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Ranjana U.K. Piyadasa[1], Gayani Ranasinghe[2]

[1]Department of Geography, University of Colombo, Sri Lanka.
ranjana@geo.cmb.ac.lk

[2]Department of Town and Country Planning, University of Moratuwa, Sri Lanka.
gayaniprasadika@gmail.com

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Exploration of Recent Land Use and Land Cover Changes of the Bentota River Basin in Sri Lanka

Piyadasa, R.U.K. [1]
Ranasinghe, G.[2]

[1]University of Colombo, Sri Lanka.
ranjana@geo.cmb.ac.lk

[2]University of Moratuwa, Sri Lanka.
gayaniprasadika@gmail.com

Abstract

Land is one of the most important natural resources for the survival and prosperity of humankind, and it is the platform on which human activities take place. The terms land use and land cover are not synonymous and the literature draws attention to their differences so that they are used properly in studies of land use and land cover change. However, the distinction between land use and land cover, although relatively easy to make at a conceptual level, is not so straightforward in practice as available data do not make this distinction clearly all the time, a fact that complicates the analysis of either one of them. Taking into account the available land use data, this study is carried out to explore both land use and land cover change from 1983 to 2013 of the Bentota River basin located between the Western and Southern Provinces of Sri Lanka. Changes in both the qualitative as well as the quantitative characteristics of land use are described considering the extent of land use and the level of detail conditioned by the spatial level of analysis and the availability of requisite data. Temporal mixed land use diversity of the area was examined calculating land use 'entropy' values for different time periods. Findings indicate that 80% of paddy lands of the Bentota basin have been abandoned and converted into marshes, grasslands and scrubs. Tea and cinnamon are the emerging crops, while rubber and coconut lands in the area are seeing a reduction. The level of mixed land use diversity of the area during the last three decades is similar. Future land use activities of the area will consist of water retention areas, commercial use, recreational use, and tourist activity use due to the upcoming Dedduwa Lake Tourism Development Project.

Keywords: Entropy value, Land use and Land cover change

1. Introduction

Land is the platform on which all human activity is being conducted and the source of the materials needed for this conduct. Human use of land resources gives rise to "land use and land cover" which varies with the purposes it serves, whether they be food production, provision of shelter, recreation, extraction and processing of materials, and so on, as well as the bio-physical characteristics of land itself (Briassoulis,1997,p.23). Hence, land use and land cover takes place under the influence of two broad sets of forces that are human needs and environmental features and processes. Descriptive studies of land use and land cover change are an essential part of any analytical endeavour as a first step towards more refined analyses. For this study, the Bentota Divisional Secretariat Division (DSD) located in the Southern Province of Sri Lanka is considered since the Bentota River valley annually faces the natural phenomena of flooding in the rainy season and saltwater intrusion in the dry season. At present, more than 80% of paddy lands of Bentota River basin have been

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abandoned due to contrasting degrees of saltwater intrusion. Hence, this study intends to explore the changes in the areal extent of each type of land use and land cover of the Bentota area from year 1983 to 2013and to identify the change of the extent of abandoned paddy lands in the area as one of the major land use issues.

2. Literature Review

The terms land use and land cover are not synonymous and the literature draws attention to their differences. Land cover is the biophysical state of the earth's surface and immediate subsurface (Turner, Skole, Sanderson, Fischer, Fresco & Leemans, 1995, p.45). In other words, land cover describes the physical state of the land surface: as in cropland, mountains, or forests (Meyer & Turner, 1994, p.238). Land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation and the purpose for which the land is used (Turner, Skole, Sanderson, Fischer, Fresco & Leemans, 1995, p.46). Meyer & Turner state that land use is the way in which and the purpose for which, human beings employ the land and its resources (1996, p.239). Briefly, land use denotes the human employment of land. However, both in the case of land cover as well as of land use, the meaning and conceptualization of change is much broader. Briassoulis shows that changes in the uses of land occurring at various spatial levels and within various time periods are the material expressions, among others, of environmental and human dynamics and of their interactions which are mediated by land (1997, p.29) .

