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MAPPING AND ANALYSIS OF LAND COVER/ LAND USE CHANGE IN VAVUNIYA DS DIVISION OF VAVUNIYA DISTRICT, SRI LANKA

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Abstract

The land use and land cover features in Vavuniya Ds Division of Vavuniya District are rapidly changed due to anthropogenic activities. The main objectives of this study are to map out the land cover distribution and to estimate the land use/land covers changes and their transformation of land use features using Landsat TM images for the period of 1997 to 2017. The land use and land cover are classified as forest, cropland & human habitation, fallow land, built-up area, water, and bare land. It shows that the larger areas are converted into other land use in the period of 20 years. The change detection matrix depicts that the total area of 630.72km² in different land cover features periodically transformed from one type of land use to another one or more types of land use. Population pressure, demand for urban-land and, agricultural expansion were the major driving forces behind the land use/cover change in the Vavuniya DS division. The expansion of the built-up area is directly linked to population growth which indirectly creates severe threats to the forest resources. The land use and land cover statistics from supervised classification showed that cropland & human habitation, water and bare land declined from 234.56km² (37%) to 157.16 km² (25%), 18.66 km² (3%) to 7.55 km² (1%) and 12.14 km² (2%) to 6.97 km² (1%) respectively. Whereas, fallow land, forest and built-up area increased from 93.64 km² (15%) to 122.81 km² (19%), 247.10 km² (39%) to 294.91 km² (47%) and 26.30 km² (4%) to 41.69 km² (7%) respectively. The Land cover change detection process produced relatively accurate information with overall accuracies of 93.33% and 90.83% and Kappa coefficients of 0.9200 and 0.0.8900 in 1997 and 2017 respectively. Therefore, it was assumed to have performed adequately for the purpose of detecting changes in land cover extent in Vavuniya DS Division of Vavuniya District, Sri Lanka. 120 samples were selected for ground truth verification of classified land cover and land use features. Overlay of the classified map of 1997 and 2017 shows land use/ land cover changed from 1997 to 2017 remarkably.

Key words: Land use, human habitation, land cover anthoropognic activities.

Introduction

In recent times, monitoring the changing pattern of land use and land cover has been improved using remote sensing data. The extent and patter of changes in land cover and land use over a period of time can be measured more accurately with the help of remote sensing data (Cornforth, Fatoyinbo, Freemantle, & Pettorelli, 2013). Satellite data have become an important source of land use change detection due to its repetitive coverage at short intervals (Luque, 2000). Today, anthropogenic activities directly alter the land use and land covers (35). General information about land use change is necessary for updating land covers map. The change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (multi-temporal variations) (Singh, 1989). Change detection can be done precisely as GIS technology has a high volume of special data handling capacity. In addition, GIS technology helps us to do the overlay process with multilayers. Hence the main objectives of this study are to map out the land cover distribution and to estimate the land use changes and their transformation of land use features using Landsat TM images for the period of 1997 to 2017.

Literature review

The primary reasons for degradation of forest cover are population pressure, the practice of agricultural methods, and lack of awareness about the land use and forest cover. Changes in Land use/Land cover are defined broadly to include the conversion of forested lands into croplands and pastures, the abandonment of agricultural lands, deforestation, reforestation, afforestation, and urban sprawl (Drummond & Loveland, 2010). Assessment of the land use/land cover in any terrain should be taken into account the following essential factors such as the rate of depletion, the reason for the deterioration and remedial measures to restore. Assessment of land use and land cover change is not an easy task. It takes time to perform the assessment. It can be made easier only through Geographical information system and Remote Sensing techniques. Change detection and monitoring activities can be performed effectively by utilizing remote sensing technology (Yismaw, 2014). The major four aspects of change detection are detecting the changes, identifying the nature of change, measuring the aerial extent of change and assessing the spatial pattern of change. Those aspects will be considered in remote sensing as well (Mcleod & Conglton, 1998).

Land use/land cover monitoring using conventional method is labor intensive, insufficient, time-consuming and done infrequently. More recently, remote sensing data become the foremost data source for change detection studies because of its temporal resolution, synoptic view, and digital format. Working with satellite data produced more accurate assessment than doing in the traditional method (Fonji & Taff, 2014). Digital data obtained from satellite permits advanced computer analysis, classification and compatible with GIS (Treitz, Howarth, & Gong, 1992). In response to increasing rate of land use and land cover change, most developing countries apply remote sensing data for change detection and monitoring at the national and regional level.

