Archaeological Site Impacts in the Hambantota District, Sri Lanka: Markov Chain/GIS/RS-based Analysis of Land Use and Change Detection, 1972-2014

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Abstract: *The Greater Hambantota area features a variety of archaeological sites and monuments carrying considerable importance in Sri Lankan history. Recent expansion of land use patterns in the Hambantota District shows a rapid encroachment on ancient cultural landscapes in the area, and have obliterated almost all tangible evidence of important sites that remain above ground. Cultural inheritance is an essential component of development in all societies, and gaining insights from this point view, the present study justifies the suitability of the Hambantota district as a unit of analysis. Real knowledge of the cultural landscape and understanding landscape changes could facilitate and improve prediction concerning the current and future condition of landscapes, as this is especially important for urban planners developing such schema. This research attempts to evaluate and present the spatial determinants and other related factors exerting influence on the changing land use patterns in the Greater Hambantota area, and how those changes are affecting important cultural heritage sites. Here we evaluate land use changes during the period 1972 – 2014, and offer insight into possible future land uses by way of a Markov Chain analysis.*

Keywords: *Land Use; Land Use Planning; Geographic Information Systems (GIS); Markov Chain Analysis; Archaeology; Cultural Sites; Sri Lanka.*

1. INTRODUCTION

Archaeological sites in Sri Lanka are extremely vulnerable due to changing land use practices, and the present land use pattern of change in the country has accelerated in modern times compared to ancient times; present-day landscapes have been created by the expansion of modern urban settlements. This research attempts to evaluate and examine the spatial determinants and other related factors that have been influential in changing the land use patterns in the Greater Hambantota area. These and similar studies are important in that they can aid in minimizing the destruction of the tangible cultural landscape, as well as assist in regional planning, management, and economic development. The use of modern technologies such as geographical information system (GIS), remote sensing (RS), spatial statistics, and more traditional statistical methods are considered to provide a valuable tool for the protection of cultural heritage sites from human and environmental threats.

Heritage management is a fast-growing academic sub-discipline of archaeology, concerned with the management of not only the endangered cultural properties but also living monuments for the sake of future generations. Modern urban configurations have resulted in near-boundless expansion of land use in unpredictable ways (Eniyew, 2018; Sen, Gungor, and

Sevik, 2018; Li, Wei, and Korinek, 2018). Economic expectations are among the main determinative factors of this proliferation, and its penetration into traditional landscapes with ancient monuments has produced unexpected socio-cultural consequences as well as threats to historic artifacts (Elfadaly et al, 2018; Lane, 2011); modern methods are working to assist in the protection of endangered sites (Rayne et al, 2017).

A central tenant of archaeology is the preservation and conservation of a cultural landscape, as sites can be exposed to many destructive factors, both natural and human. The role GIS and RS platforms play in archaeological applications cannot be understated (Wheatley and Gillings, 2000; McCoy and Ladefoged, 2009; Llobera et al, 2011; Wernke, 2013). Archeologists can uncover patterns of settlements, locate otherwise difficult-to-find items, and these systems can greatly aid in site analysis of potential archaeologic digs. Recently, application of GIS and RS to cultural heritage management, cultural resources inventory, impact assessment studies, protection planning, and heritage management planning has increased, and the use of such systems has aided archaeologists in answering important questions (Wernke, 2012; Supernant and Cookson, 2014). Urban planners need tools to understand current land uses and patterns in order to move toward more sustainable systems in terms of their relationship to archaeology (Hirtz, 2014; Vazquez and Albendin, 2015; Deur and Butler, 2016).

Research of this type has been described in past studies. Mohamed (2009) examined urban growth impacts on tourism north of the United Arab Emirates (UAE) in which he observed that tourism resources were under threat, suffering from decline and degradation due to a combination of direct and indirect impacts of urban growth. He further showed that many archaeological sites in the study area were located on private property, which might make management and preservation difficult. The results indicate that natural resources and archaeological sites in the northern UAE require protection. Nghiem et al (2013) studied land use change in the Jura Mountains in the east of France. The objective of the research was to conduct cost analysis of land use changes over the previous thirty years. The authors stated that those changes were also directly impacted by climate change, which favors certain vegetation types over others. The results of their research were used to produce land use changes maps and create particular models of prediction of land use changes, and to suggest future corrective actions to reduce the intensity of those disturbances. Olukole (2008) discussed the changing cultural landscape and heritage tourism potential of Ijaiye-Orile archaeological sites in southern Nigeria. In his work, the author examined archaeological perspectives on the changing cultural landscape in the region. Robert and David (2009) examined prehistoric site distributions in an upland prairie area of central Illinois (United States). They describe a formal predictive model of site location developed for the area using GIS and logistic regression analysis. Their model is based on archaeological data from a systematic survey and environmental data obtained from maps, and has implications for applying GIS and RS data to the preservation of an area’s cultural heritage.

The continuity of human occupation of the Greater Hambantota area from the late Pleistocene is discussed by Deraniyagala (2007). The oldest known site is the Minihāgalakanda, situated approximately 40 km (24.8 mi.) east of the present research area in the Miocene formation (Cooray, 1984), and houses crude stone implements. This site has been dated to the middle Pleistocene epoch (Deraniyagala, 2007). Additionally, there are four prehistoric sites in the vicinity of the present study area, namely Bundala, Patirājavela, Udamalala, and Pallemalala; these sites have calibrated dates showing the existence of prehistoric culture dating to around 3,000 BC (Katupotha, 1988). Archaeological surveys carried out in recent decades show there is evidence of early agricultural iron-using communities in the area, and not only pre- and proto-historic sites but early and late historic periods as well. Hunter-gatherer societies in transition to agriculture in the area have yet to be confirmed; however, it is accepted that the lower limit of prehistoric culture on the island of Sri Lanka can be placed roughly at the end of the second millennium BC (Deraniyagala, 2007). There is no consensus concerning inferring the period of decline of the hunter-gatherer culture of the present area. Further research shows there is evidence for early iron-using agricultural communities, and in the eastern section, burial grounds are evident. Excavation of shell middens at Pallemalala, located approximately 10 km (6.2 mi.) west of the Hambantota area, indicates that this sedentary culture may have immediately followed the hunter-gatherer phase (Somadeva, 2006). Further, artifacts such as pottery and beads taken from the layer positioned immediately above the prehistoric layer in the strata are identical in nature to those of iron-using settlements in both Sri Lanka and the southern portion of India (Deraniyagala, 2007), furthering the evidence for the movement away from hunting and gathering.

