EXPLORING URBAN LAND USE CHANGE USING GIS INTEGRATED GEOSTATISTICAL ANALYSIS REFERENCE TO COLOMBO URBAN FRINGE, SRI LANKA

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ABSTRACT: Colombo is the Capital city of Sri Lanka. Its urban expansion gradually moves towards its urban fringe. In the period of time, the fringe area also expands to outward rural areas. Its ultimate result is converting fertilized agriculture land into urban land uses. Identification of this changing process and factors effecting to these changes are important for future land use planning. Present planning is not considering this situation and it is a clear research gap existed in the urban analysis in Sri Lanka. Therefore, this study aimed to analyze the existing land use changing pattern in the Colombo urban fringe and affected driving factors. GIS based statistical analysis was used to explore this changing pattern. Paper maps, digital maps, lidar images, satellite images and Google maps were used as data of this study. The land use change was analyzed using cross tabulation using the change detection method embedded in ArcGIS 10.3. Using those data, an urban change map and different criterion maps were identified based on factors affecting to land use change. The data sample was determined based on the simple random sampling method. Relationship between land use change and affecting factors were calculated using logistic regression. The outcome of the analysis shows how the land use in the Colombo fringe area has been converted over three decades using land use maps and it highlighted the gradual increase of the built-up land with decrease of green land. In addition, results explore land value, population density and proximity factors were mostly affected to this conversion pattern. Identification and quantification of this pattern is very useful for future planning activities in the Colombo urban fringe. The analysis can be applied to whole urban fringe area and its results contributes to develop knowledge planning framework for development plan exercises in Sri Lanka.

1. INTRODUCTION

Urbanization is identified as a process by which relatively large numbers of people becoming permanently concentrated into cities due to industrialization and technological development (Sanyaolu & Sanyaolu, 2018). According to the statistical data from United Nations (2018), 66% of the world's population (about 6 billion people) will be living in urban areas by 2050s. Increase of physical growth to the surrounding areas due to the rapid and complicated urbanization process and this occurrence is commonly referred to as 'urban growth' (Weerakoon, 2017). The urban growth eventually influenced for the changes in Land use changes and the utilizations (Izakoviˇcová et al., 2017). Therefore, many lands have been transformed from non-urban to urban areas. It is resulted for the large-scale modification in the land use changes of urban fringe areas (Sancar et al., 2009). Unplanned urbanization with land use changes by development of urban, urban fringe and rural areas resulted for the disruption of greenery areas, water resources and the social lifestyles (Sancar et al., 2009). However, urban fringe areas are transformed into urban uses at a disturbing rate (Csatári et al., 2013). This process negatively impacts the sustainable development and it cannot be measured. Thus, it is difficult to identify land use changing pattern in urban fringe. Land transformation in urban fringe area is a continuous process and it is of timely important to analyze such a land transformation previous to decide to mitigate the above problems (Gunawardhana & Weerakoon, 2013). Therefore, most of the researchers have adopted GIS for recognizing land use changes because it is a tool which has grown dramatically to provide better understanding for the spatial analysis (Chang & Masser, 2003).

As a developing country in Sri Lanka, the higher urban growth in the Colombo metropolitan region, the land use patterns have changed by creating negative impacts to the society, economy and the environment as well (Gunawardhana & Weerakoon, 2013). In this process, the rural land uses are rapidly converted into urban activities. In Sri Lanka, urban fringe areas conversion rate was at the alarming rate which was threaten to the sustainable development of the country (Gunawardhana & Weerakoon, 2013). Colombo urban fringe has showed considerable expansion, growth due to the developmental activities such as road construction, building, deforestation and many other development activities since its inception in recent year. Therefore, there is a need of a scientific, systematic and reliable way for evaluate the land use changes in urban fringe areas for decision making process (Chang & Masser, 2003). But very limited studies have been conducted related to land use change in urban fringe areas in Sri Lanka and no one has conducted such a research to identify land use changing pattern and factors affecting using GIS integrated logistic regression. The study aims to analysis of urban land use changing pattern in the Colombo urban fringe.

2. LITERATURE REVIEW

Urbanization is accompanied by a shift from rural-agricultural activities to urban industrial activities. This process makes changes in the economic and social structure of both urban and rural areas (Aziz et al., 2012). The increase of physical growth to the surrounding areas due to this rapid and complicated urbanization process is called 'urban growth' and it is the result of the changes in land use which is due to physical, socio-economic, and environmental forces acting on different levels of the land (Weerakoon, 2017). Urban fringe is an area located between urban and rural area that is most dynamic, sensitive, and rapidly changing area in the urbanization process (Huang et al., 2016). This area is changing from agricultural and other rural land uses to urban use. In the present time urban fringe can be seen from developing countries like Sri Lanka than developed countries (Albrecht, 2007; Iaquinta & Drescher, 2000).

