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Land-use and Land Cover Change on Clay and Sand Mining: A Spatiotemporal Analysis in Ma-Oya Downstream in Sri Lanka

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Abstracts: Mining is one of the main methods of extracting mineral resources. Due to mining potentially decreasing biodiversity, farmland, soil fertility, and contamination from mining waste may add additional stress on environmental quality and ecosystem services. The research was conducted to identify the loss of land and land-use changes due to clay and sand mining in the left Ma-Oya riverbank of the Katana Divisional Secretariat Division (KDSD). Geographically, environmentally, and socio-economically, the Ma-Oya River basin is one of the unique river basins in Sri Lanka. Due to sand and clay mining, the Ma-Oya River basin's left and right riverbanks have been highly degraded during the last few decades.

The study used the mixed method to identify the land use and land cover changes, especially the GIS and statistical techniques with quantitative and qualitative data. The study revealed that Ma-Oya left bank with significant modifications and land loss due to critical natural resource exploitation. Mainly clay has been excavated up to 835-meter distance from the left Riverbank of Ma-Oya, covering more than 60 hectares. According to the present value of lands in the area, it was the amount of Rs. 2,728,774,720 (27287 Rs/M). It is noted that there are four or five people lose their life annually due to drowning in these water holes. Moreover, the future prediction of land-use change has become a severe issue. Therefore, it is essential to involvement of government institutes to minimize the risk and establish sustainability.

Keywords: Land Degradation, Spatiotemporal analysis, Clay and Sand Mining, Land use and land cover change

I. Introduction

Sand is a natural aggregate formed by rock erosion over thousands of years (Dan Gavriletea 2017). Soil is an essential source of raw materials such as clay, sand, gravel, and minerals (Madyise 2013). Sand deposits have two origins: terrestrial and marine. Terrestrial sources include residual soil deposits, river channel deposits, and floodplain alluvial deposits, and the most common marine sources are shore and offshore deposits (Dan Gavriletea 2017).

The leading nations mining and processing sand, gravel, and clay are the United States of America, Australia, Austria, Belgium, Brazil, India, Spain, Nigeria, Kenya, and South Africa (Madyise 2013). In Sri Lanka, mining sand deposits in rivers traditionally obtained the sand required for construction (Piyadasa 2011). The increasing use of mechanized extraction in the late 1990s has resulted in heavily localized turbidity, lowering of water tables, bank erosion, land degradation, and salinity intrusion resulting in hardship for agriculture and food security (Piyadasa 2011). In an area with extensive human activity, such as a mining area, several disturbances are likely to significantly change the land use/ land cover (Mi et al. 2019). Existing morphology of river systems, human encroaching, and changes in the floodplains (Chaturani and Jayarathne 2019) directly help for land-use change (Senanayake et al. 2020); also, during transport with heavy vehicles, soil erosion, surface water, and groundwater pollution can be identified (Oltean, Goldan, and Nistor 2018). The land's topography is changed after the mining activity's closure, and vegetation and fauna are affected, and it impacts local biodiversity (Oltean et al. 2018). It is also a threat to worsen the global environmental problem (Senanayake et al. 2020).

The development of land use/land covers as a manifestation of the structure and function of socio-ecological systems reflects the transformation of regional ecosystems and socioeconomics (Mi et al. 2019). Also, land-use change is a dynamic process driven mainly by natural and artificial phenomena (Le and Jensen 2014). Like air and water quality deterioration, waste-disposal problems, flash flooding, high energy consumption, increasing poverty levels (Sholihah et al. 2020), gravity, perturbations (Ding et al. 2017), growing demand in time and space (Le and Jensen 2014). Land-use change and soil erosion can be accelerated by human activities, such as the expansion of agricultural activities, urbanization, deforestation (Senanayake et al. 2020), any streamflow change (Zhang and Ross 2015), and riverbank mining for sand or clay extraction. Biophysical forces, technological and economic concerns, and institutional and political structures are three causes of land-use changes at varying rates and scales (Senanayake et al., 2020).