In the case of land cover change, the relevant literature distinguishes between two types of change: conversion and modification (Turner, Skole, Sanderson, Fischer, Fresco and Leemans, 1995, p.45; Skole, 1994, p.440). Land cover conversion involves a change from one cover type to another. Land cover modification involves alterations of structure or function without a wholesale change from one type to another; it could involve changes in productivity, biomass, or phenology (Skole, 1994, p.441). Land use change may involve either conversion from one type of use to another or modification of a certain type of land use. Modification of a particular land use may involve changes in the intensity of this use as well as alterations of its characteristic qualities/attributes such as changes of suburban forests from their natural state to recreation uses (the area of land staying unchanged), and so on. While the distinction between land use and land cover change is relatively easy to make at a conceptual level, it is not straightforward in practice as available data do not make this distinction clearly all the time, a fact that complicates the analysis of either one of them. In

the analysis of land use and land cover change, it is first necessary to conceptualize the meaning of change to detect it in real world situations. At a very elementary level, land use and land cover change means changes in the areal extent – increases or decreases – of a given type of land use or land cover, respectively. It is important to note that the detection and measurement of change depends on the spatial scale: the higher the spatial level of detail, the larger the changes in the areal extent of land use and land cover which can be detected and recorded.

3. Methodology

The magnitude of land use and land cover change on the Bentota DSD area was explored within the selected time period. Assessment of these changes depended on the source, the definitions of land use types, the spatial groupings, and the data sets used. The description of land use change was documented in a matrix considering the changes in the areal extent and percentage value of each type of land use and the changes from one type of land use to another over a given time period. Changes in both the qualitative as well as the quantitative characteristics of land use are described by addressing the question of "why" these changes have occurred or, are occurring. The level of detail of this analysis on land use and land cover change in the Bentota DSD was conditioned by the availability of requisite digital data from 1983 to 2013. Arc GIS 10.3 software was used to show the spatial and temporal distribution of land use patterns of the area.

Mixed land use diversity of the area was examined calculating the entropy value for land use patterns of the area in 1983, 1996, 2001, 2008, and 2013. The entropy value was calculated by applying the following formula developed by Cervero & Kockelman (1997,p.210) to assess the similarity and diversity of land use types of the area used categorized as built-up areas, home garden, paddy, rubber, coconut, cinnamon, tea, other cultivation, land underutilization, scrub, forest, marshes, grasslands, mangroves, barren land, reservoir, sand, and rock area.

$$H = -1\left[\frac{\sum\left(P_j\right) * \ln\left(P_j\right)}{\ln(K)}\right]$$

Where H is the entropy value, K is the number of different types of land use in the area. P indicates the proportion of the total land area in the land use type and ln is natural logarithm

using e (approximately 2.718) as its basis. Entropy values range between 0 and 1, with 1 representing equal proportion of each land use type and 0 representing the presence of a single dominant land use.

4. Analysis

4.1 Details of the study Area

Geographically, the Bentota DSD is situated between north latitudes 6^0 $20^/$ - 6^0 $21^/$ and east longitudes 80^0 $9^/$ - 80^0 $9^/$. As an administrative boundary, Bentota is situated on the northern limit of the Southern Province, in the district of Galle 62km away from Colombo, at the confluence of the sea and the Bentota River. Bentota Divisional Secretariat Division is about 7379 hectares large and consists of inland reservoirs, a lagoon and a few islands. In terms of land area, 4.5% of Galle District belongs to the Bentota DSD. This area is placed tenth according to area among other divisional secretariat divisions of the Galle District. The highest point of this area is *Mahauragahakanda* and it is 236m high. Bentota DSD is part of the low country wet zone. The average highest temperature in Bentota is about 29ºC during the months of March and April and the average lowest temperature is about 26ºC during the months of June, July, and August with an annual mean temperature of 27.3ºC. The annual mean rainfall in the area is 3933mm ranging from 3096mm at the lowest to 4699mm at the highest. The mean total monthly rainfall in the Bentota River basin is 328mm.Bentota River basin has received the highest total monthly rainfall as 1069mm with effect of southwest monsoon during the month of May and with effect of second inter monsoon during the month of October in past.