Land is a limited natural resource and a major production factor used for different purposes such as residential, industrial, agriculture, commercial and education etc. (Kaminski, 2016). Land use is the socio-economic activities on a land system, and it differs from area to area but closely linked to characteristics of the earth's surface. Lambin et al., (2003) emphasizes that land use changes are complex processes that can also occur due to the interaction between environmental, social, and economic factors on different spatial and temporal scales. Population growth has effects on land use change especially in developing countries at longer time period (Meyor & Turner, 1992) and it is influenced by a variety of biophysical and societal factors operating on several spatial and temporal levels and acting in intricate webs of place- and time-specific relationships.

Table 1: Affected factors for land use change

Physical and environment	Economic	Social	Policy
Soil fertility	Distance from markets	Population size	Proximity to red zone
Soil drainage	Demand for different uses	Legislation	Proximity to sensitive area
Slope angle	Proximity to bus routs	Government policies	Proximity to commercial zone
Climate and weather	Costs of production	Size of the household	Proximity to industrial zone
Topography	Distances to settlements	Age and gender	
Bedrock and soil type	Proximity to new development projects	Education	
Surface water	Land values	Political factors	
Groundwater	Proximity to main town centers	Population migrating	
Forest distribution		Local culture	
Proximity to water bodies			
Proximity to green area			

The process of recognizing the changes in objects or phenomena in an area at different times using GIS can be called change detection. The fundamental goal of change detection is to compare spatial representation of two places in an area in a time frame by controlling all the fluctuations (Lu et al., 2004). If change detection research is good, it should give the important information namely change speed, change pattern of area, spatial distribution of modified things and assessment of changes detection accuracy. The quantification of land use, land cover changes and the application of appropriate change detection methods depend heavily on the type of changes that have occurred in landscapes and how these changes are seen in the images. Variations can be shown as continuous or categorical data. According to Abuelgasim et al., (1999), detection of changes in continuous changes in the area focuses on measuring the degree of change in quantity or concentration over time.

Land use changing pattern analysis is analyzing how land use in the suitable data since past years and existing year has been changed. Land use data are the records which contains the data related to what extent an area is covered by wetlands, forests, agriculture, impervious surfaces, and other land and water forms (Lagro, 2005). Geographical Information System (GIS) can be considered as a useful tool to characterize the land use change patterns which occurs in a particular area which can be used for deriving maps of land use changes with the use of given land use data from two points of time (Reddy & Mallupattu, 2013). GIS is an intergraded tool for trouble solving in related to any short of spatial problem. Detailed information extracted from satellite data on a temporal basis and can be used as an input into GIS for effective decision making. In this manner GIS is an effective tool for monitoring and analyzing the problem and take decision to minimize any kind of quandary.

3. STUDY AREA

Homagama is one of the local authorities located in the Colombo urban fringe located in the Colombo district in the western region away from the 21km from the City of Colombo in Sri Lanka. It is one of the local authorities located in the Colombo urban fringe and more than 50% of the area shows rural land-use features. It consists of the most valuable agricultural land and green areas. That is the reason to spread out urban growth establish some room for urban development.

