
FOREST COVER ASSESSMENT IN SRI LANKA

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Summary

In the changing landscape it is important to understand the spatial distribution of forest cover of Sri Lanka and its changes over time. Periodic assessments of forest cover have been carried out since 1956. This study completed in 2010, estimated and mapped forest cover of Sri Lanka by visual interpretation and subsequent on screen digitizing of IRS satellite images. It estimated forest cover of Sri Lanka as 1.95 million ha including dense forests, open forests and savannah forests. Majority of the forests is confined to the Northern part of Sri Lanka while forest area in Central Highlands and South Western part of Sri Lanka is limited. Forest loss was observed in the districts of dry zone while forests in the wet zone remained constant.

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INTRODUCTION

Knowledge on forest cover and its spatial distribution is essential in making decisions on sustainable forest management, biodiversity conservation and watershed management. In the pace of rapid development after conflicts in Northern and Eastern Provinces, striking the balance between development and environmental protection has a paramount importance. In order to make informed decisions with regard to the protection of vital ecosystems in Sri Lanka, updated information on natural resource base needs to be generated. For this purpose periodic assessment of forest cover is carried out by the Forest Department. The latest assessment was conducted in 2010 after 11 years of the previous assessment.

This assessment was done with the main objective of estimating the forest cover and its spatial distribution. Detection of the changes in the forest cover was another objective of this study.

METHODS AND MATERIALS

IRS satellite images were used as primary source of data for this assessment since spectral, spatial and temporal resolution of the images are quite adequate to assess the vegetation cover of the country. IRS images used for this assessment had four spectral bands with spatial resolution of 23.5 m. Forest cover classification was done by visual image interpretation and

subsequent on-screen digitizing in ArcGIS. Polygons that were drawn by on-screen digitizing were labeled with an appropriate cover class. They were further verified by ground observations and comparison with ancillary data such as Google images and ground surveyed forest maps. Elevation and rainfall data were used in the classification of forests into different forest types.

Image acquisition and processing

Image acquisition

Ten cloud free IRS images with four spectral bands, acquired during 2008 and 2009 covering the whole country were used for this assessment. Four spectral bands were green, red, near infrared and short wave infrared.

Geometric correction

Staked images were geo-referenced using the projection parameters indicated in table 1 to make all images and other data compatible to the Sri Lankan geo-reference format. Ground control points were selected from scanned topographical maps of 1:50,000 scale for georeferencing. Transformation and re-sampling was done in this process. In order to match an image with another image or map, a higher order transformation such as projective or polynomial may be required (Janssen *et al.*, 2004). Therefore, polynomial transformation was used in this study. Since the raster data are stored in regular rows and columns, the cells of the new

Table 1 : Geo Reference and Projection Parameters for Sri Lanka

Parameter	Value
Projection type	Transverse Mercator
Datum	Kandawala
Spheroid Name	Everest 1830
Scale Factor	0.9999238418
Longitude of Central Meridian	80:46:18:16700
Latitude of Origin	07:00:01:69750
False Easting	200,000m
False Northing	200,000m

image need to be re sampled to re-establish a regular grid. The nearest neighbor resampling method does not change the original cell value (DN value of the pixel) of the image. Therefore, all spectral information is retained, which means that the resampled image is still useful for image classification (Janssen *et al.*, 2004). Therefore, Nearest neighbor resampling was done.

Image Interpretation and Classification

All ten images were subjected to visual image interpretation and subsequent onscreen digitizing in order to prepare forest cover maps. Terrain, vegetation and shadows in Sri Lankan conditions result misclassification of vegetation in unsupervised or supervised image classification. Therefore, visual image interpretation was used in this assessment for better accuracy though it is laborious a process. This section describes the methods used in image classification.

Image Interpretation

Each IRS image was opened in ArcGIS in the false colour composite. Homogeneous areas were identified in the image observing image characteristics such as colour, texture, pattern, size, shape and location. Polygons of homogeneous areas were drawn in ArcGIS using onscreen digitizing technique. These polygons were used as interpretation units. An identification number was assigned to each polygon (interpretation unit). Image characteristics of the polygon were recorded in a matrix along with the polygon identification number to develop the primary legend. All interpretation units were transferred to 1:50,000 topographical maps to ease the field observation. Interpretation team visited pre-decided interpretation units and recorded land cover of each interpretation unit and obtained the exact coordinates of the location using GPS along with a photograph of the place. This information was

included in the primary legend. Multimedia GIS file was created to make link between map information (image characteristics and location) and cover information (cover type and photograph of the site).