Since the Bentota River is connected with the sea through the Bentota estuary, tidal effects cause salt water intrusion into the lands during the dry season of the year. In the early 1970s, salt water exclusion structures and drainage schemes were constructed in several places in the Dedduwa Lake attached to the Bentota River and canals to prevent salt water intrusion. In this background, all paddy lands in the area were cultivated during *Yala* and *Maha* seasons annually up to the 1980's using irrigated water and rain. Silva states that although in the early 1970s salt water exclusion structures and drainage schemes were constructed in several places in the Dedduwa Lake attached to the Bentota River and canals to prevent SWI, these schemes have not performed well, leading to a collapse and a strong demand for the rehabilitation at a huge cost (1977, p.690).At present, all these structures have collapsed or been destroyed and only a few signs of their existence remain at several places. Piyadasa &

Wijesundara show that 25 km upstream from the Bentota River mouth, severe salt water encroachment is indicated during dry periods in the months of January, February, July, and August every year and that this situation is further complicated since the river base is located below the sea level and river-sand mining activities are carried on at several places of the upper catchment area of the river (2013, p.68). Cultivated paddy lands are submerged by the floods for a long period annually during the rainy season in May and June mostly in the *Yala* season (Resource Profile, 2014, p.20).Because of these two natural phenomena, a very high risk is involved in paddy cultivation and more than half of the paddy lands have been abandoned and converted into marsh, scrub and grass lands.

5. Recent Land Use and Land Cover Change

The Bentota area is predominantly an agricultural land and during 1980'sthis area consisted of 2524 hectares of paddy land, 754hectares of rubber land, 478 hectares of coconut land, and 341 hectares of cinnamon land. In addition, 28% of land was used for home gardening and 20 hectares of land was utilized for residential purposes (Table 1 and Figure 1). The locational advantage of Bentota DSD attracts great number foreign tourists to the area and tourism activities in the area have been rapidly increasing. At present, the extent of land used for tourism and commercial activities has gone up to 57 hectares, mostly located along the coastal belt (Table 1 and Figure 2).

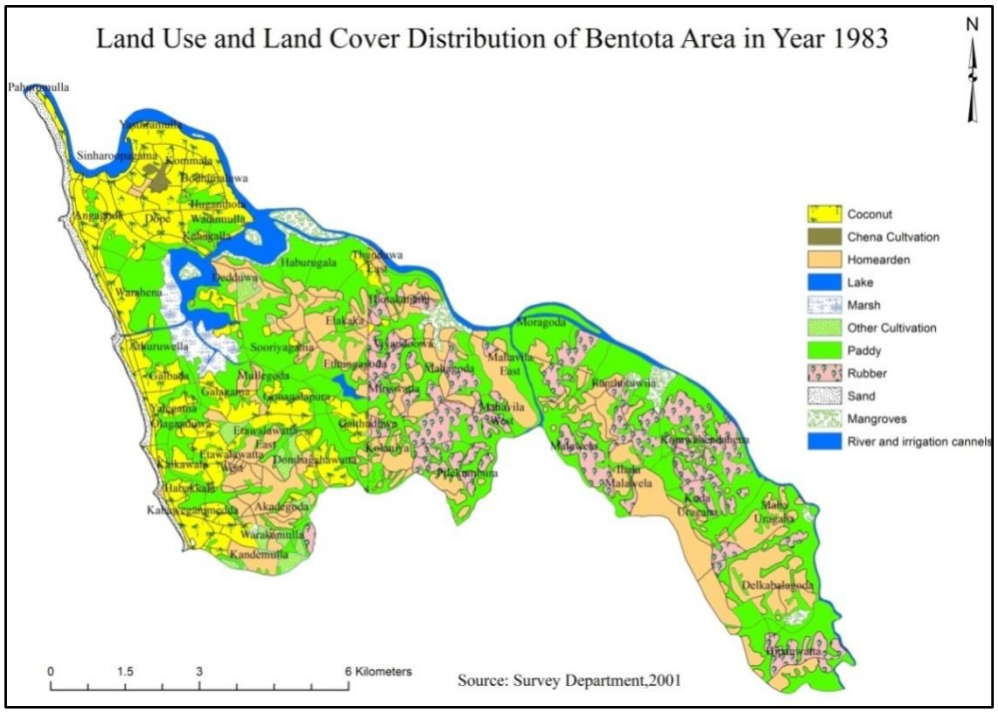
Table 1: Land use change from 1983-2013 in the Bentota area and entropy value calculation for land use types in 1983