The area entered the modern historical period around 250 BC, and two phases of development followed: 1) the expansion of early iron-using communities, and; 2) developments in the upper catchment of the river basins in the study area. It is reasonable to assume, on the basis of the built environments in the area as well as distribution patterns of these ancient settlements, that sedentary settlement and urbanization continued throughout the area post-250 BC and into the 15th century. Regional history of the southern Sri Lanka associated with Portuguese occupation began in the 16th century. The Portuguese, however, confined their activity mostly to the Hambantota area, probably due to the suitable climate for agriculture (Murphy et al, 2018). By the 18th and 19th centuries, the area was under Dutch control, and their primary activity focused on mining salt. Remnants of both the Portuguese and the Dutch influence can be prominently found throughout the region, including the fort at Katuwana (Portuguese) and several Dutch-built structures in the eastern sector of Māgampattuva (Somadeva, 2002). British presence in the area is also a major component of the cultural backdrop, with river development and dam projects occurring at Kirindioya and Tissamaharama. It is within reason to state that the shaping of the socio-economic sphere of the region was accomplished prior to modern times.

2. FOCUS and STUDY AREA

This study focuses on the Greater Hambantota area, which features a wide array and distribution of archaeological sites and monuments carrying considerable time depth. The degree of the expansion of land use patterns during the past years in the area feature rapid encroachment on ancient cultural landscapes, and has obliterated almost all tangible evidence remaining above ground – *destruction of cultural assets is irreversible*. Cultural inheritance is an essential component of development in all societies, and gaining insights from this point of view, the present study justifies the suitability of the Hambantota District as a unit of analysis. Real knowledge of the cultural landscape and understanding landscape changes could facilitate and improve prediction about the current and future condition of landscapes, and this is especially important for urban planners addressing development.

One of the most pressing issues for administrators in the Greater Hambantota area is managing improvements while remaining sensitive to the archaeological value of the area. Imagining a mitigation framework is a major component of this, as rapid development can lead to unwanted destruction of sites and objects. Identification of suitable land uses can help in producing this framework through the following:

- Exploring patterns of land use change to describe environmental determinants that may have influenced the dispersal of archaeological sites within the study area;
- elaborating on the interaction between the ancient cultural landscape and the impact of modern settlement expansion, and;
- construction of a model of ancient settlement patterns.

The focus area of the study is the southern portion of the island of Sri Lanka, in the Ruhuna area, which has history in ancient chronicles and Buddhist commentaries. Ruhuna consists of a flat valley extending to the Indian Ocean, with the southern and southeastern areas exhibiting arid conditions through most of the year. The northern section of the area is hillier, and features more temperate and moist climate conditions. Five major rivers, the Walawe, Malala-oya, Kirindioya, Manikoya and Kubukkanoya, originate in the northern portion, and produce alluvial floodplains through annual flood events. This geographic construction attracted early farmers (around the first millennium BC), and resulted in several political segments identified in the region (Wikkramatileke, 1963).

Figure 1: Location map of the study area on the island of Sri Lanka.

3. METHODS

Archaeological site survey and excavation reports provided information about archeological sites in the study area. Survey girds were established to collect artifacts found on the surface (this survey was completed by the Postgraduate Institute of Archaeology, University of Kelaniya, Sri Lanka, from 1999 to 2001). Dating is accomplished through a comparative analysis of pottery and artifacts collected at the site. The results of the archaeological survey provided valuable information about site size, name, location, and occupation dates. We also used a protected-monument list collected by the Department of Archeology, University of Colombo, Sri Lanka. The methods used include the following steps:

1. Data collection (archaeological sites) (see Table 1)
2. Preparation of datasets
3. Digitized maps and preparation of database
4. Image classification
5. Preparation of change detection maps
6. Preparation of overlay maps

All the above steps were carried out using ArcGIS®, Erdas ®, and Illwis ® software. Field data and aerial photographs were examined and used for accurate land use land cover (LULC) classification. Six LULC classes were considered: paddy land, homestead/built up, bare land, forest, water, and agriculture. The LULC-based maps were analyzed, and change detection was carried out via:

1. Calculation of the area in hectares of the resulting land use types for each study year and comparison of the land use statistics, which assisted in identifying the percentage of change, trend and rate of change between 1972 and 2014.
2. A measure of compactness which indicates a progressive spatial expansion of the area (land consumption rate, or *LCR*).
3. Markov Chain analysis for analysis of change detection.
4. Overlay operations for archeological impact assessment mapping.

Markov Chain analysis is a common technique used in LULC models when such changes and processes may prove difficult to describe in simple terms. Markovian processes utilize the known state of the system immediately preceding the analysis to model a future state, allowing for the description of land use change from period to period (Ayila, Oluseyi, and Anas, 2014). The key feature of Markov Chains is that the subsequent state is based only on what is known about the present state, with no consideration to any previous (prior to present) state (or states) of the phenomenon under study. Given some set of states (condition or use of land, for example), with *state space* set *X*, the model can describe such a set *where*

$$X = \{X_0, X_1, X_2, \dots, X_n\}$$

with some current state of X_a and the changed state of X_b given some probability as noted by the transition probabilities P_{ij} described by the transition probability matrix

$$P_{ij} = \begin{bmatrix} P_{11} & \cdots & P_{1n} \\ \vdots & \vdots & \vdots \\ P_{n1} & \cdots & P_{nm} \end{bmatrix}$$

with the *n*th state calculated by

$$P_{ij}^{n} = \sum_{k=0}^{m-1} P_{ik} P_{kj}^{(n-1)}$$

for all $(0 \leq P_{ij} < 1)$

and

$$\left(\sum_{j=1}^{n} P_{ij} = 1, i, j = 1,2, \ldots, n \right)$$

and

$$S_{t+1} = (P_{ij})(S_t)$$

where
P_{ij} = state probability matrix

n = land use type

S = status of land use

t = given point in time

This then allows the new state to be described by a change from the former state X_a such that $X_b = X_{a+1}$ in the chain (after Ma et al, 2012; Liping, Yujun, and Saeed, 2018).

Table 1: Data used in this research.

Data type	Year	Sources	Process	Output
Maps (1:63,360)	1972	Survey department, Sri Lanka (govt.)	Digitization, coordinate integration	LULC map 1972
Topographic map (1:50,000)	1990	Survey department, Sri Lanka (govt.)	Digitization, coordinate integration	LULC map 1990
Satellite images	2008	Survey department, Sri Lanka (govt.)	Enhancement, classification	LULC map 2008
Quick Bird satellite images	2014	Land use planning department, Sri Lanka (govt.)	Enhancement, classification	LULC map 2014
Statistical record, population	1972 - 2014	Census and statistics department, Sri Lanka (govt.)	Developed database	Population expansion map
Archaeological site data	1990 - 2002, 2012	Site survey by department of Archaeology and PGIAR (SMR project), Colombo University, Sri Lanka	Developed database	Archaeological sites distribution map

Attention has been given to the land use changes to identify patterns and trends. The main objective of the analysis was to identify land use changes using the years 1972, 1990, 2008 and 2014. The static LULC distribution for each study year as derived from the maps are presented in Table 2 below. Land use statistics and transition matrices are important information to be used in analyzing the changes of land use. In order to identify changes for all four images pertaining to the years listed above, a change detection analysis was conducted and the images were grouped into six LULC classes. The total classified area was 91,300 hectares. Each land use category and change over time for 42 years has been summarized in Table 2 below, and Figures 2-6 present the LULC for the study area for these years.