Cover Classes

Based on image characteristics and field observations main land cover classes were identified. They were water; built up areas, grass, shrubs, dense forests, open forests, savannah forests, mangroves, marshes, forest plantations, rubber, tea, paddy and home gardens.

Preparation of Primary Cover Maps

Information generated in the primary legend along with field observations and image characteristics were used to interpret cover classes described in table 2. Definitions for these cover classes are similar to FAO definitions with few exceptions (FAO, 2001). These interpreted cover classes were marked as polygons using on screen digitizing technique in ArcGIS. This was done for the land area covered by each 1:50,000 topographical map sheet separately. At the end of this exercise 92 primary cover maps were created covering whole Sri Lanka. Each polygon of the primary cover map was labelled with the forest cover class and polygon identification number. Non forest cover classes such as built up areas, water bodies, homesteads, tea plantations, rubber plantations and coconut plantations were not mapped.

Field Verification

Primary cover maps were overlaid on 1:50,000 topographical map sheets and hard copies were created. These hard copies were sent to District Forest Officers for field checking. The shape of the polygon and assigned cover class were changed by the field staff to suit the actual ground condition. After field verification these maps were sent back to the interpretation team. They further reviewed the changes made by field staff using ancillary data such as Google images, existing survey maps and 1988 topographical map sheets along with processed satellite image. After reviewing, the interpretation team altered the primary cover maps considering acceptable suggestions proposed by field staff. This was done for 92 digitized files separately.

Preparation of District and National Forest Cover Maps

Cover maps for each district were prepared by merging field verified cover maps and subsequent clipping by district boundary. Forest cover map of Sri Lanka was prepared by merging all district cover maps together.

Table 2 : Definition of Forest Cover Classes

Cover class	Description
Dense Forest	Land spanning more than 5 hectares and the tree canopy cover is more than 40 percent. It does not include lands that are predominantly under agricultural or urban land use. Excludes tree stands in agricultural production systems, such as fruit tree plantations, oil palm plantations and agroforestry systems when crops are grown under tree cover and rubber plantations from forest category.
Open Forest	Land spanning more than 5 hectares and the tree canopy cover is between 10 to 40 percent. It excludes all land use classes which are mentioned under dense forest category.
Shrub	Refer to vegetation type where the dominant woody elements are shrubs i.e. woody perennial plants.
Grassland	Lands covered with grass
Mangroves	Mangrove forests
Forest Plantation	Man made forests such as pines, teak, eucalyptus, excluding naturalized forest plantations with native plant species.
Savannah	Areas of scattered trees in grasslands.
Marshes	Marsh lands

Table 3 : Forest Categories Interpreted from satellite imagery and derived by GIS techniques.

Forest Category	Criteria
Lowland rain forest	Dense forests located in areas below 1000m elevation with rainfall greater than 2500 mm
Moist Monsoon Forest	Dense forests located in areas below 1000m elevation with rainfall between 1900 mm and 2500 mm
Dry Monsoon Forest	Dense forests located in areas below 1000m elevation with rainfall below 1900 mm.
Montane Forest	Dense forests located in areas above 1500m elevation.
Sub montane forest	Dense forests located in areas where the elevation between 1000m and 1500 m.
Tropical Savannah	Open savannah type of forest with scattered trees in grasslands
Forest Plantation	Man made forests such as Pines, Teak, Eucalyptus, Exclude naturalized forests plantations with native plant species.
Mangroves	Mangrove forests located in coastal areas
Riverine Forest	Rich vegetation associated with river banks in dry and inter mediate zones.

Identification of Forest Types

Dense forest consists of different forest types such as lowland rain forests, dry monsoon forests, montane forests, sub montane forests and moist monsoon forests. The species composition and structure of the forest vary with the forest type. However, those variations cannot be identified merely by the image characteristics. Previous studies have identified, rainfall and elevation as the main determinants of forming forest types. Koelmeyer (1957) classified forests of Sri Lanka considering rainfall and elevation along with species composition and structure. Therefore, this study used elevation and rainfall categories of Koelmeyer's classification to identify forest types. Even though this approach could not use information such as species composition and structure, it turns out fairly good representation of

distribution of forest types of Sri Lanka. Forest categories identified using GIS techniques are given in table 3.