Type of Land Use	1983				1996		2001		2008		2013	
	Ex.he	%	ln (P_j)	(P_j)*ln(P_j)	Ex.he	%	Ex.he	%	Ex.he	%	Ex.he	%
Built up areas	20	0.27	-5.920	-0.015	37	0.50	42	0.56	50	0.67	57	0.77
Home gardens	2098	28.16	-1.267	-0.356	2236	30.01	2139	28.71	2263	30.38	2360	31.68
Croft Garden	40	0.54	-5.227	-0.028	173	2.32	95	1.28	86	1.15	28.2	0.38
Paddy (Total)	2524	33.88	-1.082	-0.366	2131	28.60	1927	25.87	1645	22.08	1630	21.88
Paddy (Irrigated)					163	2.19	850	11.41	810	10.87	245	3.29
Paddy (rain fed)					786	10.55						
Paddy (Abandoned)					1182	15.87	1077	14.46	835	11.21	1385	18.59
Rubber (Total)	754	10.12	-2.290	-0.231	626	8.40	559	7.50	540	7.25	343.8	4.61
Rubber (good mgt)					18	0.24						

Rubber (moderate mgt)					524	7.03						
Rubber (inter cropping)					69	0.93						
Rubber (Abandoned)					15	0.20						
Coconut (Total)	478	6.42	-2.789	-0.171	420	5.6	390	5.23	394	5.29	347	4.66
Coconut (moderate mgt)					247	3.32						
Coconut (Poor mgt)					75	1.01						
Coconut (good mgt)					2	0.03						
Coconut (inter cropping)					59	0.79						
Coconut & animal husbandry					1	0.01						
Cinnamon	341	4.58	-3.144	-0.135	361	4.85	476	6.39	784	10.52	795	10.67
Tea	0	0.00		0.000	2	0.03	12	0.16	56	0.75	141	1.89
Other cultivation/ Chena	10	0.13	-6.613	-0.008	77	1.03	26	0.35	16	0.21	32	0.43
Land under utilization	80	1.07	-4.533	-0.048	105	1.41	75	1.01	65	0.87	40	0.67
Scrub	10	0.13	-5.514	-0.022	40	0.54	37	0.50	42	0.56	59	0.66
open forest	2	0.03	-8.222	-0.002	1	0.01	1	0.01	1	0.01	1	0.01
Conservation forest	3	0.04	-7.817	-0.003	3	0.04	3	0.04	3	0.04	2	0.03
Playground/ Cemetery	13	0.17	-6.351	-0.011	11	0.15	8	0.11	8	0.11	8	0.11
Grasslands	34	0.46	-4.927	-0.035	100	1.34	106	1.42	123	1.65	158	1.99
Mangroves	110	1.48	-4.215	-0.062	98	1.32	65	0.87	53	0.71	47	0.63
Marshes	170	2.28	-3.668	-0.093	288	3.87	312	4.19	668	8.97	807	10.70
Barren Land	60	0.81	-5.227	-0.028	38	0.51	32	0.43	30	0.40	8	0.38
Reservoirs/Lake	580	7.79	-2.552	-0.198	580	7.79	560	7.52	514	6.90	482	6.47
Sand	105	1.41	-4.262	-0.060	105	1.41	97	1.30	97	1.30	94	1.26
Rock area	18	0.24	-6.025	-0.014	18	0.24	12	0.16	12	0.16	10	0.13
Total	7450			-1.895	7450		7450		7450		7450	
Entropy Value			0.619		0.671		0.699		0.686		0.678	