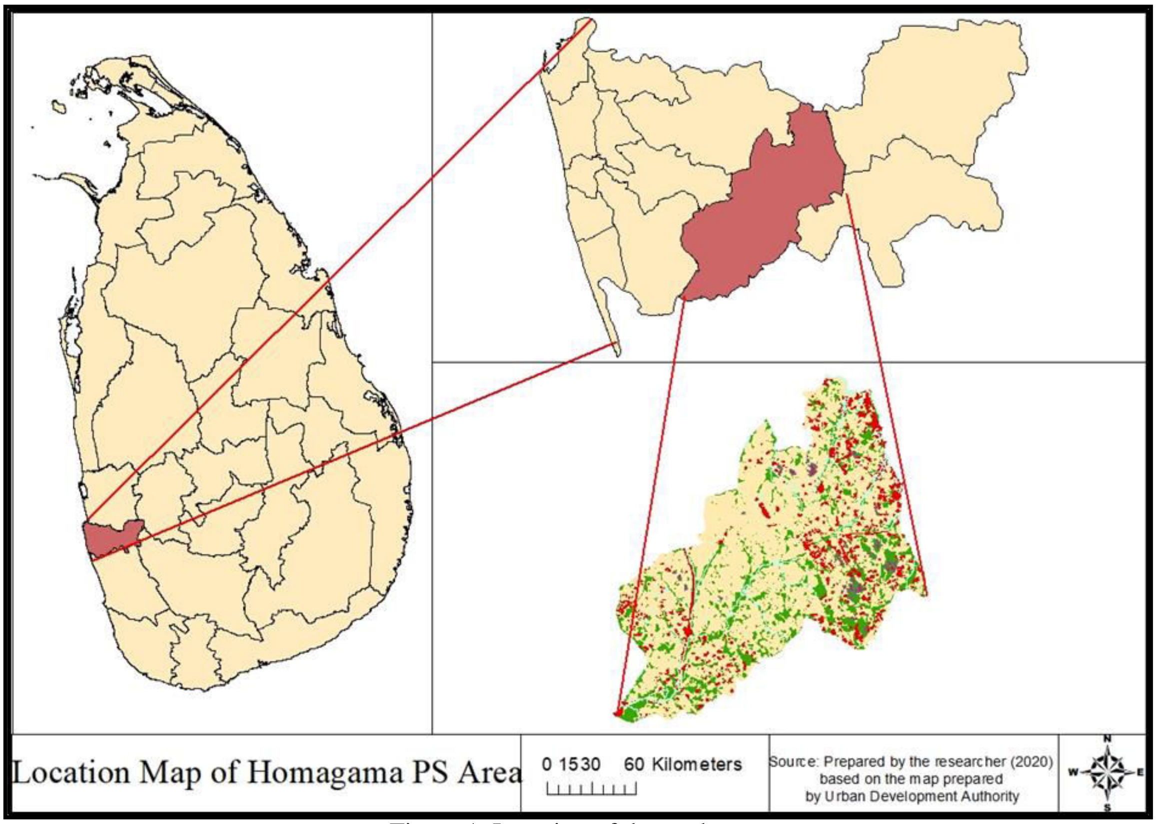


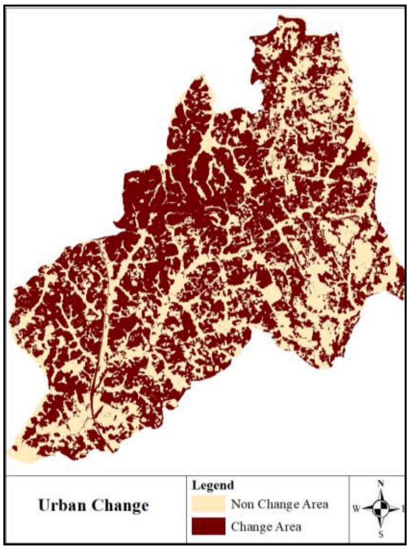
Figure 1. Location of the study area

4. DATA AND METHOD

This research mainly based on land use data and data were collected and updated through Paper maps, digital maps, lidar images, satellite images and Google maps. . Prepared land use data were classified under five categories as follows: Agriculture, Built up Area, Environment Sensitive area, Quarry and Others Land. The changes of urban land use in the Homagama PS area during 1981, 2004 to 2020 were analyzed through ArcGIS cross tabulation. Based on that change use were identified. Secondly focuses on identify the factors influencing on land use change pattern and land use change in the Homagama PS area and the research has basically focused on four criteria which are namely, physical, socio economic, policy and environment. Using ArcGIS, several maps and data layers were created as factor maps such as land use map, population density map, housing density map, proximity to water bodies map, proximity to green area map, proximity to new development project map, proximity to commercial zone, proximity to industrial zone, proximity to sensitive area, proximity to public bus roots, proximity to technical zone, proximity to main town centers and land values (figure 3). Those variables consider as independent variables. Urban change and non urban change (Build up area and non built up area) considered as the dependent variable of the study. Next spatial sample is important and this research used random sampling methods to balance the sample size and spatial interdependence. Figure 2 shows selection of sample of the area.

Table 2: Dependent Variable

Dependent Variable	Categories
Urban Change	Changed area (Built Up Area) = 1 Unchanged area (Non Built Up Area) = 0