RESULTS

Forest Cover Statistics

The total natural forest cover of Sri Lanka is estimated as 1,951,473 ha out of which only 1,438,275 ha are dense forests (Table 4). The spatial distribution of forests in Sri Lanka is shown in figure 1. It shows that majority of the forests are confined to the northern part of the country.

Table 4 shows that forest cover is about 30% of the total land area of the country. In addition to these forests, there are around 343,000 ha of shrubs and grasslands which accounts to 5.3% of the land area. District wise distribution of forests is given in table 5.

Table 4 : Estimated extents of forests by cover classes

Cover Class	Extent (ha)	Percentage
Dense Forest	1,438,275	21.9
Open and Sparse Forest	429,484	6.5
Mangrove Forest	15,670	0.2
Savannah	68,044	1.0
Total for Natural Forests	1,951,473	29.7
Marshes	3,254	0.1
Shrubs and Grasslands	342,934	5.3

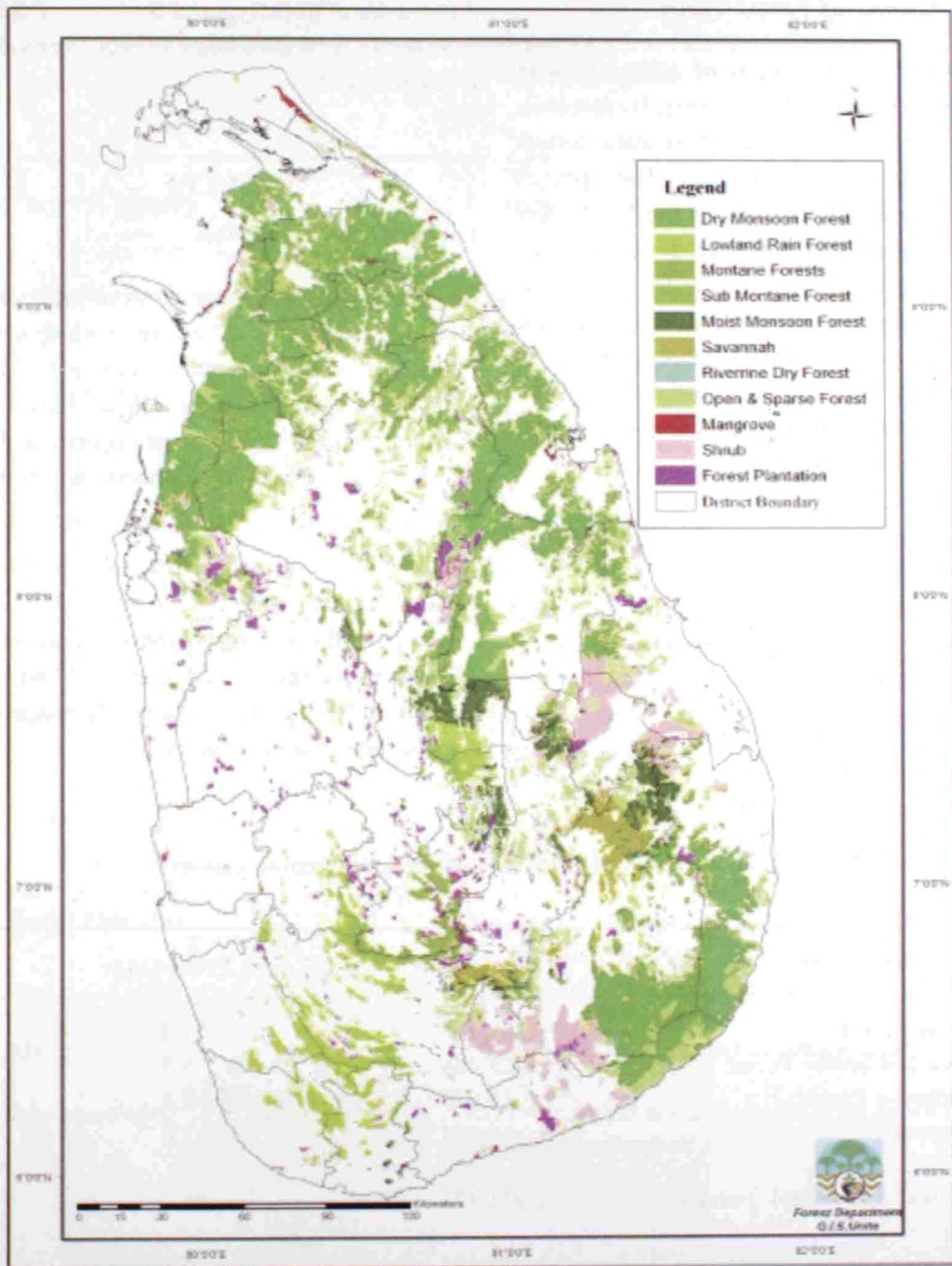


Figure 1 : Forest Types of Sri Lanka

Table 5 : Estimated extents of forest cover classes by district in ha

District	Total Area of the District *	Dense Forest	Open and sparse forests	Mangrove	Savannah	Total Forests	% of of the District
Ampara	441,500	115,782	31,744	618	2,965	151,109	34.2
Anuradhapura	717,900	173,387	85,006			258,393	36.0
Badulla	286,100	24,522	28,086		16,240	68,848	24.1
Batticaloa	285,400	23,436	24,960	2,071		50,467	17.7
Colombo	69,900	1,736	276			2,012	2.9
Galle	165,200	19,466	1,438	406		21,310	12.9
Gampaha	138,700	340	1,257	634		2,231	1.6
Hambanthota	260,900	32,290	24,912	692		57,894	22.2
Jaffna	102,500	1,383	959	2,505		4,847	4.7
Kalutara	159,800	15,752	1,760	75		17,587	11.0
Kandy	194,000	28,022	9,413			37,435	19.3
Kegalle	169,300	12,872	2,576			15,448	9.1
Kilinochchi	127,900	31,292	4,883	1,885		38,060	29.8
Kurunegala	481,600	7,873	13,845			21,718	4.5
Mannar	199,600	106,958	17,799	1,351		126,108	63.2
Matale	199,300	60,711	11,797			72,508	36.4
Matara	128,300	19,259	696	39		19,994	15.6
Moneragala	563,900	141,329	37,828		45,535	224,692	39.8
Mullativu	261,700	155,403	14,978	1,041		171,422	65.5
Nuwara eliya	174,100	40,026	5,722			45,748	26.3
Polonnaruwa	329,300	97,491	37,310			134,801	40.9
Puttalam	307,200	58,283	23,937	1,958		84,178	27.4