Table 2: LULC classification statistics, 1972, 1990, 2008, and 2014.

Land use type	**1972**		**1990**		**2008**		**2014**	
	Area (Ha)	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Paddy	4,645	5	13,973	15	13,997	15	17,028	19
Bare land	817	1	814	1	783	1	1,393	2
Homestead/Built up	6,502	7	12,994	14	14,467	16	24,029	26
Forest	59,483	65	39,816	44	39,594	44	32,160	34
Water	8,670	10	7,253	8	7,231	8	5,639	7
Agriculture land	11,181	12	16,449	18	15,226	16	11,050	12
Total	91,300	100	91,300	100	91,300	100	91,300	100

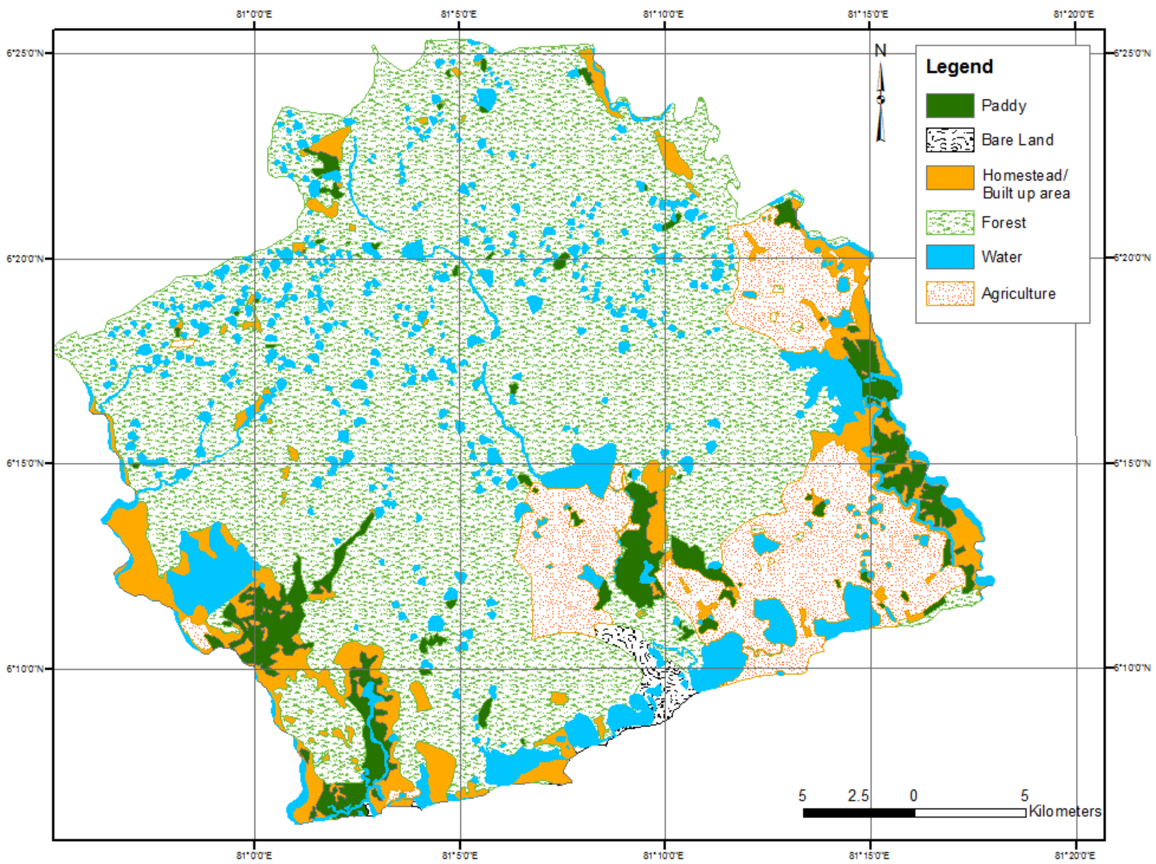

Figure 2: LULC, 1972.

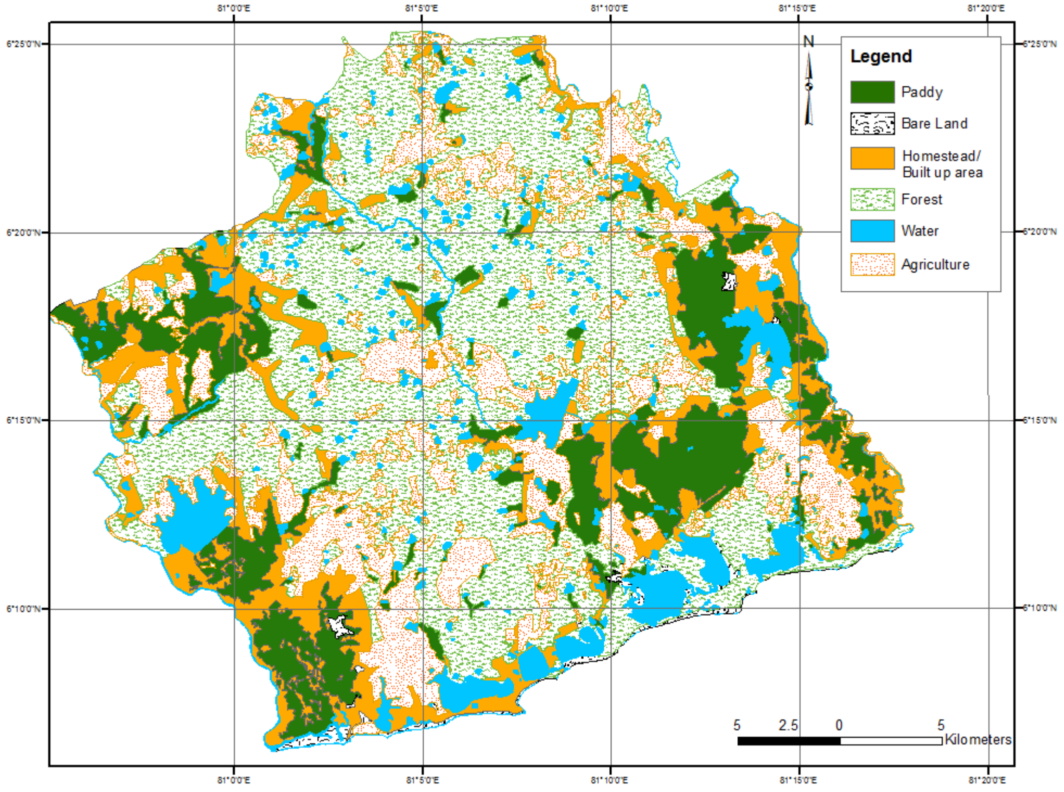

Figure 3: LULC, 1990.