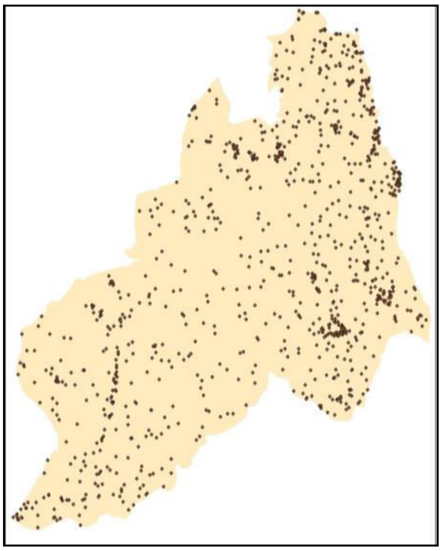


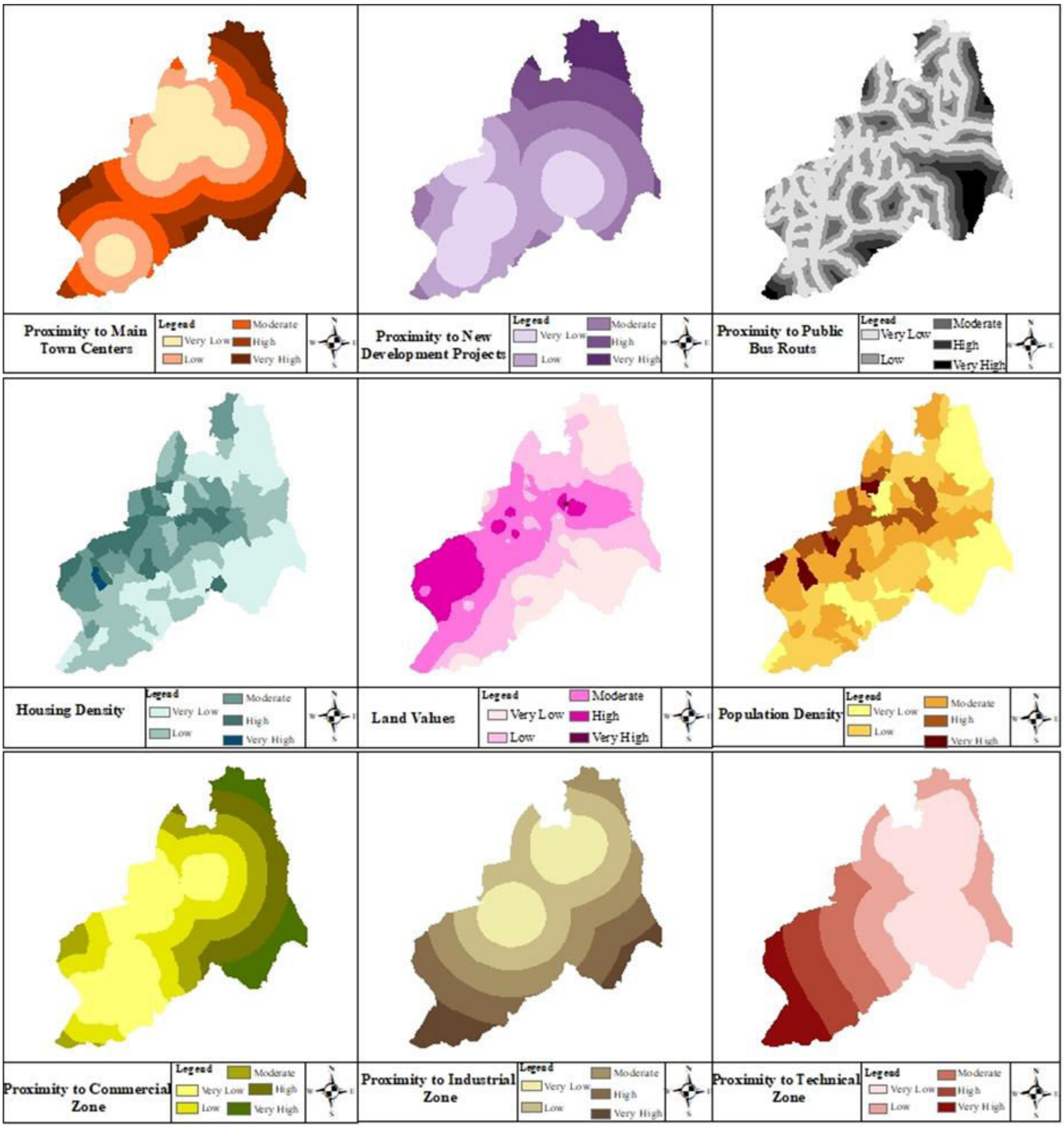
Figure 2. Dependent Variable and Spatial sample selection

The factors analysis represents latest factors identified within the area. All other factors except land use and sensitive area reclassify according to distance and values as follow, 1= very low, 2= Low, 3= Moderate, 4= High, 5= Very High.

