

Research Article

Spatial-statistical Approach to Evaluate Land Use Change in Galle DSD, Sri Lanka

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Abstract: This study attempts to identify how land use has changed over time in Galle Divisional Secretary Division (DSD) with emphasis placed on change in built-up land. Galle DSD which encompasses 22.4 km² is a semi-urban area which includes Galle city area, the capital of southern Sri Lanka. Land use change in Galle DSD from 1983 to 1999 has been reviewed using the available maps considering the five key land use classifications for the area: homesteads, built-up land, agricultural land, non-agricultural land and water bodies. Geographical Information Systems (GIS) assisted spatial analysis revealed that, built-up land has remarkably expanded by 1.33 km² (approximately 6% of total area) during the 16 years period observed in this study, mainly at the expense of homesteads and agricultural land. Built-up land expansion has been taking place mainly adjacent to the homesteads and the existing built-up land. Bivariate correlation analysis was performed in order to determine the relationships between the key land use classifications. Comparatively higher negative correlations were noted between the extent covered by homesteads and the two land use categories; agricultural land and built-up land and these correlations were statistically significant. The ratio of built-up land to agricultural land has become almost half during the 16 years period. This continuing replacement of pervious surfaces by impervious built-up areas being one of the major reasons for Galle DSD area to experience frequent flooding problems highlights the necessity to control the urban growth in a sustainable manner.

Keywords: Built-up land, Galle, land use, spatial analysis, statistical analysis

INTRODUCTION

Several factors have influences on land use change process, including both physical aspects and human aspects. Urban growth is usually associated with and driven by the socio economic factors. In contrast, the process of urbanization has a considerable impact on the economics of the society in that area (He *et al.*, 2006).

In the Sri Lankan context, land use change is becoming vital component in the country's current strategies for managing natural resources while promoting sustainable development. Taking into consideration the natural limits and constraints as well as the development potential of the southern region, ADB (2009b) has identified the need for striking a balance between the built and un-built environments which is crucial to the long term social, economic and ecological sustainability of the region.

Magnitude of surface runoff and floods are directly or indirectly impacted by the types of land surface covers. Several studies have shown that, increased surface runoff and incidents of flood take place due to increased extent of impervious surfaces in urbanized

areas which reduce the time of runoff and increase the peak discharge (Praskievicz and Chang, 2009; Weng, 2001; Zhongchang *et al.*, 2013).

Effective planning of future urban development demand local authorities to identify the pattern of urban expansion and the direction it is likely to move in the years to come. Thus, information about land use change is very important to assess the cause and impact of the changes in the past, present as well as in the future. So the detection of land use change in the Galle DSD which is a semi-urban area has become significant for local authorities in the process of urban planning. Only little is known about the land use change in Galle DSD and the intensified flooding characteristics pertaining to the area make it of interest to undertake the present study. Thus, this study is carried out with the aim to evaluate and document the status of land use change that has taken place between 1983 and 1999 in the Galle DSD. Change of spatial extent of different land use classes, interrelations between land use transformations and statistical data generated in this study will assist to enhance current land management practices and future policy formulations.