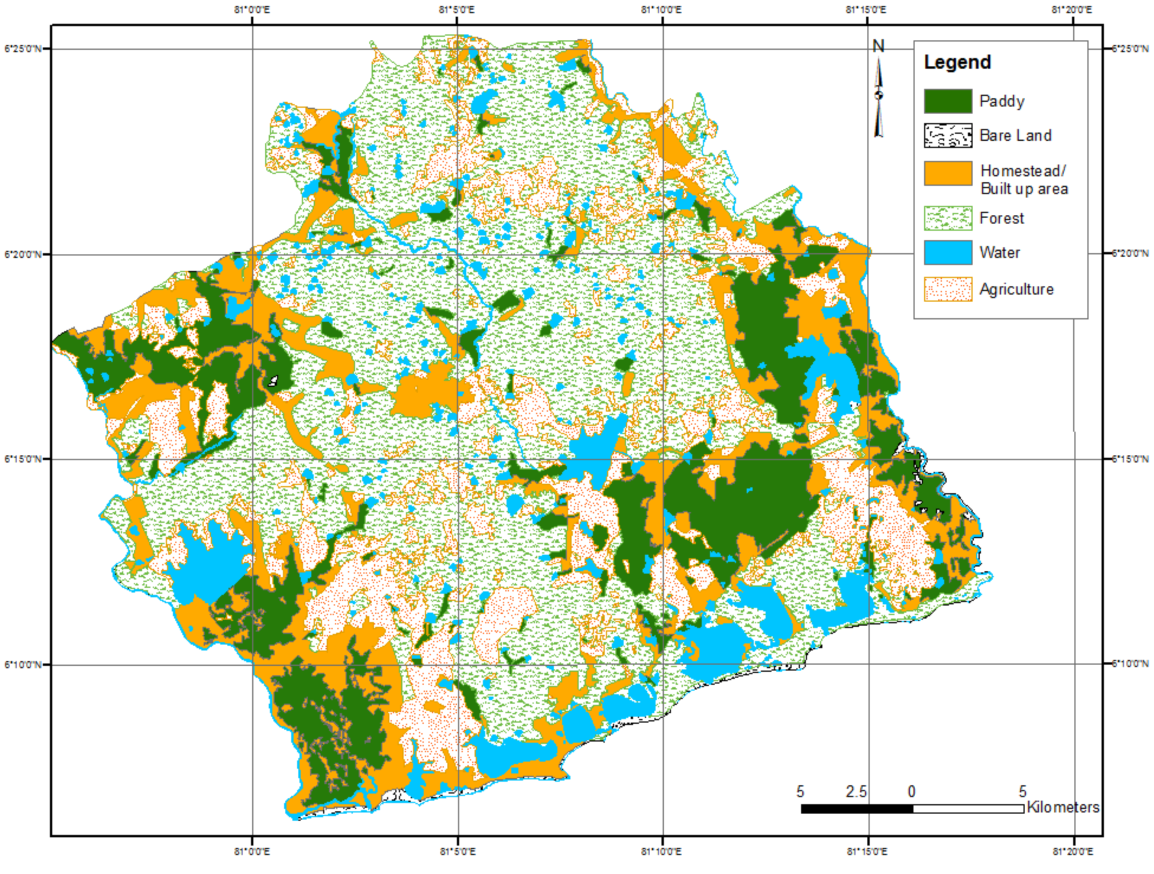

Figure 4: LULC, 2008.

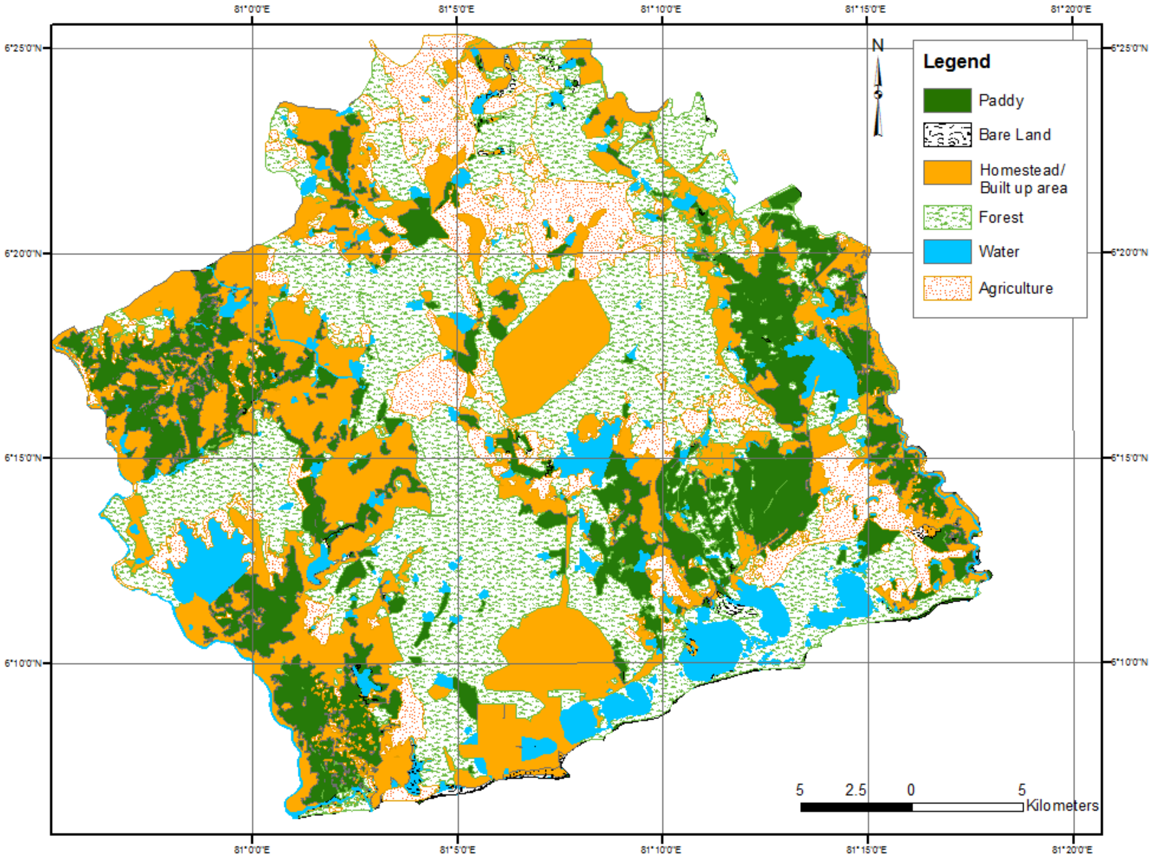

Figure 5: LULC, 2014.