Table 3. Independent Variable

Categories	Independent Variable	Description
Physical	Land use (LU)	Five land use type are located in the study area. The values to these land use categories were considered using coding. (1= Environment Sensitive, 2= Quarry, 3= Others, 4= Agriculture, 5= Built_Up_Area)
Socioeconomic	Population Density (POP_DEN)	The population density calculated using the population of study area calculated in 2012.The high density and lowest density is shown in five interval.(1=3-11, 2= 12-18, 3= 19-27, 4= 28-38, 5= 39-105)
	Housing Density (HOU_DEN)	The housing density calculated using the houses of study area calculated in 2012.The high density and lowest density is shown in five interval. .(1=0-3, 2=4-5, 3=6-7, 4=8-14, 5= 15-33)
	Land Values (LAND_VALUE)	Average land values of 65 locations are studied. The higher and lowest values are shown in five interval. .(1= very low, 2= Low, 3= Moderate, 4= High, 5= Very High)
	Proximity to main town centers (PROX_MTC)	There are five town centers within the study area and their proximity has been considered according to the distance gradients and actual continuous values.
	Proximity to public bus roots (PROX_PBR)	Public buses are the main mode of transportation in the study area, with main public bus routes going through the study area. Their proximity has been considered according to the distance gradients and actual continuous values.
	Proximity to new development project (PROX_NDP)	Six main newly development project are located in the study area and proximity to these newly development projects were considered using distance gradient and actual continuous values.
Policy	Proximity to commercial zone (PROX_CZ)	Commercial zone is located in the study area and proximity to these commercial zone was considered using distance gradient and actual continuous values.
	Proximity to industrial zone (PROX_IZ)	Industrial zone is located in the study area and proximity to these industrial zone was considered using distance gradient and actual continuous values.
	Proximity to tech zone (PROX_TZ)	Tech zone is located in the study area and proximity to these tech zone was considered using distance gradient and actual continuous values.

	Sensitive area (SA)	Sensitive area is located in the study area. The values to these land use categories were considered using coding.
Environment	Proximity to green area (PROX_GREEN)	Green area is located in the study area and proximity to these green area was considered using distance gradient and actual continuous values.
	Proximity to water bodies (PROX_WB)	Water bodies are located in the study area and proximity to these water bodies was considered using distance gradient and actual continuous values.