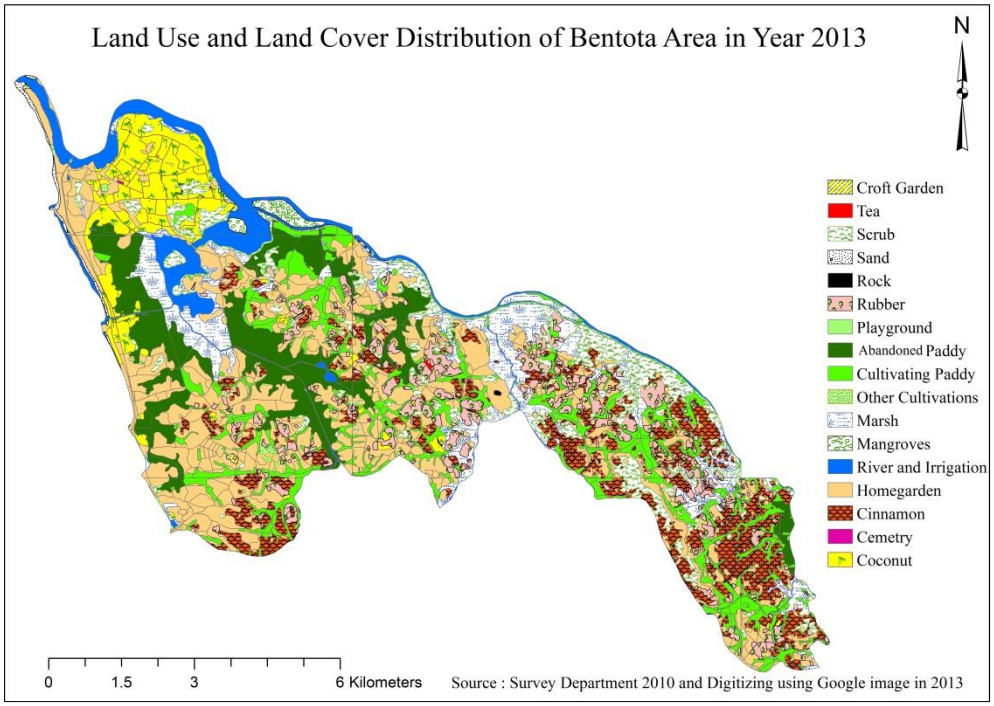
Source: Author constructed based on Survey Department data (1985,2010),Resource Profile,2014, Galle District Atlas 1996, Digitizing data 2013