High-resolution imageries (Quick Bird, IRS etc.) should be used to detect land use change and produce a map with high accuracy. However, high-resolution imageries are costly. Hence, lower cost imageries (Landsat TM, ETM+, etc.) have been used to monitor land use/land cover change with the acceptable level of accuracy.

Over the past couple of decades, many types of research applied to satellite images to detect land use and land cover change. For instance, (Unni, Roy, & Parthtasarathy, 1985), (Luque, 2000), (Imbernon & Branthomme, 2001), (Young & Wang, 2001), (Karia, Porwal, Roy, & Sandhya, 2001), (Boyd, Foody, & Ripple, 2002), (Larsson, 2002), (Roy & Joshi, 2010), (Reis & Yomralioglu, 2006), (Panigrahy, Kale, Dutta, Mishra, & Banerjee, 2010), (Sakthivel et al., 2010), (Forkuo & Frimpong, 2012), (Yismaw, Gedif, Addisu, & Zewudu, 2014), (Kayet & Pathak, 2015), (Sajjad et al., 2015), (Sadeghi, Malekian, & Khodakarami, 2017), (Mihai, Săvulescu, Rujoiu-Mare, & Nistor, 2017). The basic principle of change detection through remote sensing is that the changes in spectral signatures commensurate with the change in land use and land cover. The temporal impacts can be measured through the process of change detection (O'Callaghan, 2012). Change detection can be done precisely as GIS technology has a high volume of special data handling capacity. In addition, GIS technology helps us to do the overlay process with multilayers.

Study area

The study was conducted in the Vavuniya DS Division, Vavuniya District, Sri Lanka. Geographically study area lies within 80 40' 00" to 90 00' 00" Latitude and 800 15; 00" To 800 40' 00" Longitude (figure 1). The altitude of the study area is 104 meter above sea level. The total population of the area is117153 persons and the population density is about 199/km2 (Department of Census and Statistics, 2012). The area consists of different types of land use and land cover. The study area was selected as a representative site of the entire Vavuniya District. The selection of this study area is strongly related to the variety of natural environment and land use and land cover types.

