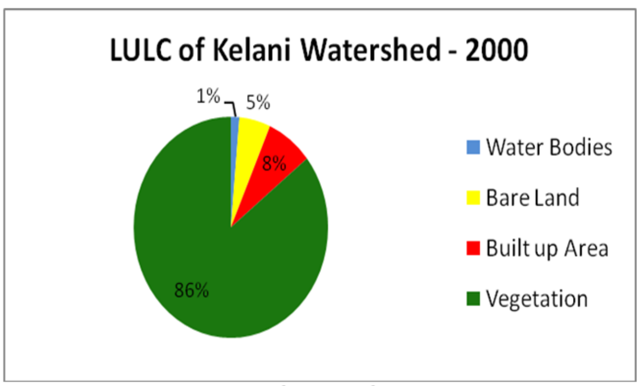

Fig. 8 Percentages of extents of LULC types in year 2000

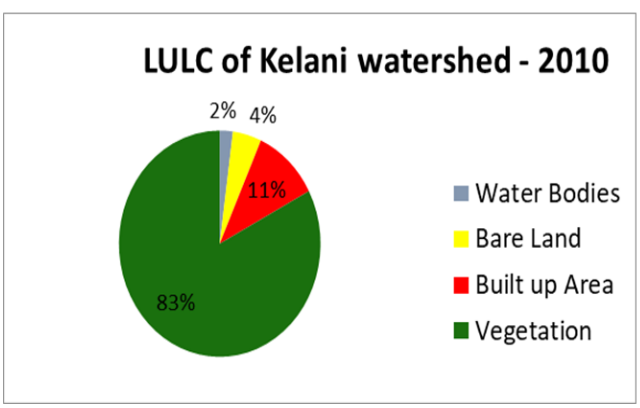

Fig.9 Percentages of extents of LULC types in year 2010

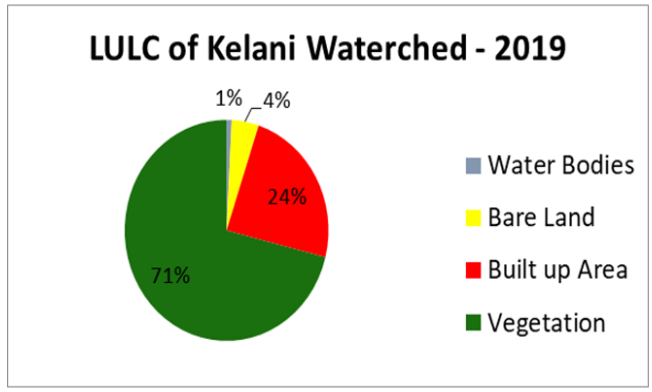

Fig.10 Percentages of extents of LULC types in year 2019

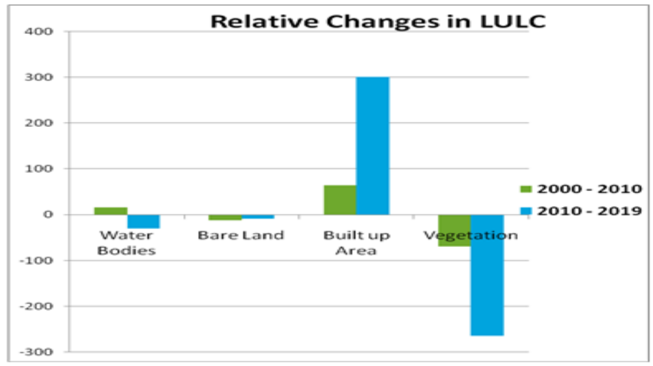

Fig. 11 Relative change of LULC types in the time frames 2000-2010 and 2010-2019

F. Post Classification Change Detection

Change detection statistics were obtained by using the "Land Cover Change" tool in Semi-Automatic Classification Plug-in in the QGIS 3.8.3 software. The obtained statistics provided a detailed tabulation of change between two classified images. When applying change detection technique for the time frame 2000-2019, the reference image (initial state image) was the LULC classified image of year 2000 and the classification image (final state image) was the classified image of year 2019. . A separate raster containing the "LULC change classes" was formed for each time frame (2000-2010, 2010-2019 and 2000-2019) as a result of this procedure. Figure 12 shows the LULC change classes from year 2000 to 2019.