Figure 1: Land use and land cover distribution of the Bentota area in year 1983



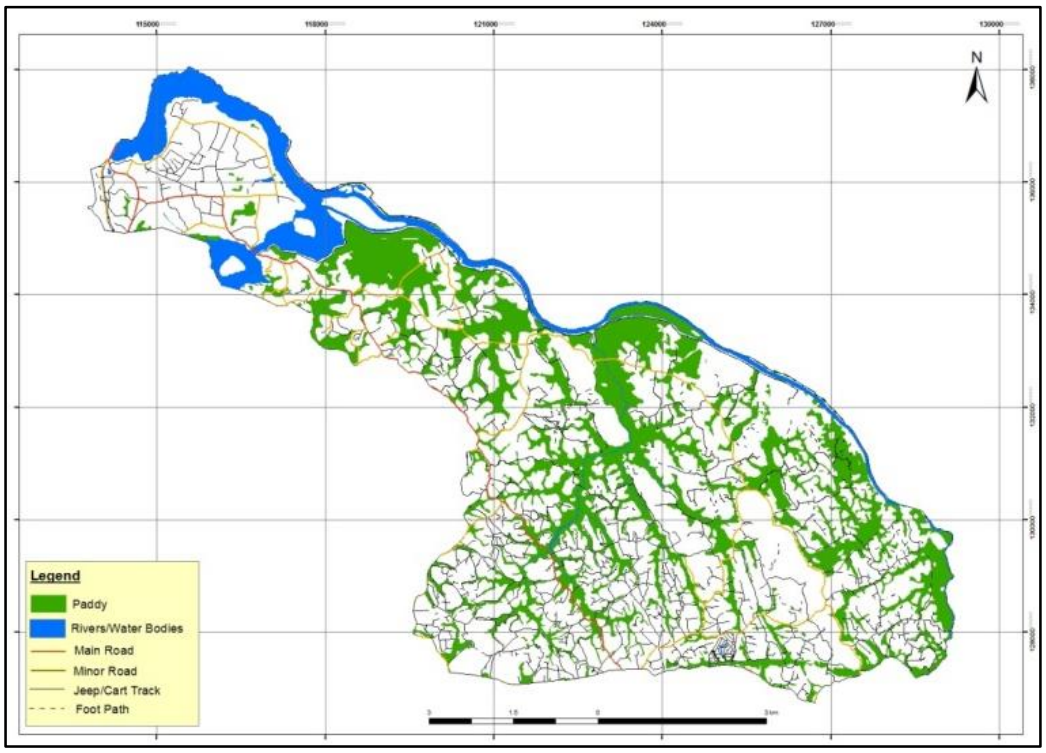
Source: Survey Department, 1985

Figure 2: Land use and land cover distribution of the Bentota area in year 2013



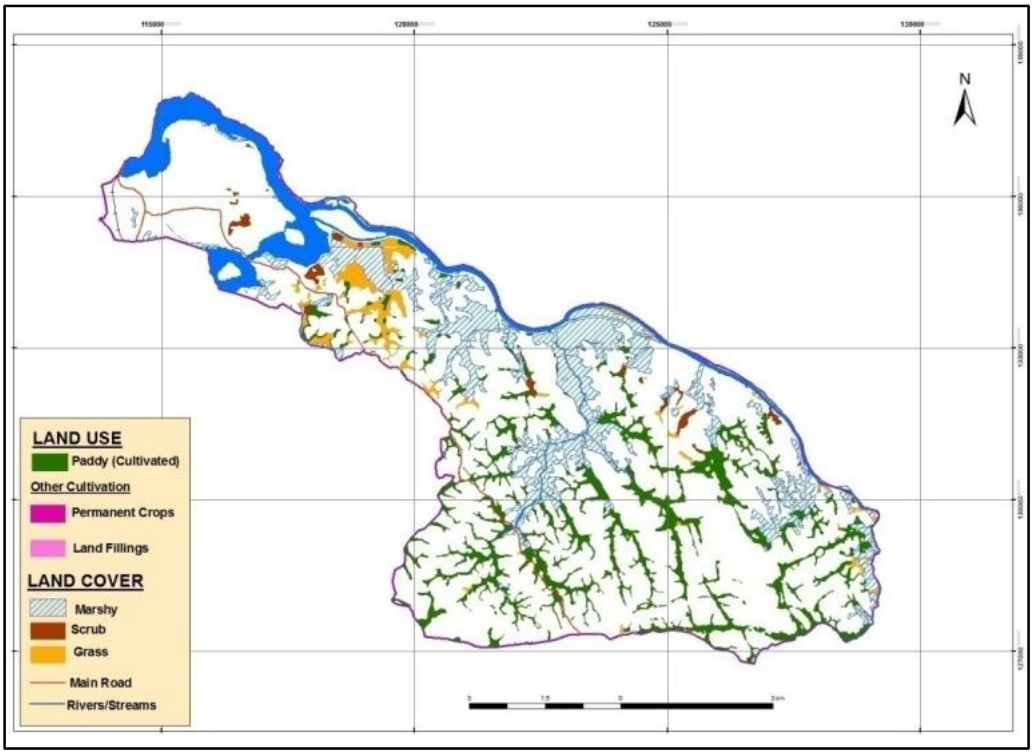
Source: Survey Department, (2010) and Digitizing Google data in 2013

Figure 3: Paddy land extent in part of the Bentota area from 1960-2005



Source: Land Use Office, Galle

Figure 4: Change of paddy land extent in part of the Bentota area in 2013



Source: Land Use Office, Galle

Table 2: Change of paddy land extent from 1983 to 2013 in the Bentota area

Change of Paddy Land (1983-2013)	Extent (ha)2013
Cultivated Paddy Lands in 2013	245
Abandoned Paddy Lands in 2013	1385
Converted to Permanent Crops	12
Converted to Land Fillings	5
Converted to Marshy	637
Converted to Grasslands	124
Converted to Scrub	49
Converted to croft and Chena	67
Total Paddy Land in 1983	2524