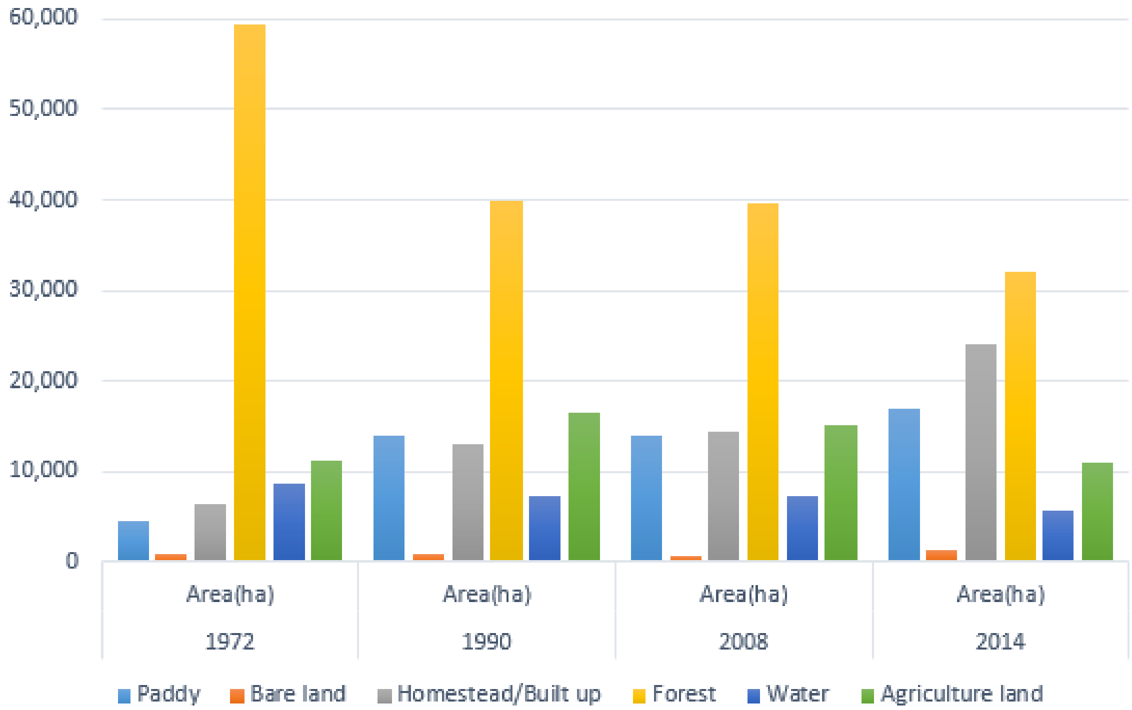

Figure 6: LULC, 1972 to 2014.

4. RESULTS AND DISCUSSION

Land use maps and characteristic data results of this study are presented below. Each LULC category and changes over time for 42 years are summarized in Table 3 below. According to observed data, from 1972 to 1990 forest land has decreased to 19,667 hectares (decrease represents 65% to 44% of the total area) but the built up area showed an increase to 6,493 hectares (increase represents 7% to 14 %). In the second phase (2008 to 2014) there is a 10%, or 9,562 hectare increase in the homestead/built up area of the study area. Similarly there has been consistent reduction in the forest land in the study area by 7,434 hectares (8%). A similar decrease of 1,591 hectares (1.7%) in the water area (Table 3).

Table 3: LULC area change in hectares and percent.

Land use types	**Change 1972-1990 (Ha)**	**Change %**	**Change 1990-2008 (Ha)**	**Change %**	**Change 2008-2014 (Ha)**	**Change %**
Paddy	9,328	10.2	24	0.026	3,030	3.31
Bare land	-4	-0.004	-30	-0.003	609	0.66
Homestead/ Built up	6,493	7	1,472	1.61	9,562	10.4
Forest	-19,667	-21.5	-222	-0.24	-7,434	-8.1
Water	-1,417	-1.5	-22	-0.02	-1,591	-1.7
Agriculture	5,267	5.7	-1,222	-1.33	-4,176	-4.5

Between 1972 and 2014 the land-use pattern of the study area changed considerably. The proportion of homeland/built up increased significantly. Thus, the proportion of forest land was cut by approximately one -half. On the other hand, there were considerable losses of water area, which were mostly converted into paddy/agriculture. The figures presented in Table 4 below represent the static area of each LULC category.

Table 4: LULC change, 1972 to 1990.

Period	To 1990	Paddy	Bare land	Homestead /Built up	Forest	Water	Agriculture land	Total
From 1972	Paddy	2,843	127	825	417	129	305	4,646
	Bare land	21	77	56	526	84	54	818
	Homestead /Built up	944	165	3,365	775	310	944	6,502
	Forest	7,053	33	6,263	32,891	2,281	10,963	59,483
	Water	925	177	930	2,020	3,801	818	8,671
	Agriculture land	2,186	235	1,557	3,188	649	3,366	11,182
	Total	13,973	813	12,995	39,816	7,254	16,449	91,300

Land Change Modeler (LCM) was used to analyze the LULC changes between various classes during the period 1972 to 2014. The basic principle used in the model is to evaluate the trend of the change from one land use category to another, and the impact of influencing factors such as roads and structures. The land use changes were assessed through evaluation of gains and losses by classes, with most of the classes showing both. During the period 1972 to 2014, forest land was lost and homestead/built-up area was gained; classes that have undergone transitions from one class to another during the 1972 to 1990 period are shown in Figure 7, which also displays the degree of changes (gains + and losses -) in the study area resulting from the land cover conversions (Table 5). It can be concluded that all land cover classes experienced some form of transition, either gain or loss.

Table 5: Change trajectory, 1972 to 1990.

From 1972	%	Paddy	Bare land	Homestead/ Built up	To 1990 Forest /Boggy	Water	Agriculture	Total
Paddy	5	4	0	1	0	0	0	5
Bare land	1	0	0	0	1	0	0	1
Homestead/Built up	7	2	0	3	0	0	2	7
Forest/Boggy	65	5	0	5	42	1	12	65
Water	10	3	0	0	2	4	1	10
Agriculture	12	2	1	2	3	0	3	12
Total	100	16	1	11	44	8	18	100

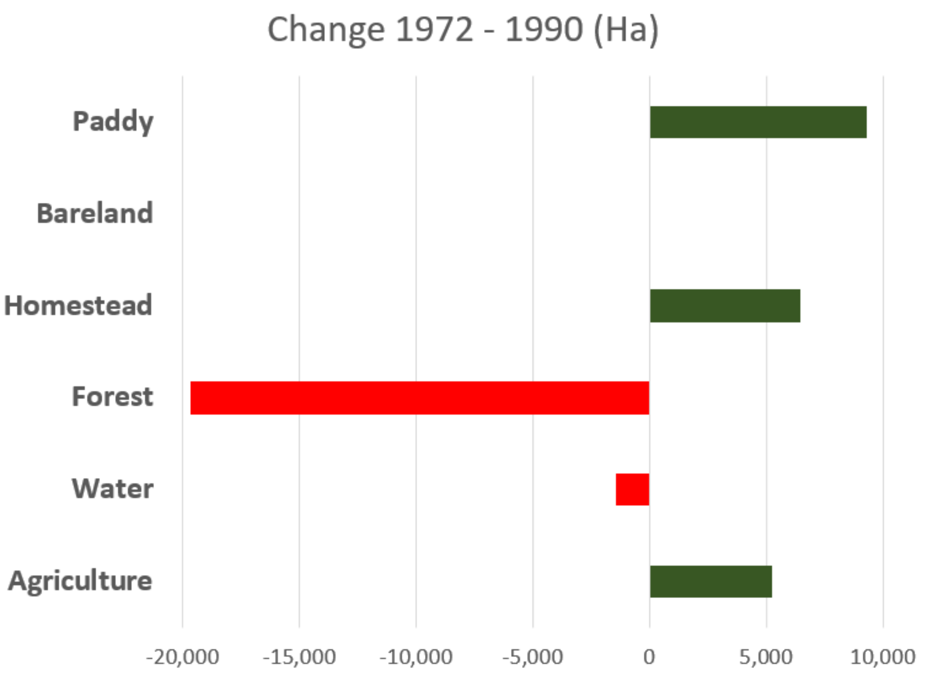

Figure 7: Change (gains and losses), 1972 to 1990 (in hectares).