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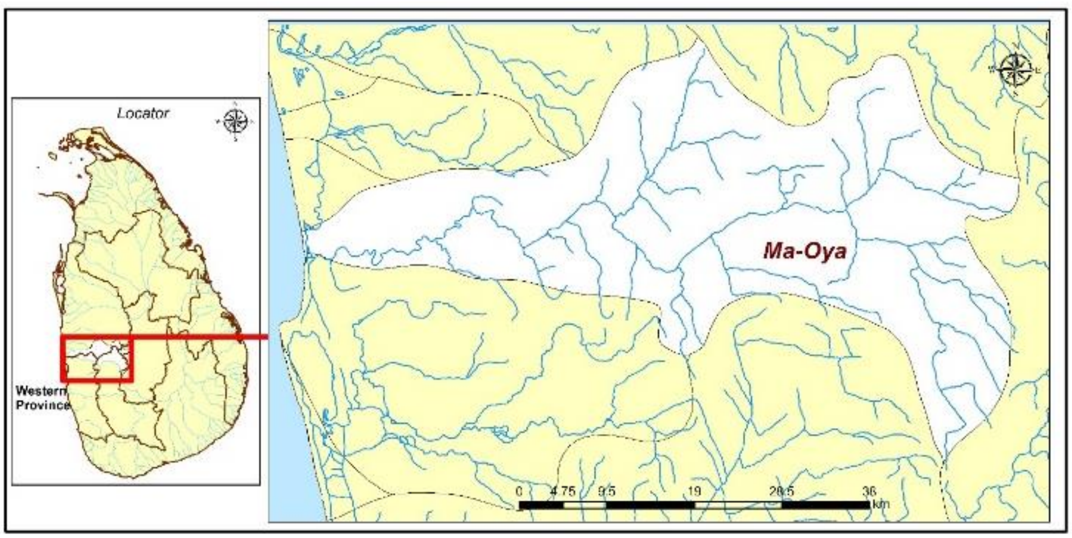
River sand mining is one such activity that has resulted in both direct and indirect impacts on the physical, natural, and social environments. The immediate effect of river sand mining can be readily discerned within rivers through changes in the movement of water and sediment, channel geometry, bed elevations, substrate composition, in-stream roughness, and the stability of the river bed, banks, and riparian zone (Piyadasa 2011). As a cheap and readily accessible resource, many companies are legally and illegally involved in their mining without considering the environmental damage they are causing (Madyise 2013).

The average demand for sand for building construction within the country is approximately 7–7.5 million cubic meters per year. As a clay product, 800 million bricks are produced annually in Sri Lanka. Tile, pottery, and related product industries also use a high number of cubic meters of clay annually. The increased demand for sand and clay has led to a significant increase in sand and clay Mining in many areas, with sand sources including sedimentary deposits and sand associated with river beds and floodplain deposits (Piyadasa 2011). River sand and clay mining directly affects the natural equilibrium of river systems. The rapid expansion of riverbed and riverbank sand and clay mining has caused widespread environmental, social, and economic problems. These are mainly linked to people's livelihoods, agriculture, health, land and air pollution, and an inflow of seawater into the rivers, causing droughts and flooding. Ultimately the result is the extraction of clay and sand, Land use, and land cover changes in respective areas.

The Ma-Oya is one of the main rivers in Western Sri Lanka that suffers from sand and clay mining. Map 01 shows the Ma-Oya River basin.

Map 01 The Ma-Oya River basin.



Source: Department of Land-use and Policy Planning – 2018

Especially Ma-Oya downstream area legally and illegally, rapidly increasing these issues within the last few decades. Due to this situation, land use and land cover of the respective site are quickly changing. The result of sand and clay mining generates large waterholes in particular areas, and less than five people sacrifice to these waterholes annually. The study aims to analyze land use and land cover changes within the considering period and predicts future land-use changes and related issues based on clay and sand mining.