Source: Land Use Office, Galleand Digitizing land use data in 2013

This area involves a very high risk for paddy cultivation due to saline water intrusion during dry periods in January-February and July-August in most years and more than half of the paddy lands have been abandoned and converted into marsh, scrub and grasslands. Other than salt water intrusion, heavy floods occurring during May and October also pose a threat to paddy cultivation. According to Table 2, out of the 2524 hectares of paddy land cultivated in 1983, only 245 hectares have been cultivated during 2013. The other lands have been used for cultivating permanent crops, croft and *Chena* cultivations such as coconut, cinnamon, and fruits. Correspondingly, 637,124 and 49 hectares of abandoned paddy lands have been converted to marshy lands, grasslands and scrubs during last three decades. People have illegally filled and encroached around 5 hectares of paddy land in order to expand their home garden area. Table 1 clearly shows how the extent of paddy land has been reduced during 1996, 2001, 2008, and 2013 and how the paddy lands have been converted to other uses. This was further evidenced by the gradual increase of the land extent of marsh, scrub and grasslands from 1983 to 2013 (Table 1 and Figure 1 and 2). The Land Use Policy Planning Department, Galle, has conducted a study in 2013 to identify the change of the extent of paddy land in part of the Bentota area and Figure 3 and 4 also clearly highlight the conversion of paddy land into other land use and land cover.

The Bentota River is connected to sea through the Bentota estuary and consists of a few beautiful islands that had a thick coverage of Mangroves before the 1990s. However, this valuable environmental system has been reduced to a small area (47 hectares) due to many anthropogenic activities which have been taken place along the Bentota River and estuary. The rubber land of the area has been cleared to a half of its size in 1983 and converted into residential developments, cinnamon, and tea cultivations. Illegally, a few abandoned paddy lands have also been converted to cinnamon and tea cultivation land since cinnamon and tea cultivation has proven economically more beneficial to the community than rubber and paddy cultivation. A major part of the inland-land area has been utilized for cinnamon and tea cultivations, them being the most emerging crops in the area (Figure2).The area near the coast and estuary consists of coconut cultivations due to the desirable soil and climate conditions and around 111 hectares of coconut lands have been converted into residential, home garden and croft garden areas during the last three decades.

To identify the change of mixed land use diversity of the area during last three decades, the entropy value for land use pattern of the area in 1983, 1996, 2001, 2008, and 2013 was calculated considering the types of land use as built-up areas, home garden, paddy, rubber, coconut, cinnamon, tea, other cultivation, land underutilization, scrub, forest, mashes, grasslands, mangroves, barren land, reservoir, sand and rock area. Accordingly above formula was applied to calculate entropy value for each year and K was 21 since there are 21 types of land use in the area. Then the proportion of each land use type out of the total land area and its ln value was multiplied and divided by ln value of 21. Entropy value in year 1983 is comparatively lowest (0.619) and it evidenced that extent of total paddy lands was dominated in that year than the later years by comparing with other major land use extents. Entropy value in year 2001 is comparatively highest (0.699) and it reveals that more or less that there is equal proportion of each major land use type in the area. The level of mixed land use diversity of the area during 1996, 2008 and 2013 is similar since entropy values are correspondingly 0.61, 0.686 and 0.678 and it may be due to the conversion of some land use in to other making them also into major land use such as growth of tea, cinnamon and marsh land extent during those years and reduction of rubber, coconut, mangroves and paddy lands.

6. Conclusion

Recent land use and land cover change of Bentota area was examined as analytical endeavor as a first step towards development of land use optimization model for the area. The area is predominantly based on Agriculture and currently more than 80% of paddy lands in of Bentota area have been abundant and converted in to Marshes, Grasslands and Scrubs. Tea and Cinnamon are the emerging crops while reducing Rubber and coconut lands in the area. The level of mixed land use diversity of the area during last three decades is similar, but major land use types have been changed time to time being more or less equal proportions of each. Proposed Dedduwa Lake tourism development project by the Government of Sri Lanka will utilize 1,800 hectares of abundant paddy lands and marshes lies 15 Grama Niladari Divisions. The Conceptual Plan has identified tourism activities such as, boating, fishing, bird watching, cycling, camping, golf, nature or village walks, agro-tourism and water sports. The proposed tourism facilities include, water bungalows, chalets, floating rooms, camping tents, observation tower or decks, cinnamon museum, amusement park, floating restaurants, Āyurvedic spa and souvenir shops. Once this project is completed, the whole coastal area between Bentota and Balapitiya will become one large tourist development and the future land use activities of the area will be rapidly changed and will consist with more water retention areas, commercial, recreational and tourism activities.

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