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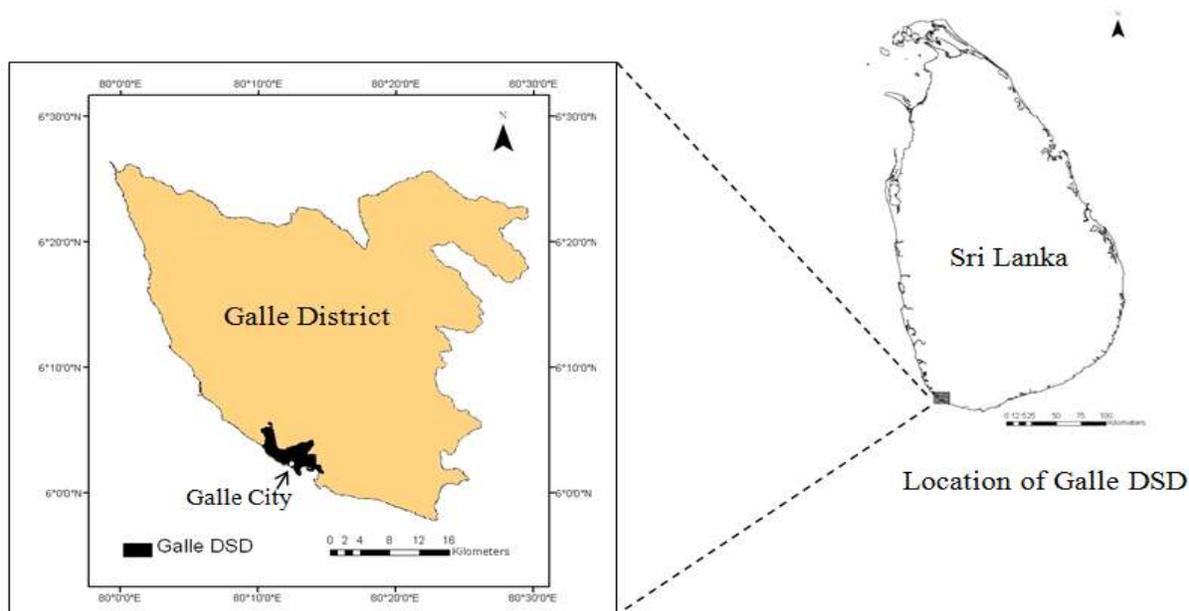


Fig. 1: Location of the study area

For the analysis of land use and land cover change, there is no single, perfect method or approach. The alternative methods each have their specific strengths and limitations. The selected method should fit the research question and available data. Considering these facts, this study incorporated a spatial-statistical approach to assess the land use change in Galle DSD.

DESCRIPTION OF THE STUDY AREA AND BACKGROUND

The study area, Galle DSD is found in the Galle district in the southern region of Sri Lanka. Galle city, the centre of the study area is located about 115 km away from Colombo. The study area lies approximately between geographic coordinates 6°1' N to 6°6' N latitude and 81°10' E to 80°15' E longitude. Fig. 1 shows the location of the study area.

The Gin River which originates from the Gongala Mountains in Deniyaya is the main surface water source to cater various water demands in the Galle district. It runs through Neluwa, Hiniduma, Baddegama and reaches the Galle DSD where it joins the Indian Ocean at Gintota with a total catchment area of 932 km². Galle DSD receives ample rainfall with an annual average of 2000 mm. The topography of the area is mainly characterized by almost flat terrain where the maximum elevation is 45 m above mean sea level.

Galle DSD is a semi-urban area which includes Galle city area, the capital of southern Sri Lanka. This area is becoming important as a potential centre for population growth and economic development for the southern region of Sri Lanka. Galle district is the third densely populated district in Sri Lanka (613 persons/km²) according to the population census of 2001. Based on 1981 and 2001 population census, Galle

Municipality area's population grew by 34.32% in 20 years (ADB, 2009a). Moreover, Galle Municipality area acts as the urban center that provides services to the surrounding rural areas and small townships. Thus, the growing population, development activities and related planning policies suggest that this area will undergo significant urban development.

Generally, homesteads is the major land use in Galle DSD. Other key land use types of the area include built-up land, agricultural land, non-agricultural land and water bodies. Galle DSD and its surrounding area are experiencing land use changes due to various natural and human induced factors. Wickramaarachchi *et al.* (2013) have shown that socioeconomic, proximity and biophysical driving factors were remarkable for the land use change in the Gin catchment to which part of the Galle DSD belongs. These land transformations call into question how the replacements have been taking place and how they interrelates since the land use pattern in the area are of great concern for the surface runoff generation process causing floods even during small localized rain event.