II. Study area

The study area is located downstream of the Ma-Oya River basin, nearby the delta in the Western province of Sri Lanka. The length of the Ma-Oya River is 134km, and the size of the river basin is 1528sqkm. (Department of survey 2001). Also, the western province is the highest population density representing the country. The study were carried out in the Ma-Oya left bank in the Katana Divisional Secretariat Division (KDSD) in Sri Lanka. KDSD consists of seventy-nine Grama Niladhari Divisions (GNDs), and seven Grama Niladari divisions belong to the study area of the Ma-Oya left bank. Those are No-63 Katana East, No- 64 A Katana North, NO-65 Bambukuliya, No-66 Muruthana, No-67-A Manaweriya, No-67 Udangawa, and No-64 Katana west. Especially Ma-Oya downstream is famous for clay mining because the Ma-Oya flood plan has been identified as a location for good quality clay material for clay-related industries. Moreover, due to the high density of population in the western province, colossal demand can be identified for sand in the construction field. Figure 01 shows the map of the study area.

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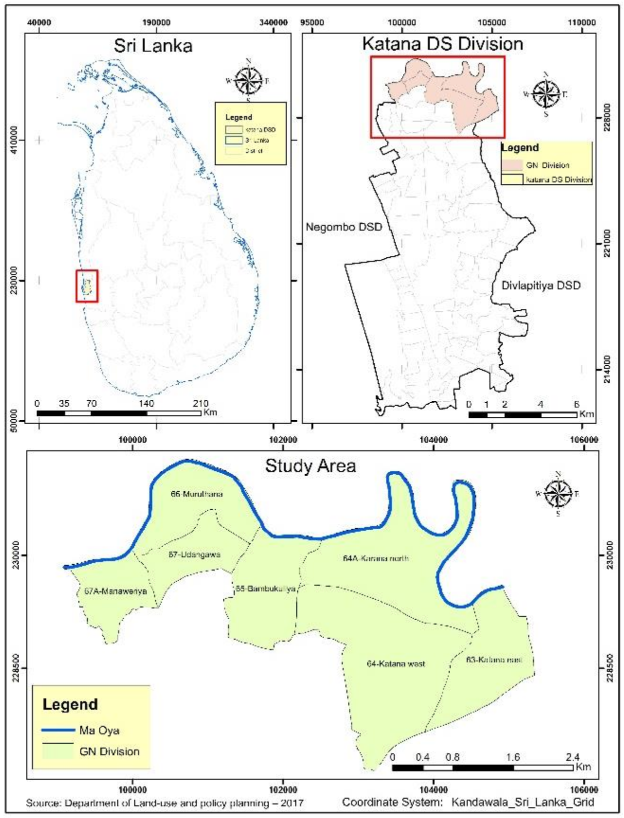
Figure 01. Study Area



Source: Department of Land-use and Policy Planning – 2017

III. Methodology

Both primary and secondary data were used for this study. Changing land use and land cover patterns are to be identified with gathered data from the Department of Land-use and Policy Planning and analyzed to determine the long-term trends in Land use and land cover in the area. Also, collect the data using the Participatory Rural Approach (PRA) method and Global Positioning System (GPS) to finalize the 1982 and 2018 land use and cover. The photographs were captured to show the exact situation of the land use and land cover changes of the study area.

The methodology used for this study is a mixed method comprising quantitative and qualitative approaches. Apart from the data collected from people in the villages, lengthy discussions were held with Government officials' and community-based organizations in the area.