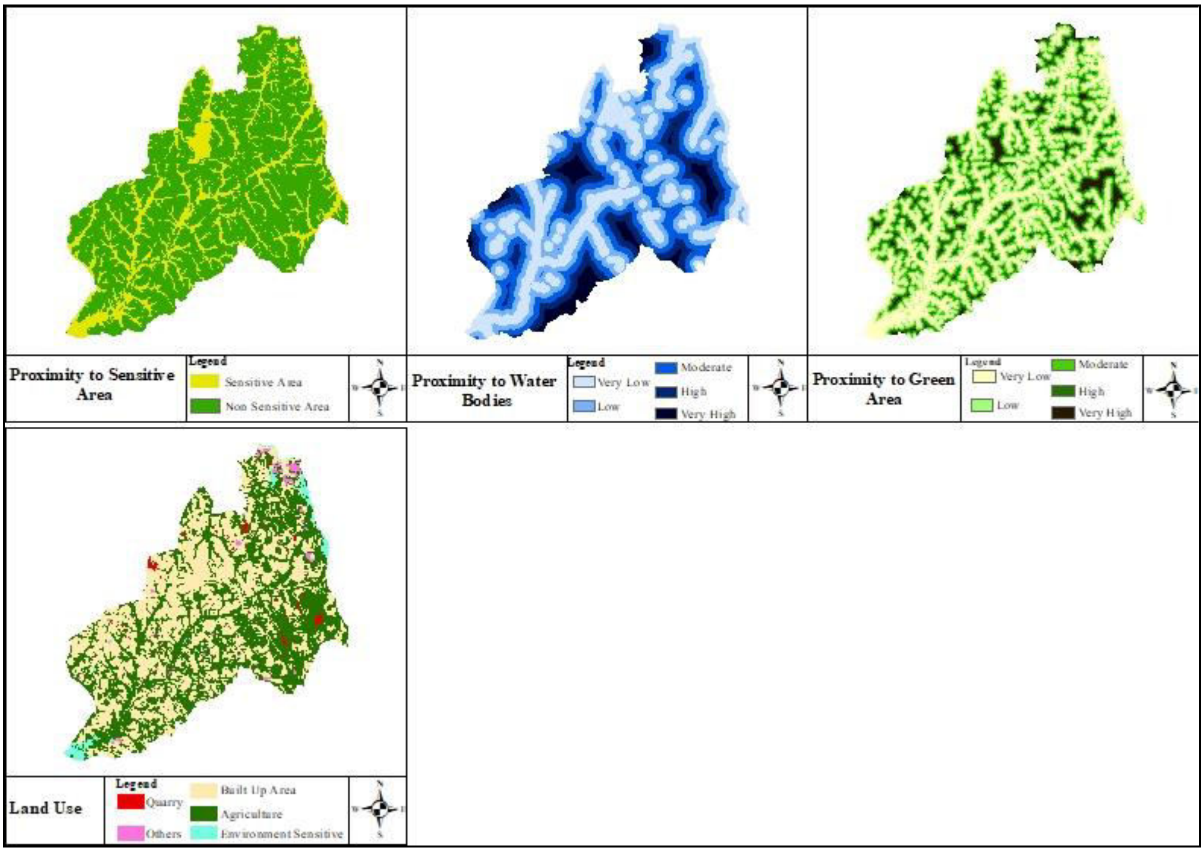


Figure 3. Factor maps

5. RESULTS AND DISCUSSION

5.1 Land use change between 1981 to 2020

Table 4 shows cross tabulation of land use in Homagama PS, from 1981 to 2020. In 1981 largest amount of the portion of the land is comprised for Agriculture, but in 2020, Built_Up_Area occupied the highest portion of the study area. Agriculture land decreased from 7,524 to 5,035 hectares while Built Up area increased from 5,390 to 7,810 hectares from 1981 to 2020. Environment sensitive area and Quarry land categories have been increased respectively by 67 hectares and 51 hectares during the time period. And others land category has been decreased by 49 hectares.

Table 4: Cross tabulation of land use in Homagama PS, from 1981 to 2020

		Land Use of 1981					
		Agriculture	Built Up Area	Environment Sensitive	Others	Quarry	Grand Total
Land Use of 2020	Agriculture	**4904**	2205	91	260	64	**7524**
	Built_Up_Area	21	**5209**	24	136	0	**5390**
	Environment Sensitive	9	29	**97**	15	0	**150**
	Others	95	362	5	**24**	2	**488**
	Quarry	6	5	0	4	**43**	**58**
	Grand Total	**5035**	**7810**	**217**	**439**	**109**	**13610**

Out of the 7524 hectares of agricultural land in 1981, only 4904 hectares has remained until 2020, and rest of the land area from 5035 has been added from built up (21 hectares), environmental sensitive (9 hectares), others (95 hectares) and quarry (6 hectares). And 7524 hectares of agriculture land in 1981 has been converted to built up land 2205 ha, environment sensitive 91 ha, others 260 ha and quarry 64 ha by 2020. In the same way, only 5209 hectares of built up area has been remained as built up area since 1981 until 2020. 2205 of agriculture land, 29 of environment sensitive land, 362 of others land and 5 of quarry land have been converted into built up area during the time period. Built up land coverage has sacrificed its coverage by 21 for agriculture land, 24 for environmental sensitive and 136 for others land. In the same way, there are new additions and removals from environment sensitive, others and quarry lands.

Table 5: Overall changes in 1981, 2004 and 2020

Land Use	1981		2004		2020	
	Ha	%	Ha	%	Ha	%
Agriculture	7524	55.28%	6285	46.18%	5035	36.99%
Built_Up_Area	5390	39.60%	6764	49.70%	7810	57.38%
Environment Sensitive	150	1.10%	266	1.95%	217	1.59%
Others	488	3.59%	189	1.39%	439	3.23%
Quarry	58	0.43%	106	0.78%	109	0.80%
Total	13610	100%	13610	100%	13610	100%

Built up land, agriculture, environment sensitive and quarry shows various pattern of change, which agriculture show continuous decreasing change pattern and Built-up lands shows continuous increasing change pattern during the time period. The broad land use dynamic change level isn't too acute generally, among them, the broad land use change level from 2004 to 2020 is relative larger, because result from fast economic development, newly development project and higher population growth. The increment in infrastructure development of Homagama PS area from time to time has played a major effect on the extension of built-up areas. The environment sensitive areas show a great increased and decrease in time period due to developments of new irrigation systems and declaration of irrigation reservation areas caused to rise of environmentally sensitive areas by 2004. Furthermore, bare land continues to increase by moderate rate, because of agricultural lands abandoned by farmers. Overall, from 1981 to 2020 built-up area increased per annum. This increase in homestead was an outcome of population growth.