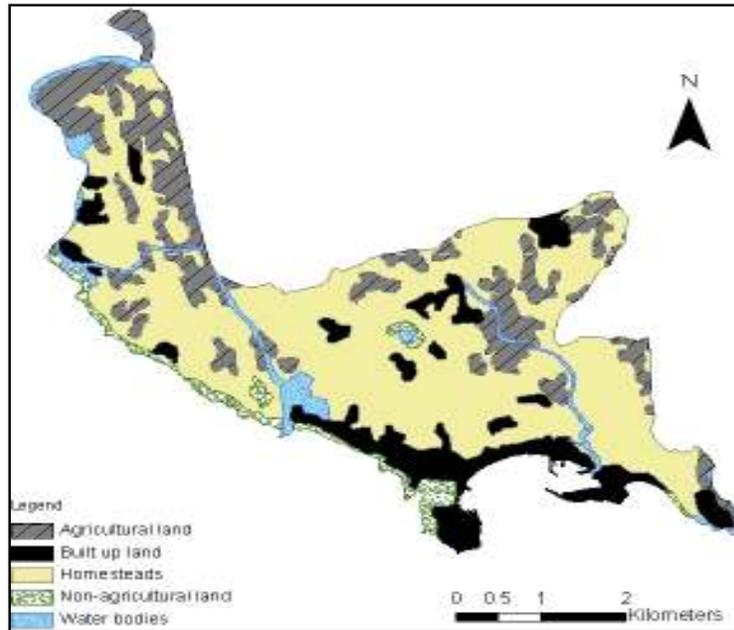
At the same time, the review of development plans for the Galle area presented by the ADB (2009b) highlighted the need to undertake an integrated study and plan for the area including measures for flood control. Accordingly, it is of timely need to estimate the change in land use and identify the pattern of change in impervious surface which facilitate investigation of increasing flooding incidents from past to present in Galle DSD.

MATERIALS AND METHODS

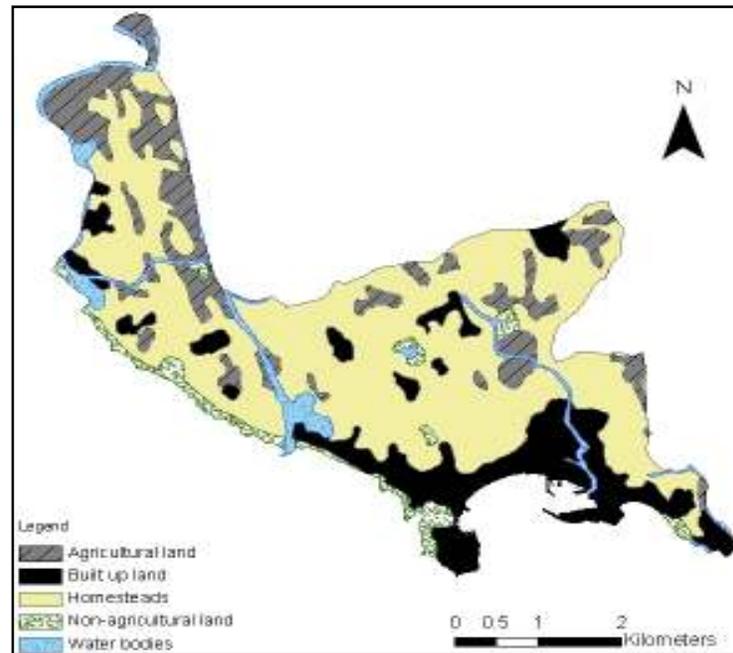
Data description: Galle DSD's land use data in 1983 and 1999 available in paper format and digital format,

respectively, were acquired from the Surveying Department, Sri Lanka. Year 1999 land use data having 1:50,000 scale had been derived by interpretation from the aerial photographs and digitizing from the existing topographic maps. Preparation of 1983 land use data having a scale of 1:100,000 was based on interpretation of aerial photographs followed by field verification.

Land use classification: In order to facilitate the analysis process, the available land use types in the area were reclassified into five representative classes. The five key land use classifications in the area have been identified as 'agricultural land', 'non-agricultural land', 'built-up land', 'homesteads' and 'water bodies'. The agricultural land includes all crop lands including



(a)



(b)

Fig. 2: Land use in Galle DSD; (a): Land use 1983; (b): Land use 1999

paddy, tea, rubber, coconut and cinnamon. Non-agricultural land is the unproductive land. These lands include scrublands as well as grasslands, sand dunes and bare lands. Homesteads refer to family residential units surrounded by home gardens and open space. Areas being used for industrial, commercial and transportation are referred as built-up land. Water bodies contain mangroves, marshes, streams and rivers.