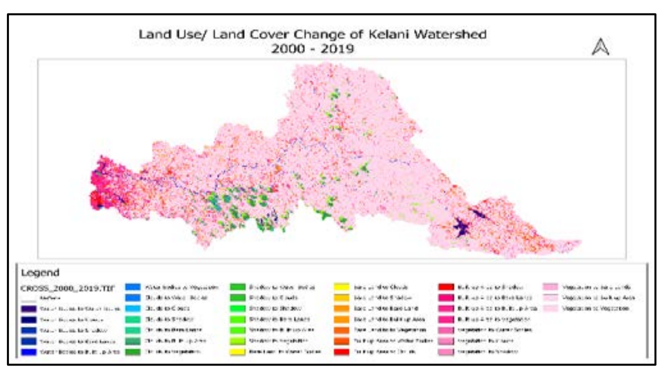

Fig. 12 LULC "from-to" change classes from year 2000 to 2019

TABLE II STATISTICAL TABLE SHOWING DIFFERENT LULC "FROM-TO" CHANGE CLASSES FROM YEAR 2000 TO 2019

Change Code	Description of the Change Code	Initial State Class	Final State Class	Pixel Sum	Area (sq. m)
1	From Water Bodies to Water Bodies	1	1	15896	14306400
2	From Water Bodies to Clouds	1	2	1367	1230300
3	From Water Bodies to Shadow	1	3	3017	2715300
4	From Water Bodies to Bare Land	1	4	476	428400
5	From Water Bodies to Built up Area	1	5	6741	6066900
6	From Water Bodies to Vegetation	1	6	8133	7319700
7	From Clouds to Water Bodies	2	1	137	123300
8	From Clouds to Clouds	2	2	3171	2853900
9	From Clouds to Shadow	2	3	2500	2250000
10	From Clouds to Bare Land	2	4	490	441000
11	From Clouds to Built up Area	2	5	8253	7427700
12	From Clouds to Vegetation	2	6	33466	30119400
13	From Shadows to Water Bodies	3	1	1230	1107000
14	From Shadows to Clouds	3	2	1925	1732500
15	From Shadows to Shadow	3	3	1544	1389600
16	From Shadows to Bare Land	3	4	601	540900
17	From Shadows to Built up Area	3	5	5933	5339700
18	From Shadows to Vegetation	3	6	28469	25622100
19	From Bare Lands to Water Bodies	4	1	232	208800
20	From Bare Lands to Clouds	4	2	2579	2321100
21	From Bare Landsto Shadow	4	3	1867	1680300
22	From Bare Lands to Bare Land	4	4	9892	8902800
23	From Bare Lands to Built up Area	4	5	57907	52116300
24	From Bare Lands to Vegetation	4	6	54110	48699000
25	From Built up Areas to Water Bodies	5	1	2581	2322900
26	From Built up Areas to Clouds	5	2	8435	7591500
27	From Built up Areas to Shadow	5	3	4351	3915900
28	From Built up Areas to Bare Land	5	4	15122	13609800
29	From Built up Areas to Built up Area	5	5	110440	99396000
30	From Built up Areas to Vegetation	5	6	46286	41657400
31	From Vegetation to Water Bodies	6	1	1012	910800
32	From Vegetation to Clouds	6	2	28369	25532100
33	From Vegetation to Shadow	6	3	23436	21092400
34	From Vegetation to Bare Land	6	4	77379	69641100
35	From Vegetation to Built up Area	6	5	364290	327861000
36	From Vegetation to Vegetation	6	6	1606237	1445613300

As well, a separate csv file containing different "from-to" change class combinations were formed for each time frame. Table 2 shows the statistics of LULC change classes from 2000 to 2019.The two-way cross matrices are the resultants of the "Cross Classification" tool in the Semi-Automated Classification Plug-in in the QGIS Desktop 3.8.3 software. Using the cross classification analysis, an in-depth idea about the LULC change of the study area during the three time frames 2000-2010, 2010-2019 and 2000-2019 was obtained. The number of pixels and the area in m^2 which have changed from one class to another class when the time passes from initial state to the final state are shown as a two-way cross matrix.

TABLE III CROSS MATRIX OF LULC CLASSES BETWEEN YEAR 2000 AND YEAR 2019

Initial State - Area (sq.m)

Final State - Area (sq.m)

.	Water Body	Cloud	Shadow	Bare land	Built up	Vegetation	Total
Water Body	14306400	123300	1107000	208800	2322900	910800	18979200
Cloud	1230300	2853900	1732500	2321100	7591500	25532100	41261400
Shadow	2715300	2250000	1389600	1680300	3915900	21092400	33043500
Bare land	428400	441000	540900	8902800	13609800	69641100	93564000
Built up	6066900	7427700	5339700	52116300	99396000	327861000	498207600
Vegetation	7319700	30119400	25622100	48699000	41657400	1445613300	1599030900
Total	32067000	43215300	35731800	113928300	168493500	1890650700	2284086600

IV. DISCUSSION

Agricultural lands are harvested during some seasons of the year. Those harvested lands can be seen as bare lands even though they are agricultural lands. This may introduce inaccuracies in the classification. Therefore it is better if it is possible to select imageries of the study area which have not captured in the harvested seasons. In the present research, it was identified that some agricultural lands are seen as bare lands because they have been harvested.