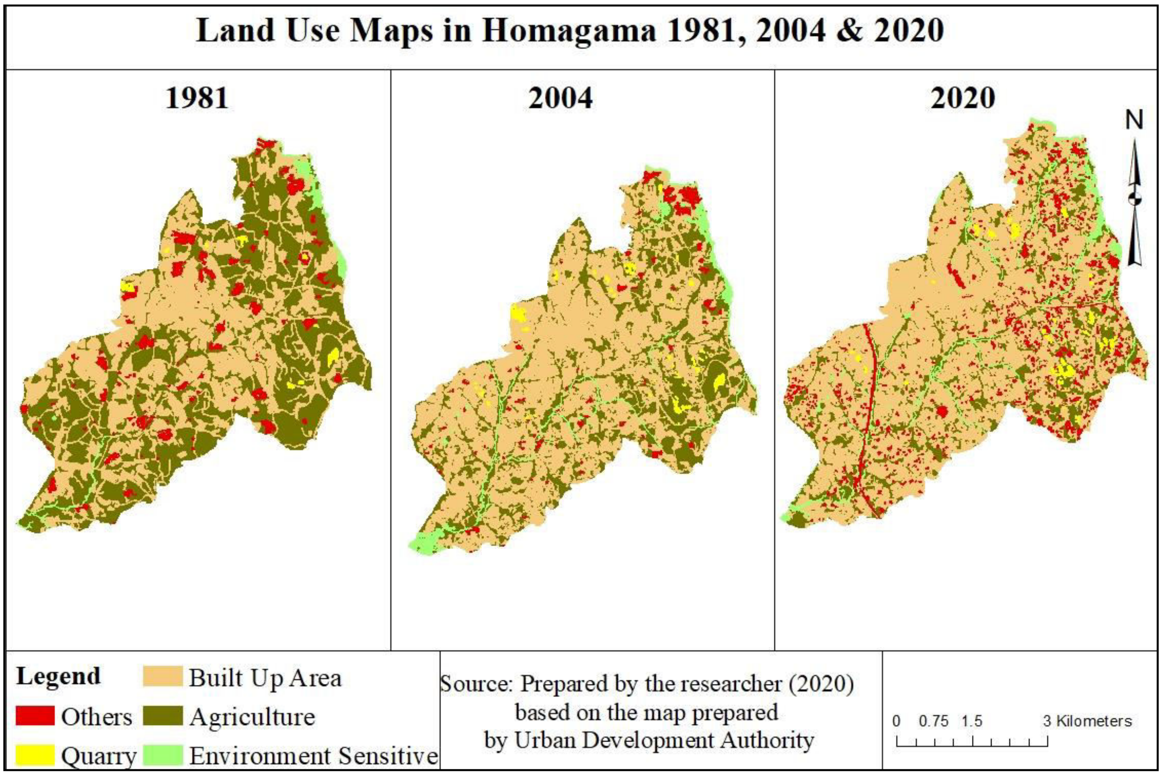


Figure 4. Land use change map of the study area

5.2 GIS integrated logistic regression model results

a. Frequency distribution

The mean value of the distribution is 3.84. Then population density of the randomly selected points in the study area is "High". According to analysis results, the mean value of the distribution of housing density, land value, proximity to new development project, proximity to commercial zone, proximity to technical zone, proximity to green areas, proximity to public bus routes and proximity to water bodies are respectively 2.15, 2.3, 2.36, 2.38, 2.3, 2.23, 1.93 and 2.44. Mean values of proximity to main town centers and proximity to industrial zone are respectively 2.69 and 2.6.

Then randomly selected points of all factors in the study area are in “low value or low distance”.

Table 6: Descriptive Statistics Table

		POP_DEN	HOU_DEN	LAND_VALUE	PROX_MTC	PROX_PBR	PROX_NDP	PROX_CZ	PROX_IZ	PROX_TZ	PROX_GREEN	PROX_WB
N	Valid	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Missing	0	0	0	0	0	0	0	0	0	0	0
Mean		3.84	2.15	2.3	2.69	1.93	2.36	2.38	2.6	2.3	2.23	2.44
Median		3.75	2	2	3	2	2	2	2	2	2	2
Mode		2	1	2	2	1	2	1	2	1	1	1
Std. Deviation		1.259	1.047	0.977	1.296	1.07	1.206	1.328	1.221	1.356	1.188	1.228
Variance		1.585	1.095	0.955	1.678	1.146	1.455	1.763	1.491	1.84	1.411	1.508
Skewness		.133	0.478	0.225	0.252	1.056	0.652	0.585	0.338	0.721	0.615	0.448
Std. Error of Skewness		.77	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077
Kurtosis		-1.030	-0.792	-0.956	-1.046	0.379	-0.543	-0.868	-0.861	-0.749	-0.685	-0.817
Std. Error of Kurtosis		.155	.155	.155	.155	.155	.155	.155	.155	.155	.155	.155

b. Goodness of fit in the model

According to Cox & Snell R Square has 0.212 and Nagelkerke R Square has 0.287. According to the R2 of Model of Nagelkerke, the R2 value of the study is 0.287 which indicates a strong relationship of 28.7% between the predictors and prediction of the model. The Cox and Snell R2 value is 0.212 and it is less than the R2 of Nagelkerke. The Cox and Snell R^2 measure operates like R^2, with higher values indicating greater model fit when all seven independent variables are entered. Accordingly, the Hosmer & Lemeshow test of the goodness of fit suggests the model is a good fit to the data as p=0.366 (>.05). Overall, 65% was correctly classified. This can be considered as a better improvement on the 50% correct classification with the constant model with significant better mode and the predictors.