Table 6: LULC change matrix, 1990 to 2008 (in hectares).

Period	**To 2008**	**Paddy**	**Bare land**	**Homestead/ Built up**	**Forest**	**Water**	**Agriculture**	**Total**
From 1990	**Paddy**	13,964	1	4	0.5	2	1	13,973
	Bare land	0	532	277	1	0.25	4	814
	Homestead/Built up	0	0.25	12,886	32	32	45	12,995
	Forest/Boggy	0	0	205	39,579	1.5	8	39,793
	Water	8	5	0.5	6	7,141	2	7,162
	Agriculture	1	245	1,095	0	56	15,168	16,564
	Total	13,973	785	14,467	39,618	7,232	15,227	91,300

Table 7: LULC change matrix, 2008 to 2014 (in hectares).

Period	To 2014							
		Paddy	**Bare land**	**Homestead/ Built up**	**Forest**	**Water**	**Agriculture**	**Total**
From 2008	**Paddy**	10,574	155	1,717	937	243	371	13,997
	Bare land	97	135	109	307	17	119	783
	Homestead/Built up	2,040	259	9,238	1,467	336	1,129	14,467
	Forest/Boggy	2,167	450	8,773	22,675	626	4,904	39,594
	Water	383	303	976	984	4,159	427	7,231
	Agriculture	1,768	93	3,217	5,791	258	4,100	15,227
	Total	17,028	1,393	24,029	32,160	5,639	11,050	91,300

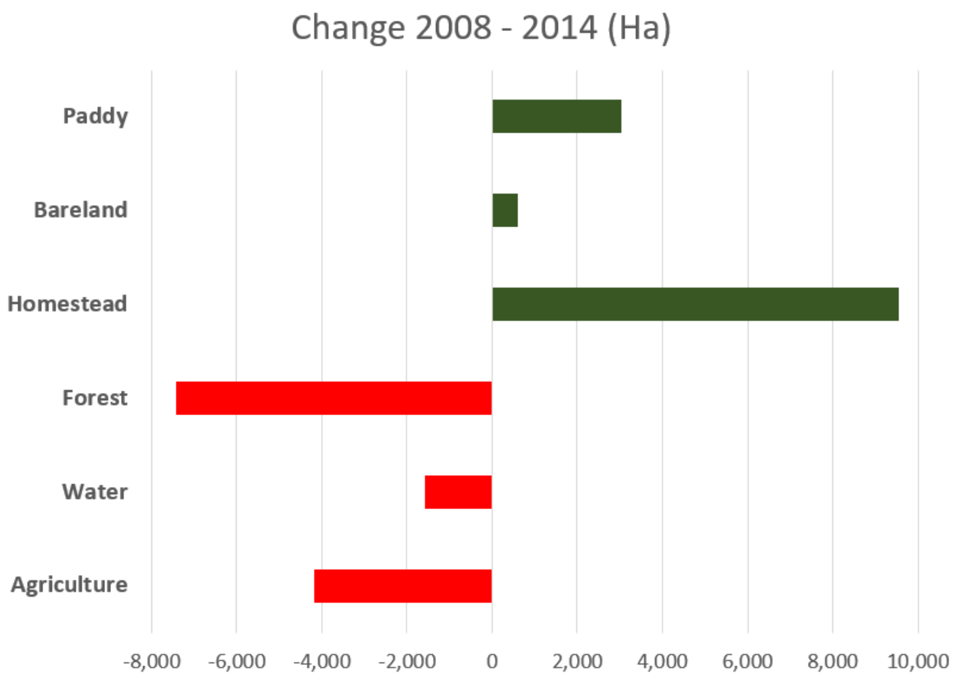

Figure 8: Change (gains and losses), 2008 to 2014 (in hectares).

Figure 8 presents the relative LULC change patterns trend (losses and gains) 2008 to 2014 in the Greater Hambantota area. An overall increase of 19% in homesteads/built up area has been observed during this six-year time period and a 29% decrease in forested land. Markov Chain analysis describes the prediction for 2008, shown in Tables 8-10 below, as well as the results of the analysis to the year 2032.

Table 8: Validation predictions for 2008.

Types	Predicted 2008 (%)	Present 2008 (%)
Paddy	25	15
Bare land	3	1
Homestead/Built up	19	16
Forest	33	44
Water	5	8
Agriculture	15	16
Total	100	100

Table 9: Comparison of validation predictions for 2008.

Paddy	0.2975464	0.0168806	0.3190876	0.2324878	0.0427802	0.0912173
Bare land	0.2969967	0.0168834	0.3193073	0.2327230	0.0427879	0.0913015
Homestead/Built up	0.2971446	0.0168828	0.3192476	0.2326590	0.0427874	0.0912786
Forest	0.2969454	0.0168837	0.3193281	0.2327449	0.0427886	0.0913094
Water	0.2967482	0.0168862	0.3193853	0.2328269	0.0428158	0.0913375
Agriculture	0.2970125	0.0168833	0.3193012	0.2327161	0.0428158	0.0912991
	1.7823940	0.1013000	1.9156572	1.3961578	0.2567477	0.5477433

Table 10: Quantity change (transition area matrix) through the Markov Chain model, 2014 and 2032, in percent.

Types	2014 (%)	2032 (%)
Paddy	19	33
Bare land	2	2
Homestead/Built up	26	32
Forest	35	23
Water	6	3
Agriculture	12	7
Total	100	100

Archeological sites can be damaged in different ways, either by natural or human factors (or both). The main natural threats to archaeologic sites are seismic events, landslides, erosion, and tsunami or flooding (Jusseret, 2014; Johnson, Marrack, and Dolan, 2015; Radosavljevic, et al, 2016; Chiabrando, et al, 2017; Cuca and Agapiou, 2018; Fandi 2018; Niculia and Margarint, 2018); however, no attention to natural factors is considered in this research, as the focus of this analysis is aimed at urban expansion, including proximity to roads. Continuously expanding cities and villages, industrialization and development, fire in agricultural use, road development, cultivation practices, and landfills and waste disposal areas are identified as the major human-derived risk factors. These factors contributed significantly to the destruction of archaeological sites and must be assessed properly in order to protect sensitive areas (Swensen, 2008; Al-Houdalieh, 2009; Agapiou, 2015). Figure 9 below shows the general outline of risk assessment for heritage sites used here, and Table 11 shows the risk assessment levels used.