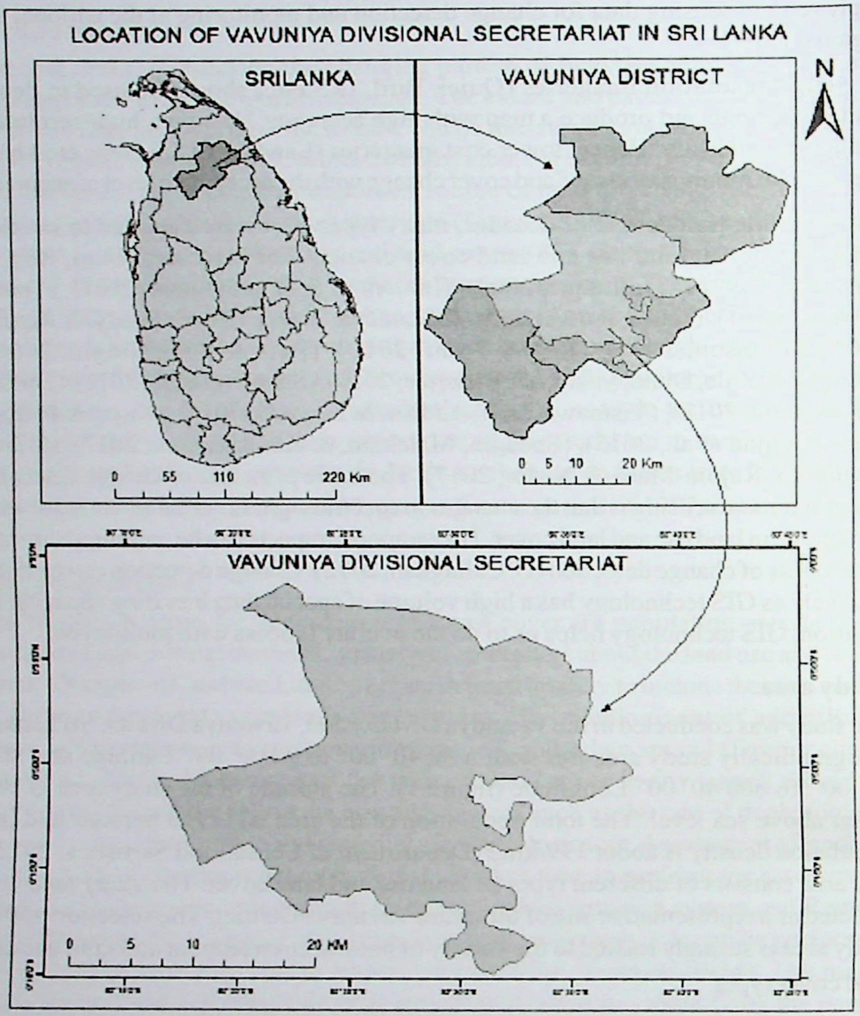


Figure 1: Map of the Study Area

Methodology

For change detection over a period of time, it is essential to have temporal satellite imageries of the same time period and same season. Landsat 5 and Landsat 8 Satellite images of two time periods acquisition date of 5th December 1997 with 7 bands and 17th December 2017 with 11 bands with the general resolution of 30 m were downloaded from United States of Geological Survey website. In addition, 1:50000 topographic maps were used for accuracy assessment of the images and geometric correction. A field survey was conducted for selecting control points. ERDAS

Imagine 15 and ArcGIS 10.3.1 were used for image processing and land cover change detection. Image processing techniques were applied to make the images for a visual explanation of land covers. These included geometric correction, radiometric correction, resampling images and clipping of the images. Both unsupervised and supervised image classification techniques were applied. An unsupervised classification was done before fieldwork. For the supervised image classification training areas were established based on the ground truth taken during fieldwork. Among different algorithms, in the supervised classification, maximum likelihood classification was utilized. Socio-economic surveys (with 50 questionnaires) and field observation were also used to determine the cause these land use/cover dynamics.

After the image classification, land use and land cover change were detected by identifying land cover types by using ERDAS Images 15 and ArcGIS 10.3.1. With the help of visual interpretation of satellite images, four types of land covers are identified such as vegetation cover, settlement and Agricultural area, bare land and water body. Descriptions of each land cover are as follows.

Table 1: Details of Land use/Land cover classification

Land use/Land cover types	Details
Forest	It represents natural and fragmented forest cover areas including small trees, bushes, shrubs, small size plant species with fewer crowns.
Cropland & Human habitation	The land that is covered with agricultural activities with scattered human settlements
Bare Land	The area with bare ground and degraded grassland
Waterbody	The Land completely occupied with water
Fallow land	The land used for farming but that is left with no crops for a season
Built-up area	The area covered by houses or other buildings

Multi-temporal data sets have been used to differentiate areas of land cover change between the dates of selected satellite images. The change detection technique that we used must be able to identify where and how much change has occurred. Further, the change detection matrix has been prepared to observe the trends and patterns of land cover change within the particular period. Kappa statistic was prepared for the different areas that were classified.

Table 2: Geospatial data used for change detection analysis of land use and land cover in Vavuniya Divisional Secretariat (in 1997 and 2017)

Datasets	Landsat scene ID	Scale/ Resolution (m)	Year	Data Source
Landsat 5 TM	LT51410541997022BKT01	30 m	1997	US Geological Survey, Earth Explorer
Landsat 8 TM	LC81410542017109LGN00	30 m	2017	US Geological Survey, Earth Explorer