Future land use prediction will be done statistically analyzed using trending analysis, field observation, and verification with the people in the study area, and spatial location data will be collected using GPS. Figure 02 shows the methodology flow chart. ArcMap 10.8.1 applications have been used to identify the spatial and temporal land-use changes and calculate the extent of land losses. Using the land-use changes from 1982 to 2018, predict the future land-use change within the next ten (2028) years and the year 2050; calculate the transitional land-use changes using statistical techniques according to the bellow equation.

$$\mathrm{TC} = \left[\frac{(\mathrm{E}_2 - \mathrm{E}_1)}{\Delta \mathrm{y}} \times \mathrm{nx}\right] + \mathrm{E}_2$$

TC = Temporal Change
E 1 – Values of the base year
E 2 – Values of the Considering year

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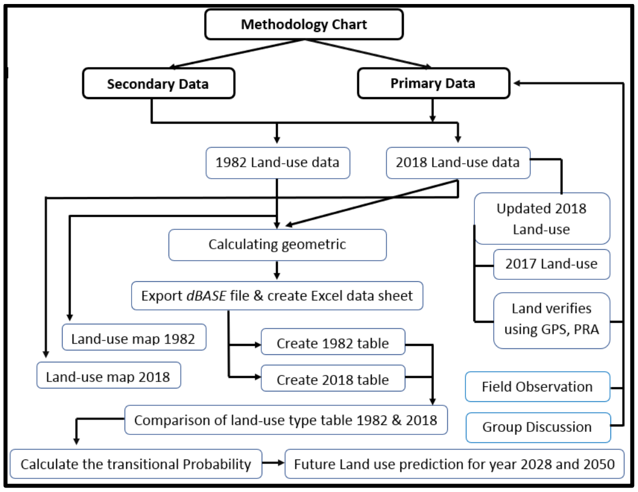
n x – Period of prediction
∆y – Difference between the E 1 and E 2

Figure 02. Methodology flow chart



Source: Compiled by author, 2022.

IV. Result and discussion

Ma-Oya downstream was mainly a sand and clay resources area in Sri Lanka. Due to that, resources, brick, tile, polysilane, and pot industries, were located in this area. Mining clay and sand continuously, land use and land cover were changing rapidly. The total area of the study was 1074 hectares, and according to the survey in 1982-year, land-use and land cover patterns are shown in figure 03. The prominent land type on the map is Coconut, extending 852.01 hectares. The lower land type is an industrial factory extending 0.10 hectares. Table 01 shows that other land-use types of 1982 and the critical land types were this area's clay pit and water hole because the Ma-Oya riverbank was dilatated during these periods due to the clay and sand mining.

Before 1990 the primary clay production was deficient because the demand for clay products was significantly less. Therefore, the clay excavation level is also low; that condition can be seen in figure 03 and table 01. Around the Western province, industrialization and urbanization were at the initiation level in this period. It was the reason for the low demand for sand mining in these areas. Also, the population density is not much higher than after the year 2000.

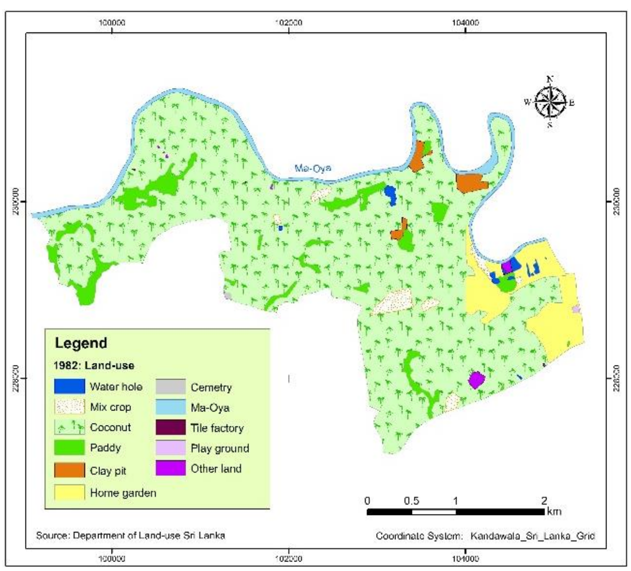


Figure 03. Land use map of 1982.