Land use maps (1983 and 1999): According to Fig. 2a and b, the biggest share of the Galle DSD's land was homesteads in both 1983 and 1999. Built-up land showed an increasing trend from 1983 to 1999. Inland water bodies shared about 4.5% of the total land area.

Spatial analysis: Conventional survey and mapping techniques are expensive and time consuming for the estimation of land use change. As a result, increased research interest is being directed to the monitoring of land use and land cover change using GIS and remote sensing techniques (Ayele, 2010). Moreover, Harris and Batty (2001) stated that GIS can effectively be used to monitor and evaluate the dynamic changes of land use transformation.

- **Spatial pattern of land use change:** Galle DSD's land use in 1983 and 1999 were compared in Table 1 and 2. The main change of land use in Galle DSD can be identified as conversion of other types of land use into built-up land. According to Table 1 and 2, 5.87% (1.32 km²) significant reduction of agricultural land has been noted from 1983 to 1999, out of which 4.66% have been converted to

homesteads. Overall, this did not contribute to considerable increase in homesteads land in 1999. Built-up land have expanded to include 1.33 km² more land, an increase of 5.96%, compared to 1983. This expansion mainly occurred at the expense of homesteads, 1.22 km² followed by agricultural land 0.1 km².

In Table 2, calculation of the ratios of the area occupied by the built-up land in relation to the agricultural land, non-agricultural land, homesteads and water bodies, showed a significant reduction from 1983 to 1999. Remarkably, the ratio of built-up land to agricultural land has become almost half during the 16 years period.

Generally, the extent covered by agricultural land (specially paddy fields), non-agricultural land and water bodies act as retention area for rain water during rain events thus controlling flooding. It is apparent that pervious surfaces including the flood retention areas in Galle DSD have been converted to impervious surfaces between 1983 and 1999.

- **Change in proximity areas to 'built-up land':** In order to determine how much of the land in close proximity to different land use types had become built-up land, 100 m buffer zones were created (Table 3).

It was determined through spatial analysis that within 100 m buffer zones of 1983 land use, the extent that had become built-up land in 1999 (Table 3). Comparatively significant built-up land expansion has noted in 1999 in close proximity to homesteads in 1983 (1.4 km²) and existing built-up land in 1983 (0.6 km²).

Table 1: Comparison of 1983 land use against 1999 land use in Galle DSD

		1983 land use (%)					Total
		Agricultural	Non-agricultural	Homesteads	Built-up	Water bodies	
1999 land use (%)	Agricultural	13.83	0	0	0	0.19	14.03
	Non-agricultural	0.37	2.83	0.36	0	0.04	3.60
	Homesteads	4.66	0.49	52.25	0.70	0.27	58.37
	Built-up	0.86	0.24	5.46	12.92	0.10	19.58
	Water bodies	0.17	0.25	0.17	0	3.82	4.42
	Total	19.90	3.81	58.25	13.62	4.42	

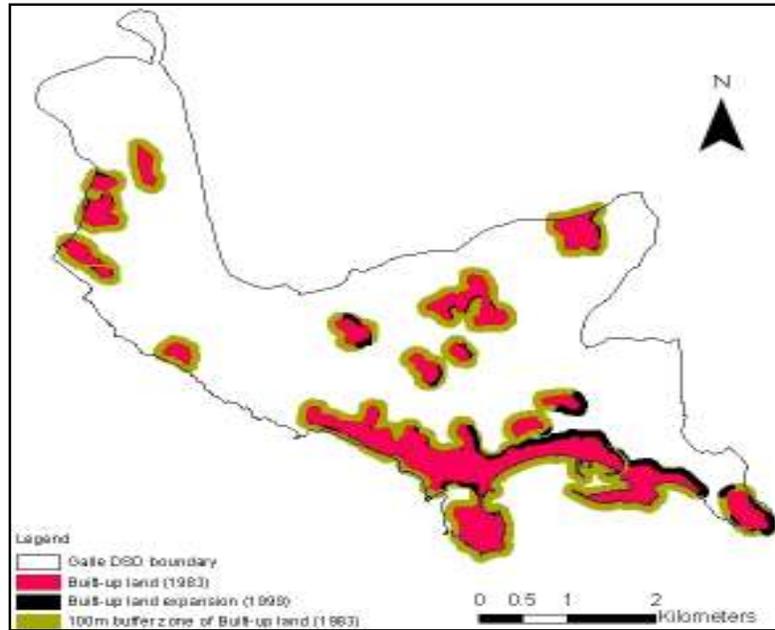
Table 2: Areas occupied by the key land use types in 1983 and 1999 in Galle DSD and the changes with respect to the situation in 1983