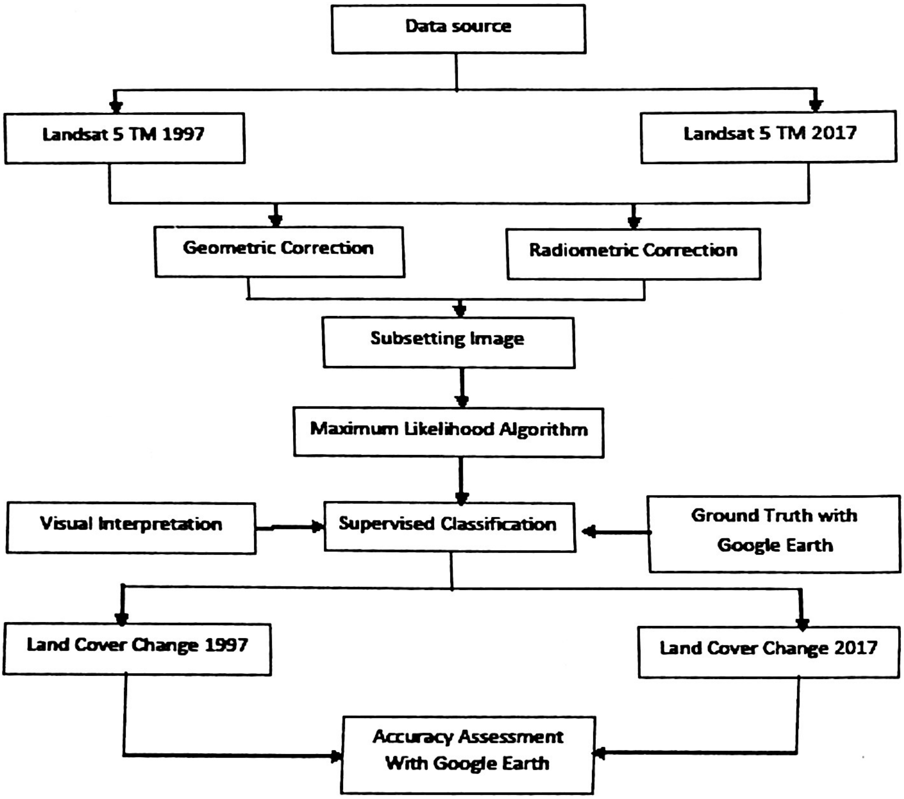


Figure 2: Flowchart of a methodology for land use/ land covers change

Results and discussion

The land use/ land cover map of Vavuniya DS Division of years 1997 and 2017 is presented in figure 3. The overall classification accuracy for the year 1997 and 2017 were 93.33% and 90.83% and overall kappa statistics were 0.9200 and 0.8900 respectively (Tables 3, 4, 5, and 6). The land use/ land cover classification results for 1997 and 2017 are summarized in Table 7 which shows percentage of classes of the land cover/land use practices observed in Vavuniya DS Division during 1997 and 2017.

Table 3: Accuracy Totals for Land use/land cover classification 1997

Accuracy Totals for Land use/land cover classification 1997					
Class Name	**Reference total**	**Classified Total**	**Number correct**	**Producer accuracy**	**User accuracy**
BARE LAND	19	20	18	94.74%	90.00%
WATER	20	20	20	100.00%	100.00%
FALLOW LAND	23	20	19	82.61%	95.00%
CROP LAND & HUMAN HABITATION	20	20	18	90.00%	90.00%
FOREST	20	20	19	95.00%	95.00%
BUILT-UP AREA	18	20	18	100.00%	90.00%
Overall Classification accuracy = 93.33%					

Table 4: Accuracy Totals for Land use/land cover classification 2017

Accuracy Totals for Land use/land cover classification 2017					
Class Name	**Reference total**	**Classified Total**	**Number correct**	**Producer accuracy**	**User accuracy**
BARE LAND	19	20	17	94.44%	85.00%
WATER	20	20	20	100.00%	100.00%
FALLOW LAND	23	20	17	89.47%	85.00%
CROP LAND & HUMAN HABITATION	20	20	18	78.26%	90.00%
FOREST	20	20	19	95.00%	95.00%
BUILT-UP AREA	18	20	18	90.00%	90.00%
Overall Classification accuracy = 90.83%					

Table 5: Kappa Statistics for 1997

Kappa Statistics for 1997	
Overall kappa Statistics = 0.9200	
Conditional Kappa for Each Category	
Class Name	**Kappa**
BARE LAND	0.8812
WATER	1.0000
FALLOW LAND	0.9381
HUMAN HABITATION	0.8800
FOREST	0.9400
BUILTUP AREA	0.8824

Table 6: Kappa Statistics for 2017

Kappa Statistics for 2017	
Overall kappa Statistics = 0.8900	
Conditional Kappa for Each Category	
Class Name	**Kappa**
BARE LAND	0.8235
WATER	1.0000
FALLOW LAND	0.8218
HUMAN HABITATION	0.8763
FOREST	0.9400
BUILTUP AREA	0.8800

Change detection method was employed in order to detect land use changes between 1997 and 2017. The rate of land use and land cover change is presented in table 7. There has been marked land use/land cover change during the period of 20 years based on the comparison of each class of 1997 and 2017.