Even though all the satellite imageries which were used for the present research are imageries of Landsat series, it was identified that, wavelength range of sensors on-board Landsat 5 and Landsat 7 have slight differences with the same bands in the sensors on-board Landsat 8. Therefore, two signature files were created using two set of training samples. The satellite images which were captured by Landsat 7 (image of 2000) and Landsat 5 (image of 2010) were classified using one signature file. The satellite imagery of the Kelani watershed which was captured by Landsat 8 was classified using the other signature file.

The cloud cover of the satellite imageries over the study area was a severe problem when conducting the present research. It was hard to find any satellite image of the study area in particular years 2000, 2010 and 2019 without any cloud patches. So, the imageries with a minimum cloud coverage were selected as the input images for the present research. The percentage of cloud extent of the classified image in 2000 was 1.8% of the total watershed area. It was 2.4% and 0.2% in the images of the years 2010 and 2019 respectively. And the percentage of shadow extent of the classified image in 2000 was 1.4% while it was 1.3% and 0.2% in the years 2010 and 2019 respectively. However, these cloud patches and their shadows make inaccuracies and uncertainties to the final results of the research. Efforts were taken in order to enhance the accuracy of the results in several ways.

The vegetation cover of the Kelani watershed has decreased by 332.7507 km^2 when the time passes nineteen years from 2000 to 2019. The built up areas inside the watershed has been increased by 366.3999 km^2 during the nineteen years' time period. Bare lands in 2000 has been decreased by 20.5983 km^2 in extent. And also, the extent of water bodies have been decreased by 13.1544 km^2 during the time frame 2000 to 2019. It is clear that the built up areas in the Kelani watershed has increased by about 208% during this time period. It shows a rapid urbanization in the study area which is not healthy for the natural balance of the watershed. Vegetation cover of the watershed has declined by about 17% of its initial extent in 2000. Deforestation in the study area can be seen during the 2000 to 2019 time period.

The rapid growth of the built up area class can be commonly seen along the Kelani river and its tributaries. This scenario does not looks healthy for the river. That is because, the river water can be polluted by several ways and means by the people and the industries which are around the river network. These unplanned developments which have been implemented in order to fulfil the requirements of the growing population are not suitable for the balance of the eco-system. The increment of population is a factor that cannot be controlled. But, as humans it is wiser to have well- planned developments for the needs and wants of the human, by causing minimum disturbances to the natural environment.

V. CONCLUSION

The present study was conducted in order to detect, quantify and map the LULC change which has taken place in the watershed of the Kelani river during around last two decades. It is very important, not to cause any disturbances to the natural environment of a watershed region. But it has been revealed that watershed of the Kelani river is subjected to rapid urbanization and deforestation. So, it was essential to quantify and analyse the LULC change of the Kelani watershed as an initial step of conserving the watershed area. According to the LULC change analysis, water bodies, bare land and vegetation classes of the watershed have been declined by around 41%, 17% and 17% respectively within the years 2000 to 2019. The increment of built up areas or settlements during the time frame 2000 - 2019 was 208%. These results provided better evidences of deforestation and rapid urbanization in the study area. The thematic change results in the LULC types were helpful to visualize the dynamics in the LULC categories within different time periods.

The rapid growth of the built-up area class can be commonly seen along the Kelaniriver and its tributaries. It can affect the quality of river water badly because chemical substances which are left as waste materials from some factories or industries can be added to the river water by several ways and means. And also, the household waste can be added to the river. These activities may reduce the quality of water in the Kelaniriver. But, 80% of drinking water to the capital of Sri Lanka is supplied by the Kelaniriver. Therefore, these unplanned developments along the river and its tributaries may cause a severe problem regarding the quality of water in the Kelaniriver in future. The increment of built up areas in the Kelani watershed is 208% during the time frame 2000 to 2019. It is true that the population growth is not a factor that can be controlled. And also, the needs and wants of the increasing population should be fulfilled. But as humans we must be wiser to not to make disturbances to the natural balance of the eco-system. Well-planned developments should be implemented under the supervision of responsible government bodies in order to fulfil the needs and wants of the human.

Disturbances to the natural balance of the Kelani watershed region can be minimized by an integrated land conservation plan launched by responsible authorized organizations. It will prevent the disturbance to the natural balance of the environment due to the LULC change in the watershed. Awareness programs to the public about how to consume the land wisely by maintaining the natural balance of the eco-system, will minimize the degradation of extents of LULC types.

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