	1983 (km ²)	1999 (km ²)	Change (km ²)
(1) Agricultural	4.46 (19.9%)	3.14 (14.03%)	-1.32 (-5.87%)
(2) Non-agricultural	0.85 (3.81%)	0.81 (3.6%)	-0.04 (-0.21%)
(3) Homesteads	13.05 (58.25%)	13.08 (58.37%)	+0.03 (+0.12%)
(4) Built-up	3.05 (13.62%)	4.38 (19.58%)	+1.33 (+5.96%)
(5) Water bodies	0.99 (4.42%)	0.99 (4.42%)	No change
(4):(1) ratio	1 : 1.46	1 : 0.72	
(4):(2) ratio	1 : 0.28	1 : 0.18	
(4):(3) ratio	1 : 4.28	1 : 2.98	
(4):(5) ratio	1 : 0.32	1 : 0.23	

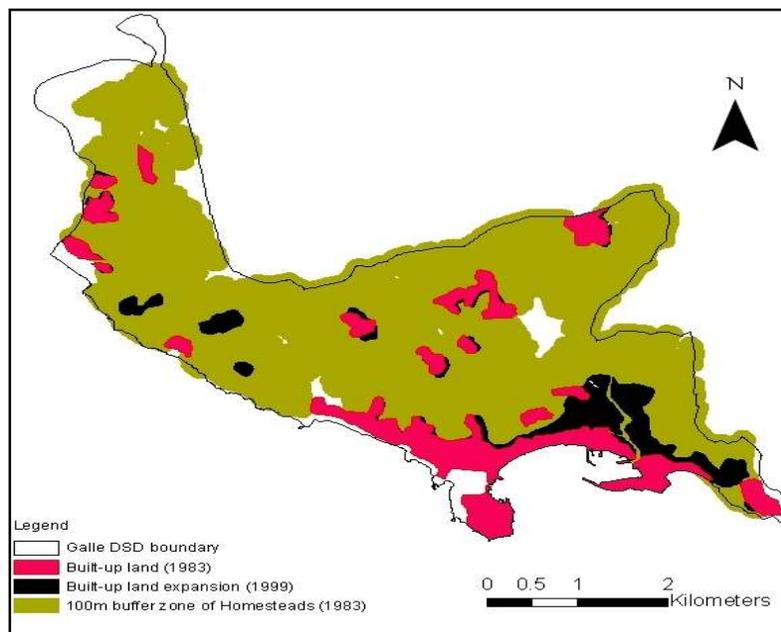
% of total area is shown within brackets

Table 3: Built-up land expansion within 100 m buffer zones of 1983 land use

Extent converted to built-up land in 1999 within 100 m buffer zones of 1983 land use (km ²)				
Agricultural	Non-agricultural	Homesteads	Built-up	Water bodies
0.3	0.09	1.4	0.6	0.3



(a)



(b)

Fig. 3: Built-up land expansion within 100 m buffer zones; (a): Built-up land expansion in 1999 within 100 m buffer zone of built-up land in 1983; (b): Built-up land expansion in 1999 within 100 m buffer zone of homesteads in 1983

Table 4: Pearson correlation coefficients for 1983 land use and 1999 land use in Galle DSD

		1983				
		Agricultural	Non-agricultural	Homesteads	Built-up	Water bodies
1999	Agricultural	0.797	-0.080	-0.478	-0.161	-0.060
	Non-agricultural	-0.046	0.755	-0.189	-0.077	-0.033
	Homesteads	-0.354	-0.184	0.751	-0.429	-0.228
	Built-up	-0.192	-0.066	-0.304	0.754	-0.094
	Water bodies	-0.087	0.021	-0.237	-0.085	0.860

All correlations are significant at 0.01 level

As shown in Fig. 3a and b, built-up lands mostly tend to grow adjacent to the existing built-up land. However, few isolated patches of built-up land were noted in Fig. 3b attributed to small townships developed during 1990's.