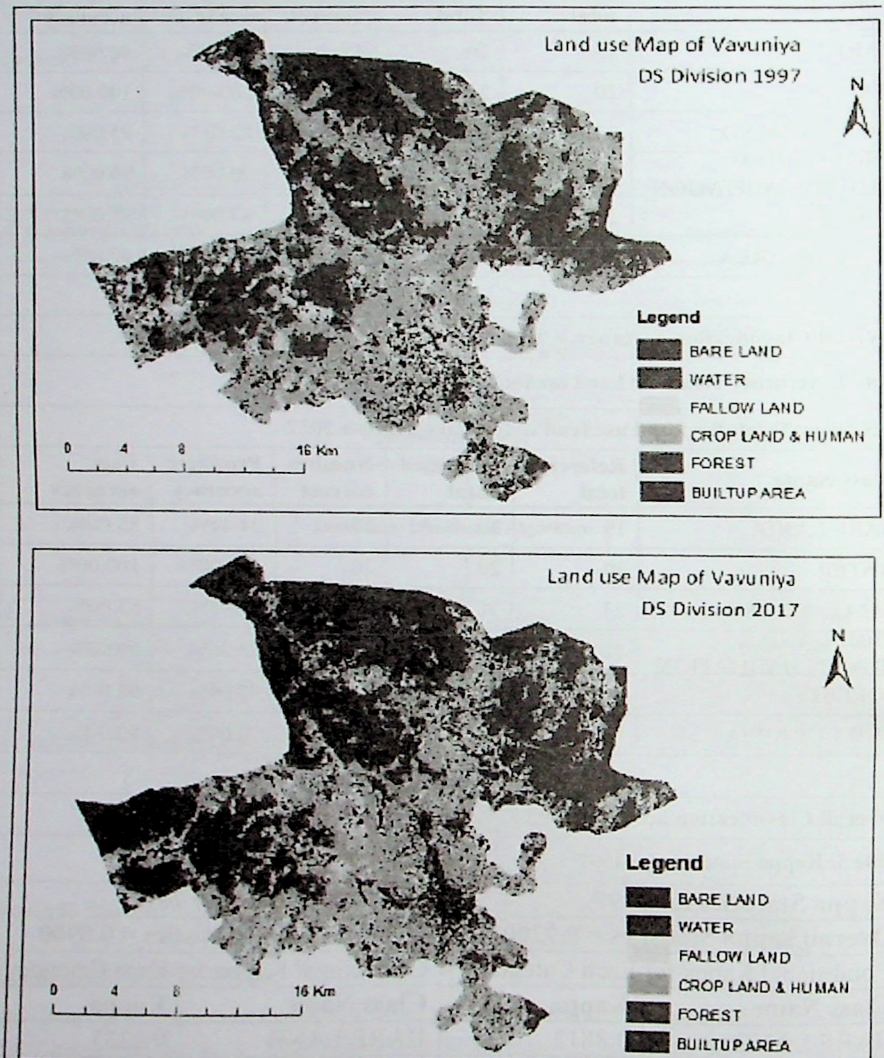


Figure 3: Land use/ Land cover classification of Vavuniya DS Division in 1997 and 2017