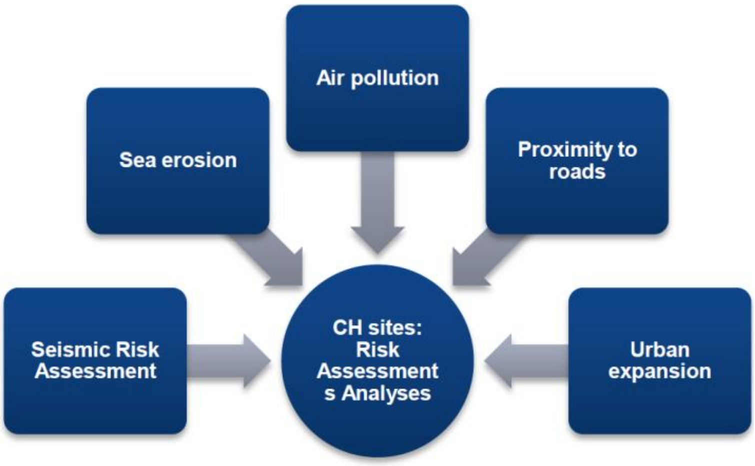

Figure 9: Risk assessment analysis for cultural heritage sites.

Table 11: Risk analysis, assessment definition criteria.

(Impact Assessment Survey, Department of Archaeology, University of Colombo, Sri Lanka)

Data layer/land use	High risk homeland/built up	Moderate paddy land agriculture	Low risk, other, all
Main road	<100m	100-200	>200
Railway road	<200m	200-500	>500
Population	High density	Low density	Low density

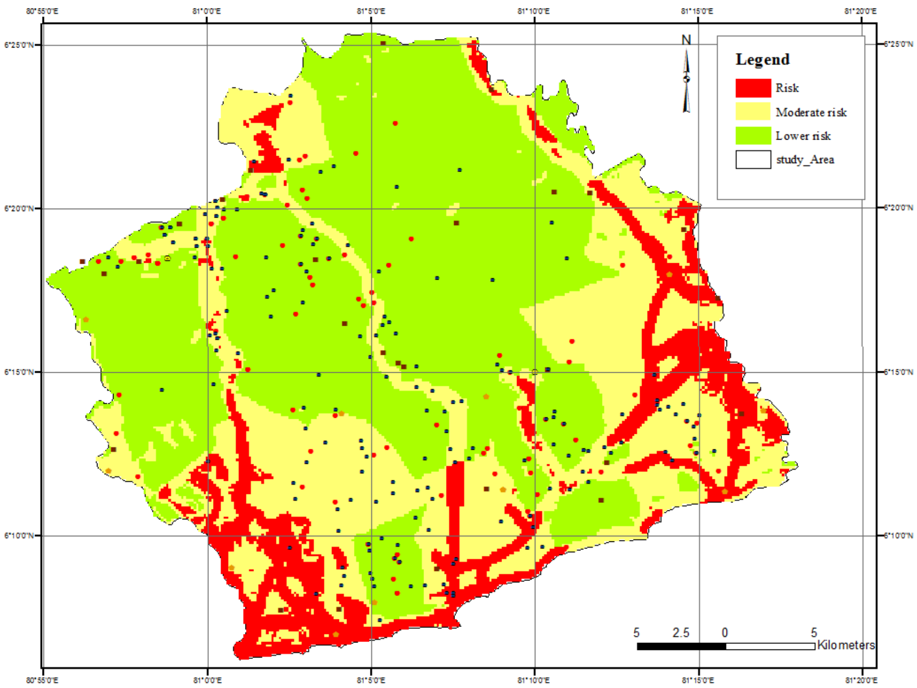

Figure 10: A comparison between archaeological sites (dots) and risk, 1972 LULC.

Eleven different classes were produced, with the first four classes categorized as low risk, next four classes align with moderate risk and final to high risk ("risk"). The final result of the classification regarding the risk area and their relationship to archaeological sites are presented in Table 12 below. As displayed in Figures 10, 11, and 12 (and Table 12), the (high) *risk* area in red has grown considerably from 1972 to 2014. Archaeological sites have, however, decreased in two of the six classes of land use: water and agriculture. Much of the higher-risk locations lie within built-up areas, which suggests that proactive protection measures could be implemented to lessen the damage to heritage cites and the artifacts located within.

Table 12: Archaeological site distribution within each land use category.

Types	1972	1990	2008	2014
Paddy	13	50	50	73
Bare	2	1	3	2
Homestead/built up	28	70	74	115
Forest	215	137	137	113
Water	49	33	31	13
Agriculture	55	72	65	43

Table 13: Statistical results of the risk assessment of archaeological sites.

	1972	1990	2014
Risk (high)	15	48	56
Moderate Risk	130	152	176
Low risk	229	174	142

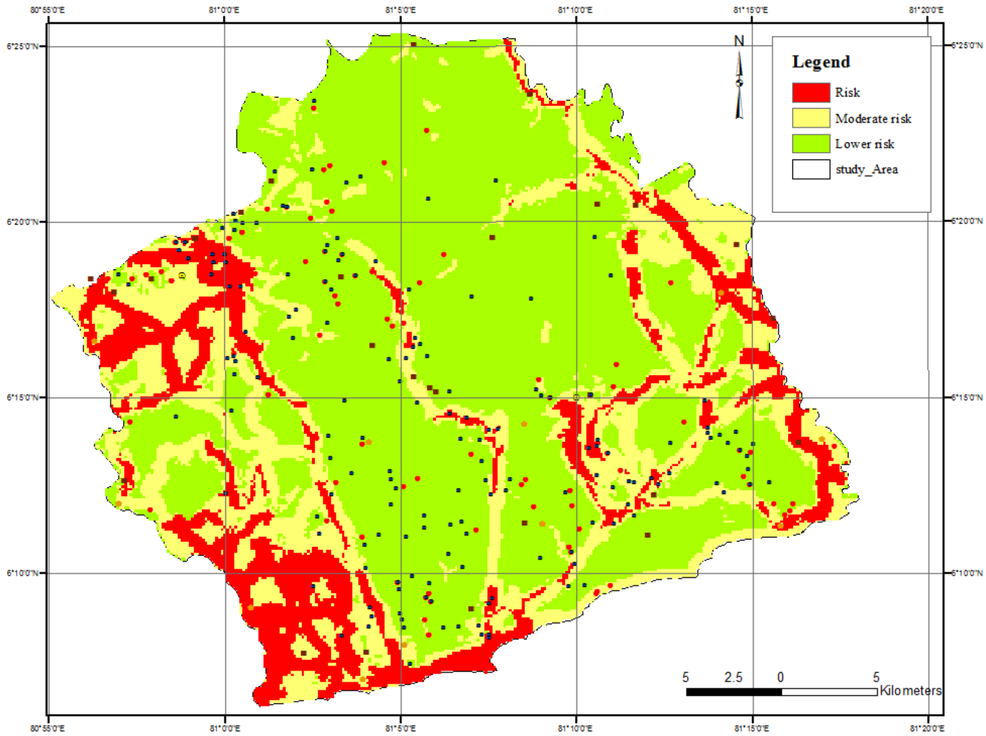

Figure 11: A comparison between archaeological sites and risk, 2008 LULC.