Table 7: Result Table

Factors	B	S.E.	Wald	df	Sig.	Exp (B)
POP_DEN	.301	.088	11.689	1	.001	1.351
PROX_BR	-.116	.069	2.820	1	.093	.890
PROX_TZ	-.303	.092	10.714	1	.001	.739
PROX_NDP	.139	.067	4.281	1	.039	1.149
PROX_MTC	-.203	.097	4.389	1	.036	.816
PROX_GREEN	.392	.061	40.917	1	.000	1.480
LAND_VALUE	.070	.073	.902	1	.023	1.072
Constant	-.213	.418	.259	1	.611	.808

POP_DEN tend to be positively significant in the prediction of innovative performance by indicating $\beta = 0.301$, $p = 0.001 < 0.05$ which means population density has positively contributed to urban change. PROX_NDP has significantly affected the outcome, indicating a coefficient value of $\beta = 0.139$, $p = 0.039 < 0.10$. PROX_WET has been positively significant to predict the innovative performance by indicating $\beta = 0.392$, $p = 0.000 < 0.05$. LAND_VALUE has been positively significant in the prediction of innovative performance by indicating $\beta = 0.070$, $p = 0.023 < 0.10$. Unit increase in POP_DEN, PROX_NDP, PROX_WET and PROX_MTC show the odds of CHANGE_URBAN by 1.351, 1.149, 1.480 and 1.072 time respectively. The other three variables tend to be important and are negatively related for the prediction of urban land use change. PROX_BR is negatively significant in predicting urban change with beta value −0.116, p =0.93 < 0.10. When PROX_BR is increased, it would significantly reduce the urban change 0.890 times. PROX_TZ is negatively significant in predicting urban land use change with the beta value −0.303, p =0.01 < 0.05 which is increased will reduce the land use change 0.739 times. PROX_MTC is negative and significant to predict urban change with beta value −0.203, p =0.036 < 0.10 by increasing variable of proximity to main town centers significantly reduces urban change 0.816 times.

Initially, thirteen factors have been identified as influencing factors for the urban change based on the existing literature to the study. The results of logistic regression shows that seven factors have influenced the land use change from non-urban to urban during the past four decades. Four factors namely, proximity to green areas, proximity to new development project, land values centers and population density have been considered as positively influenced for land use change from non-urban to urban uses. Out of these four factors, proximity to green areas and population density can be considered as the most influencing factors encouraging urban growth. The urban fringe growth consists mostly within residential developments and they are mostly occurred in the surrounding of green areas since people are willing to avoid congestion due to air and noise pollution as mentioned by Dadhich & Hanaoka, (2011). According to the analysis, approximately 600,000 people are expected to inhabit the Homagama area by the year 2030, and some of these people will likely choose to settle in environmentally sensitive areas. Therefore, there is a need for a solid development plan, which can guide future development efforts while maintaining the natural environment of this area. There are other socio-economic variables which affect positively for the changes in urban growth such as land value, population density and new development projects. The population density and land value tend to be closely related factors and land values within the areas which have a low population density are comparatively low but there is a high growth potential. Weerakoon, (2017), has mentioned that the population density is identified as the major factor influencing the urban growth in Colombo during the last four decades. According to the urban development strategies, most of the new development projects have been moved to the fringe area. That is, the NSBM green university, international playground, highway and interchange and many education institutions. The physical infrastructure within the area has been developed at the same time and most of the available areas were introduced to provide space for new residential developments. The other seven factors proximity to tech zone, proximity to public bus routes and proximity to main town centers negatively affected the change in land uses from non-urban to urban. This study revealed that physical factors (land use change) have no effect on changing urban land use.

6. CONCLUSION

According to the study, built up land and agriculture land show similar pattern of change in the study area, which agriculture lands show decreasing change pattern by 18% and built-up lands show increasing change pattern by 17% during the three period of comparison. The change in agricultural land has been affected to the overall land use change in the area. The environmentally sensitive area has been reduced in the latter period from 2004-2020 due to the unauthorized land use of the people. GIS integrated logistic regression was successful in measuring the land use changing pattern with the affected factors. The results of logistic regression shows that seven factors have influenced the land use change from non-urban to urban areas. Four factors namely, proximity to green areas, proximity to new development projects, land values and population density were the ones that positively influenced for the land use changes. Proximity to green areas and the population density were the most influential in stimulating urban growth. The other seven factors proximity to tech zone, proximity to public bus routes and proximity to main town centers negatively affected the change in land uses from non-urban to urban. Finally, urban change has a positive relationship with areas with high population density, areas close to green areas, areas close to new development projects, and areas with low land prices. These findings help the land planners and land economists to come up with the predictions on land use change which would be helpful in implementing development plans by addressing some of the negative consequences resulting from changing land use pattern in urban areas.

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