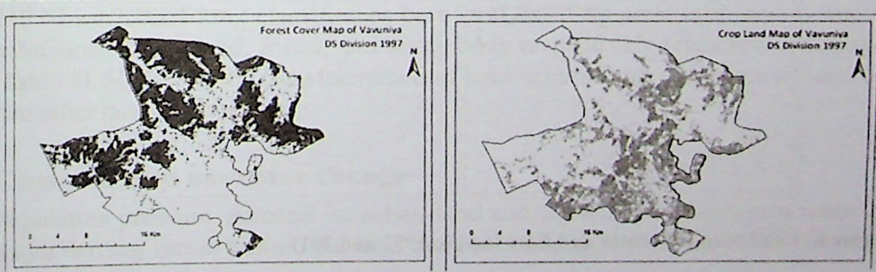
The land uses of the study area were classified into classes of the forest, crop and human habitation, fallow land, bare land, water, and built-up area. The statistics of land cover change were computed and summarized to the nature of changes based on 1997 and 2017. The dominant land use and land cover in 1997 is a forest that takes 247.10km2 of the total area, cropland & human habitation covers 234.56km2, fallow land covers 93.64 km2, built-up area covers 26.30 km2, water body and bare land cover 18.65 km2, 12.14 km2 respectively. In 2017, forest land takes the highest share of land use and land cover which covers 294.91 km2, followed by cropland & human habitation which accounts 157.16 km2, fallow land 122.18 km2, built-up area 41.69 km2, water body 7.54 km2 and bare land 6.97 km2 which covers the minimum area of coverage (Figure 3 and Table 7).

Based on 1997 land use classes, about 39% was accounted for forest land whereas cropland and human habitation cover 37% and fallow land shared 15% and built-up area shared 4% and water and bare land shared 3% and 2% respectively of the total area of the Vavuniya DS division. In 2017, forest land, fallow land, and built-up area increased in area l coverage by 8%, 5%, 2% respectively. However, cropland & human habitation, water body and bare land which are likely to change into other forms of land use became reduced as compared to the 1997 and 2017 land use classes.

Table 7: Rate of Land use/Land cover change

Land use/Land Cover	1997	%	2017	%	Change	Change %
BARE LAND	12.14336	2%	6.970809	1%	5.172554	1%
WATER	18.65891	3%	7.549509	1%	11.1094	2%
FALLOW LAND	93.64995	15%	122.8133	19%	-29.1633	-5%
CROP LAND & HUMAN HABITATION	234.5624	37%	157.1623	25%	77.40006	12%
FOREST	247.1083	39%	294.9144	47%	-47.8061	-8%
BUILTUP AREA	26.30093	4%	41.69672	7%	-15.3958	-2%
	632.4238	100%	631.1071	100%		

Two Landsat satellite TM images of 1997 and 2017 were used to compute and monitor the areal extent and rate of land use/land cover change between 1997 and 2017. Digital image interpretation was performed for each year to compute total area of land use and its percentage for each land use types were calculated and summarized. Land use/land cover map of the total area of 1997 and 2017 is presented in table 7.