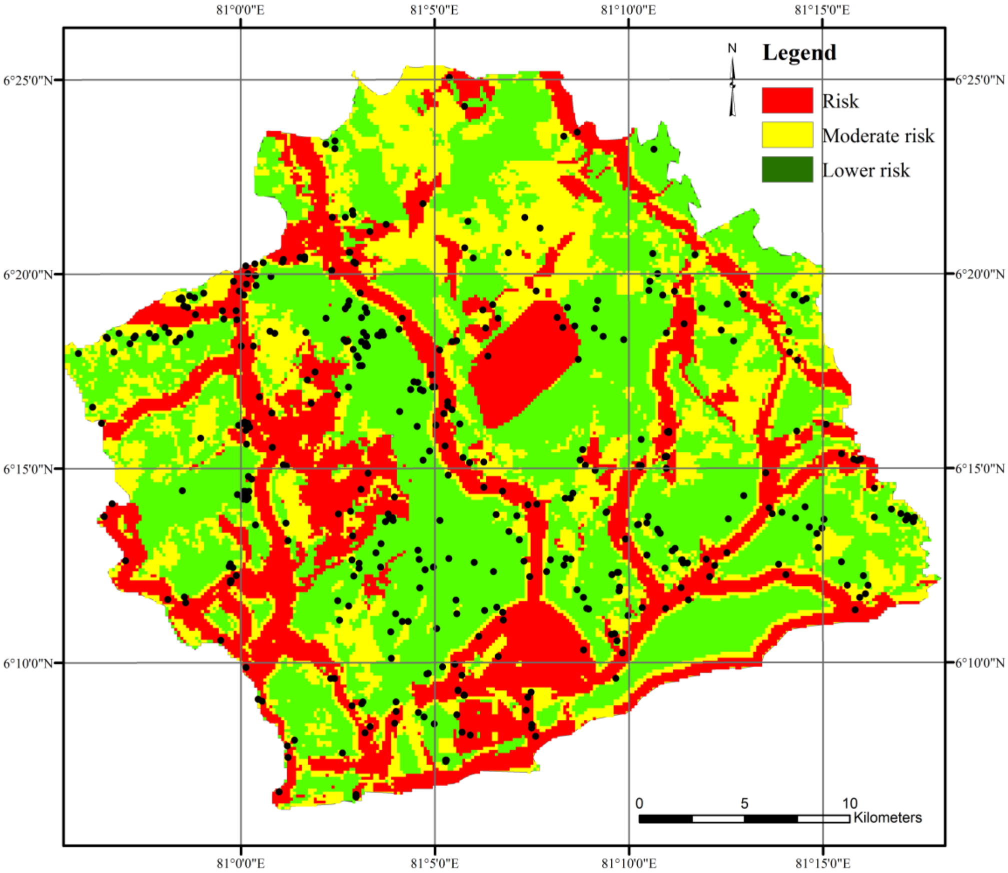

Figure 12: A comparison between archaeological sites and risk, 2014 LULC.

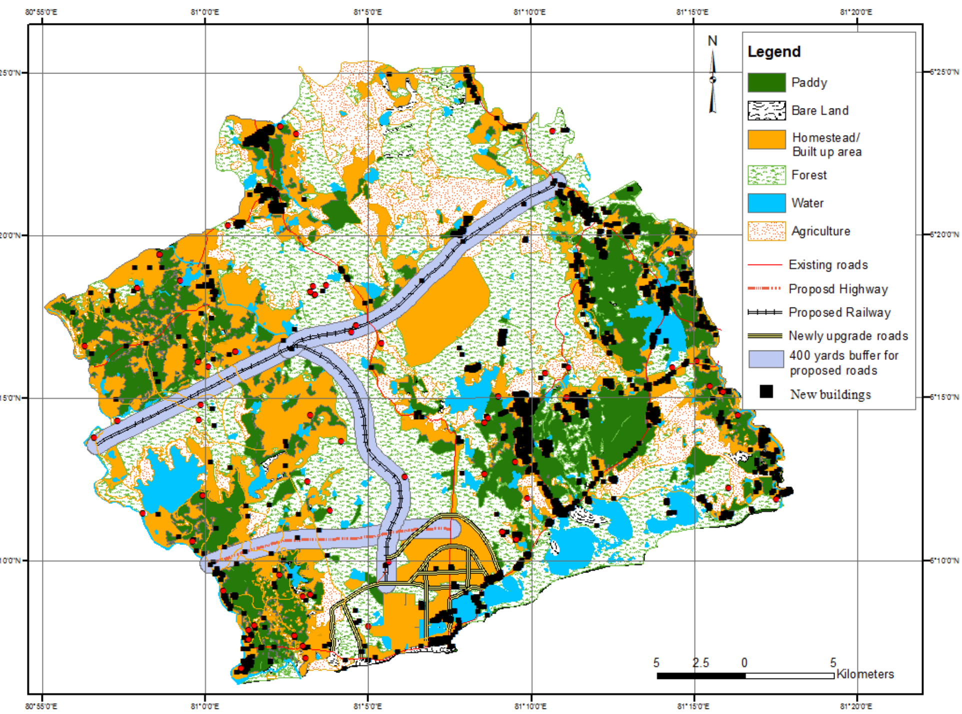

Figure 13: Present (2014) land use of the study area.

5. CONCLUSION

This research has attempted to evaluate and present the spatial determinants and the other related factors that have influenced changes in the land use patterns in the Greater Hambantota area of southern Sri Lanka by highlighting the major threatening factors to the tangible heritage in that area; these considerations are very important to minimize destruction to the tangible cultural landscape, as well as support regional planning, management and economic development. Proposed roads clearly show a threat to historical sites, and should be placed with care and caution in the presence of important cultural sites, or avoided altogether if possible. Figures 10, 11 and 12 show an increase in risk over the study period in the context of LULC. Many built up areas have encroached upon sensitive sites, and further development of those areas should be limited. While many sites lie within paddy and forested areas, future development into those areas could pose significant risks to artifacts currently in place there. Human expansion by way of urban development is unlikely to slow as population continues to increase and the need for ecosystem services increases along with it, and as such, governments need to carefully consider the threats leveled against important historical and cultural sites and objects – once destroyed, they cannot be recovered. New technologies exist which can, with relative ease given suitable and available data, be employed in previously out-of-reach analyses to assist decision makers in expansion plans, and inform them concerning the most sensitive locations when expansion is being planned, thus aiding in the protection and preservation of tangible history.

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