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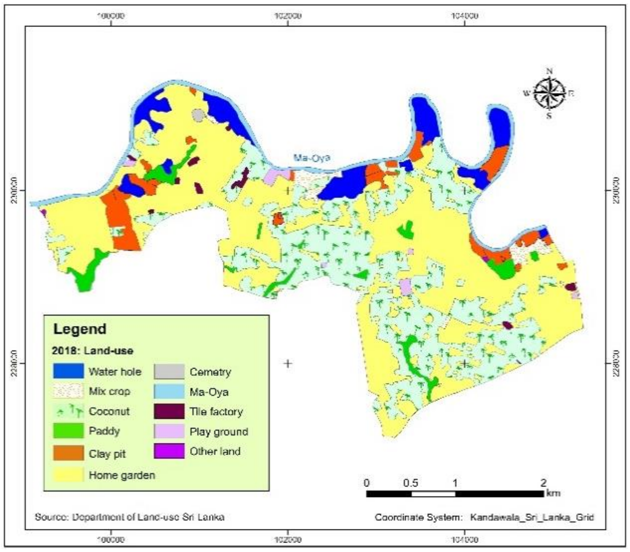

Figure 04. Land use map of 2018

Source: Department of Land-use, Sri Lanka.

The land use and land cover has changed from 1982 to 2018 significantly. Coconut land area has been reduced, and the water hole, home garden, and clay-pit area conspicuously increased. It shows that in table 01, the clay pit area widens from 12.47 ha to 60.08 ha. The gap in land-use change within the 36 years was 47.61ha and 382% changes comparatively. Also, the water hole area changes 62.58he (4.61ha - 67.19ha) within this period and remains at 1,357% change. It has direct harm to the Ma-Oya riverbank. Figure 04 clearly shows the changing pattern, and Paddy and coconut cultivation land have been affected by this change. Also, vastly coconut land has been converted into the home garden.

Table01: Land use extent-1982 and 2018

No	Land-use type	1982 Extent (ha) (E1)	2018 Extent (ha) (E2)	± (E2-E1) Land Extend	Percentage of change
1	Cemetery	0.52	1.43	0.91	175%
2	**Claypit**	**12.47**	**60.08**	**47.61**	**382%**
3	Coconut	852.01	319.31	**(532.7)**	**63%**
4	Home garden	76.91	520.81	443.9	577%
5	Industrial factory (Tile)	0.10	6.51	6.41	6410%
6	Ma-Oya	42.96	43.50	0.54	1%
7	Mix crop	18.49	20.62	2.13	12%
8	Other lands	3.7	0.72	**(2.98)**	**81%**
9	Paddy	61.68	32.44	**(29.24)**	**47%**
10	Playground	0.55	1.39	0.84	153%
11	**Water hole**	**4.61**	**67.19**	**62.58**	**1357%**
	Total	**1074**	**1074**	**-**	**-**

Source: Department of Land-use Sri Lanka 2018

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Compared with all two maps in the study period, it has been changed un-recognizably; the area near the Ma-Oya was used for the sand and clay extraction. Due to this situation, the riverbank is highly damaged, impacting the soil formation, vegetation, and biodiversity on both sides. Also, the river users cannot utilize the river daily because of the riverbank damage and water quality changes due to sand and soil extraction. The water hole has also become highly vulnerable due to the access by villages for sand extraction and other day-to-day activities like bathing and swimming; It has been reported that some people are drowning in these water holes. Moreover, staging water in the water holes directly helps mosquitoes, like dengue, as a breeding location. On the other side, water contamination could be identified due to waste discharged into the water holes by households and factories.

In 1982, the home garden area changed considerably; the result is shown in table 02. The home garden area has increased from 76.90ha to 520.80ha, with 443.90ha gaps from 1982 to 2018. It may be the reason for the identification of new resources and the establishment of the industrial area. As well it can be confirmed that the water hales and the clay pits have increased from 62.58 and 47.61, respectively. Coconut land was reduced by 532.69ha from 1982 to 2018. Concerning the map, most of the coconut land has been used for the home garden; water hales, and claypits; according to the study, land use of the study area is continuously changing and up to date, generating high vulnerability to the environment. It could be identified that after field observation and discussion with villages, 4-5 peoples annually lose their lives due to falling into the claypit and water hales. Moreover, extracting sand and mining clay may affect animals and other more sensitive flora and fauna. On the other hand, riverbank shifting can be observed in this area.