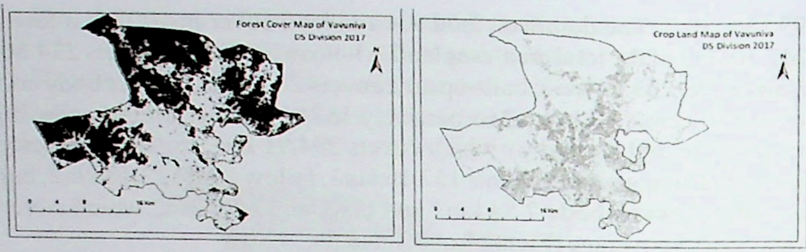


Figure 4: Land used for forest and Cropland & Human habitation in 1997 and 2017

Figure 5: Land used for Fallow land and Built-up area in 1997 and 2017

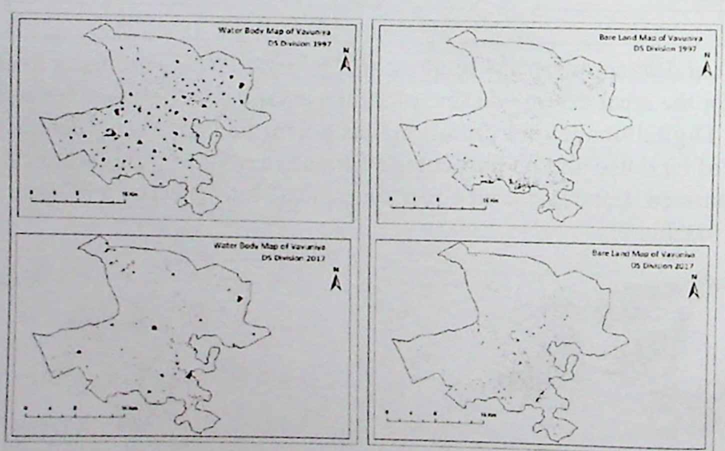


Figure 6: Land used for Water and Bare land in 1997 and 2017

The land use and land cover statistics from supervised classification showed that cropland & human habitation, water and bare land declined from 234.56km2 (37%) to 157.16 km2 (25%), 18.66 km2 (3%) to 7.55 km2 (1%) and 12.14 km2 (2%) to 6.97 km2 (1%) respectively. Whereas, fallow land, forest and built-up area increased from 93.64 km2 (15%) to 122.81 km2 (19%), 247.10 km2 (39%) to 294.91 km2 (47%) and 26.30 km2 (4%) to 41.69 km2 (7%) respectively (Table 7).

Table 8: Matrix of Land use / Land cover change between 1997 and 2017

Land use in 1997 \ Land use in 2017	BARE LAND	BUILTUP AREA	CROP LAND & HUMAN HABITATION	FALLOW LAND	FOREST	WATER	Grand Total
BARE LAND	0.275892	1.713262	4.207373	4.675936	1.14158	0.100069	12.114112
BUILTUP AREA	1.057838	3.678567	12.33167	8.039053	1.114875	0.035578	26.257584
CROP LAND & HUMAN HABITATION	3.136669	14.3471	101.802	63.9961	49.29327	1.304663	233.879752
FALLOW LAND	1.045898	14.90362	18.73977	26.84714	29.72194	2.181952	93.44032
FOREST	0.506109	3.926798	17.12237	13.86643	210.0794	0.876783	246.377924
WATER	0.946209	3.10732	2.879184	5.309606	3.357802	3.048525	18.648646
Grand Total	6.968615	41.67666	157.0823	122.7343	294.7089	7.54757	630.718338

Change matrix for 1997 and 2017 is analyzed to understand the major land cover change source. Change matrix has been produced based on satellite image classification and given in table 8. The matrix table explains the actual distribution of each land cover/ land use that has experienced transformation from one type to another or being lost areal extend or remained unchanged.

The amount of land use changed into other land use type obtained from other land use type. For example, 1.05km2 of built-up area, 3.13 km2 of cropland & human habitation, 1.04 km2 of fallow land, 0.5 km2 of forest land and 0.94 km2 of water body were converted to bare land. While the highlighted diagonal values stand for the unchanged land use/land cover that maintained its original land cover/land use unit (Table 8).

The type and amount of conversion in the land use/land cover from 1997 to 2017 showed that the land with area of 0.27km2, 3.67 km2, 101.80 km2, 26.84 km2, 210.07 km2, 3.04 km2 classified as bare land, built-up area, cropland & human habitation, fallow land, forest, and water body respectively remained unchanged (Table 8). However, the transformation of land occurs form one types of land use into other land use types.

Causes of land use/cover change

Population pressure, demand for urban-land and, agricultural expansion were the major driving forces behind the land use/cover change in Vavuniya DS division.

Change in population size, distribution and associated demographic characteristics are the most important factors affecting land use distribution and change in Vavuniya DS division. Accordingly, 71% of the respondents reported that population growth and increasing land scarcity in the urban area are the factor of the first order of importance of land use change. Fast population growth during the internal civil war in the northern part of Sri Lanka and the consequent high pressure on land are expected to have an adverse effect on the existing urban area. Substantial increase in demand for food has resulted in an expansion of croplands by encroaching on uncultivated areas including forest, shrub and bare land. This has resulted in deforestation and soil degradation. The area under human habitation and settlement land showed significant increase in the Vavuniya DS division over the 20 year period (1997–2017). A significant number of respondents (61 %) also indicated that the expansion of human habitation and settlement were the main driving force of the land use/cover dynamics in the study area.

Conclusion

It is concluded based on the result obtained from the study that the land use/land covers in the study area have altered significantly in 20 years. The decline in the area of bare land, water, and cropland & human habitation (1%, 2% and 12% respectively) and expansion of the area covered by the fallow land (5%), forest (8%) and built-up area (2%) clearly showed a shift in the land use / land cover in the study area. The water quality and accessibility will be adversely affected due to the alterations in the land cover and land use pattern. The expansion of fallow land and the built-up area may be responsible for the loss of water bodies in the study area. Hence, proper management systems and plans for reserving water should be implemented.

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