Statistical analysis: Statistical methods have been used as a powerful and flexible tool in many land use change studies. In this study, in order to determine the relationships between the land use types, correlation analysis was performed using the Statistical Package for Social Sciences (SPSS) software package.

Bivariate correlation analysis was performed so as to determine how 1999 land use has been related to 1983 land use. The bivariate correlations procedure computes the pair-wise associations for a set of variables and displays the results in a matrix. It is useful for determining the strength and direction of the association between the two variables. The Pearson correlation coefficient measures the linear association between the two variables.

Table 4 shows the results of the correlation analysis for the Galle DSD. As shown diagonally in the Table 4, there is a significant and fairly strong positive correlation between the similar land use types in 1983 and 1999. Negative correlations existed for most of the other cases.

Comparatively higher negative correlation was noted between homesteads and agricultural land. Likewise, between homesteads and built-up land, there existed a fairly strong negative correlation.

RESULTS AND DISCUSSION

The main change of land use in the Galle DSD from 1983 to 1999 can be described as the decrease in agricultural land and increase in built-up land. Agricultural land is more likely to get converted to homesteads which represents biggest percentage share of land use in Galle DSD. But the area covered by homesteads continued changing to built-up land resulting about 6% increase in built-up land from 1983 to 1999. This revealed about the increase of impervious surfaces in the area at an average rate of 0.08 km² per year.

The agricultural land which predominantly includes paddy fields showed significant decrease during the 16 year period. This reduction in agricultural land is further supported by the change in country's economic policies in late 70's which encouraged private enterprise, changing peoples' preferences from farming to other employments. The abandoned paddy fields which remain idle for several years have been filled up and gradually converting into residential areas, though there are regulations imposed in order to control the filling up of paddy fields. Previous agricultural areas, which also act as retention area for floods,

converting to impervious built-up surfaces might have significantly contributing to the flooding problems taking place in Galle DSD so far, even with a small localized rain event. It is likely that, Galle DSD becoming increasingly affected by floods if similar land use transformation continues further.

Land conversions to built-up land are most likely to take place adjoining the existing built-up land mainly along the coastal line. Patches of small isolated townships in the middle of the area and the surrounding homesteads area too have been experiencing the urban pressure. Fairly strong negative relationships have been identified between the homesteads and the two land use categories: agricultural land and built-up land. The negative correlation produced by the results showed that for each unit of decrease in one land use type, the other land use type would increase by almost the same amount.

The study revealed the spatial pattern of change in land use and identified the land use categories that are in significant dynamism with their direction of change occurring. Changing trends revealed in the study for different land use types are in line with the land use change in Galle district from early 80's to mid 90's as presented in ADB (2009a).

These results have demonstrated that GIS assisted spatial analysis and statistical methods are useful tools for evaluating the land use change. However, outcome of land use change evaluation can be affected by several factors including methodological differences in developing the maps, land use classification scheme and degree of resolution of data. According to Allen and Hoekstra (1991), the choices over scale, extent and resolution critically affect the type of pattern that will be observed. Thus it is encouraged further studies using more detailed land use classification scheme assisted by finer resolution data.

CONCLUSION

Understanding surface imperviousness is important for estimating surface runoff thus prevent occurring floods. This study evaluated the land use change from 1983 to 1999 in Galle DSD, while focusing on the spatial variation of impervious surfaces in the area in terms of built-up land.

Significant increase in the built-up land has been noted during the 16 years period resulting the ratio of built-up land to agricultural land to be dropped almost by half. This increasing trend in built-up land suggests the possibility of more severe flooding problems to be occurred in Galle DSD than the existing, unless drastic measures are taken. Results of the study are alarming the planners and decision makers to instigate actions to control the urban growth in a sustainable manner. Moreover, the findings of this study provide the basis for effective land management in Galle DSD which

subsequently brings substantial societal and economic benefit for the community.

Statistical methods and GIS assisted spatial analysis approach used in this study were simple and can easily be implemented to evaluate land use change in similar situations.

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