The second part of this study was conducted to predict the next ten-year and year 2050 land use and land cover change. When considering this land-use change constantly, it may be most critical. Figure 05 shows the year 2028 and 2050 predicted land use maps. According to the map, it presented that riverbank changes and land-use changes are happening dangerously. Statistics have shown that from 2018 to 2028, the clay pit and water hole areas respectively expanded by 13.22 ha and 17.37ha within ten years of periods. Also, the clay pit and water hole area from 2018 to 2050 will change from 29.33ha to 40.04ha, respectively. If severe environmental damage happens, land use and land cover changes may be massive damage in this area. It will directly affect the sustainability of this environment, and it may be the most vulnerable location. Changes in land extend are shown in Table 02; according to the table, land use changes patterns with coconut land and water hole, clay pit, and home garden can be observed.

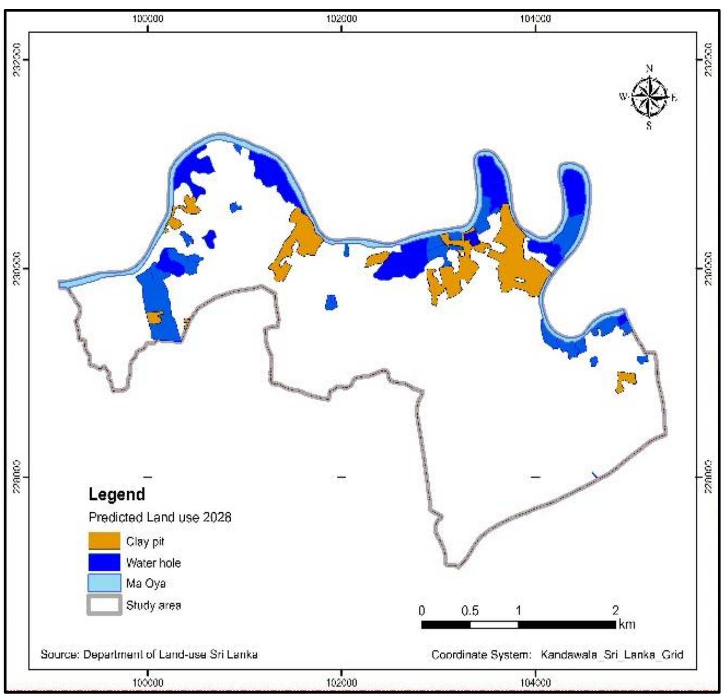

Figure 05. Map of 2050 year prediction of land use changes

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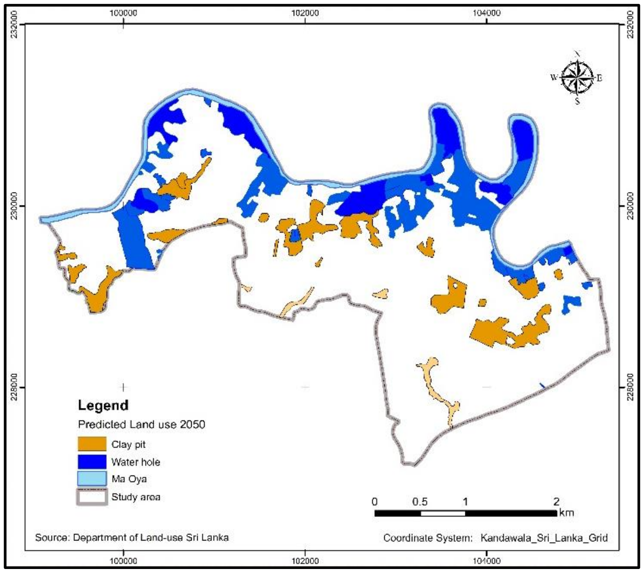

Source: Compile by the author 2022

Table 02. The land extends changes in 2028 and 2050 years.

Land-Use Type	Land Extend (E_1)1982	Land Extend (E_2) 2018	Changes of Land Extend - (L_1) 2028	Percentage of change	Changes of Land Extend - (L_2) 2050	Percentage of change
Cemetery	0.52	1.43	1.67	16.8	1.96	37.06
Claypit	**12.47**	**60.08**	**73.3**	**22**	**89.41**	**48.82**
Coconut	852.01	319.31	171.33	**(46.3)**	0	**(100)**
Home garden	76.91	520.81	644.11	23.7	793.95	52.45
Industrial factory	0.1	6.51	8.28	27.2	10.66	63.75
Ma-Oya	42.96	43.5	43.64	0.3	38.4	**11.73)**
Mix crop	18.49	20.62	21.2	2.8	21.08	2.23
Other lands	3.7	0.72	0	**(100)**	0	**(100)**
Paddy	61.68	32.44	24.31	**(25.1)**	9.59	**(70.44)**
Playground	0.55	1.39	1.6	15.1	1.72	23.74
Water hole	**4.61**	**67.19**	**84.56**	**25.9**	**107.23**	**59.59**
Total Area	**1074**	**1074**	**1074**		**1074**	

Source: Compiled by Author 2021

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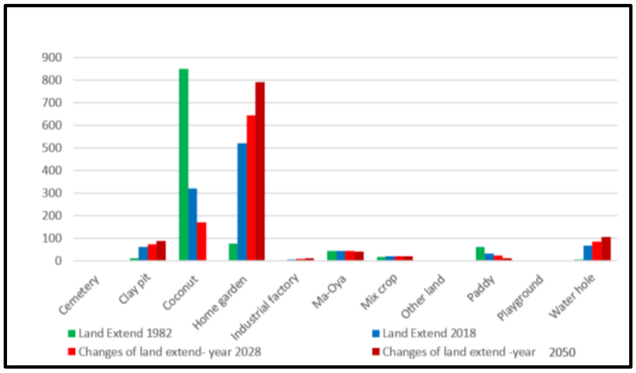
Figure 06 shows the land extend changes with a column chart. According to the chart, the extent of water holes, clay pits, and home garden land increased noticeably. Feather Coconut and paddy land areas are continuously shrinking. This situation can be observed in the following picture 01.Sand and clay extraction.

Figure 06 Land-use changing pattern 1982, 2018, 2028, and 2050 years.



Source: field survey data 2018.

Picture 01. Sand and clay extraction.

Source: Field survey 2020 February.

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Picture 01. Sand and clay extraction proved the actual situation of the study area.

This study has identified these suggestions to overcome or minimize environmental damage.

a. The authorized institution of these areas, like the Land Use and Policy Planning Department, Geological Survey and Mines Bureau, Divisional Secretariat Division, Local Authority, Disaster Management Center, and Police Department of Sri Lanka, can strictly follow the legal action against the illegal sand and clay mining sites.
b. The above institute can be limited to providing permits for sand and clay mining.
c. The most responsible officers can monitor the mining clay and sand process and retake action against those who do not follow the sand and clay mining guidelines.
d. Implement the appropriate techniques to fill the water hole after extracting sand or clay.
e. Use alternative sites far away from the Ma-Oya.
f. Introduce new tools, rules, and regulations for sand and clay mining in Sri Lanka.

V. Conclusion

Mining clay and sand resources in the study area has become a severe issue; High demand for clay from the tile and brick industry and sand for the building and other construction in the Colombo metropolitan area should be appropriately managed using alternatives.

According to the prediction for next year, 2050, this issue may become a huge disaster, like the water hole area will improve by 59.59%. Also, the claypit will increase by 48.82%. Some land may disappear, like Coconut and other land categories. Therefore, it is essential to take suitable action at the different levels of the administration sector to minimize the risk of land utilization and conduct an awareness program for the people that use this area for daily activities. On the other hand, it is necessary to conduct risk assessments and solve the land use and land cover changes. After mining, the mitigation method must be applied to prove the area's sustainability.

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