Ratnapura	327,500	58,317	13,548		3,304	75,169	23.0
Trincomalee	272,700	107,960	16,319	2,395		126,674	46.5
Vavuniya	196,700	104,385	18,435			122,820	62.4
Total	6,561,000	1,438,275	429,484	15,670	68,044	1,951,473	29.7

* Source : Department of Census and Statistics

Distribution of forest types shows that 123,000 ha of well developed lowland rain forests are found in western and southern part of the country and dry monsoon forests are found in the northern part. Table 6 shows the extent of forest by forest types.

Changes in Forest Cover

The previous National Forest Cover Assessment was done in 1999 using Landsat Thematic Mapper (TM) images using similar kind of interpretation techniques. Accurate assessment of changes in forest cover depends on the accuracy and definitions of cover classes in two estimates. Change in forest cover can be measured by comparing statistics at district and

national level. This comparison is done using the cover maps produced in 1999 and 2010.

There are two main differences in cover class identification in 1999 and 2010. Savannah forests were not identified as a separate cover class in 1999. However, around 16,000 ha of savannah forests had been identified as open and sparse forests in 1999. Shrubs, which had not been identified in 1999, were identified in 2010 as a separate cover class.

Area under dense forests and open forests excluding mangroves were 1,932,700 ha in 1999 and the extent of the same cover classes in 2010 was estimated as 1,867,760 ha. Even though the forest area difference between 1999 and 2010 is 64,940 ha it does not represent the actual extent of forest loss during the period.

Table 6: Extent of forests by forest types

Forest Type	Extent-ha	Percentage
Lowland Rain Forests	123,302	1.9
Moist Monsoon Forests	117,885	1.8
Dry Monsoon Forests	1,121,392	17.1
Montane Forests	44,758	0.7
Sub Montane Forests	28,513	0.4
Riverine Dry Forests	2,425	0.0
Mangrove Forests	15,670	0.2
Savannah Forests	68,044	1.0
Open and Sparse Forests	429,484	6.5
Total	1,951,473	29.7

The actual loss of forest is 48,940 ha as 16,000 ha of savannah forests have been identified as open forests in 1999. Based on these estimates the annual rate of forest loss (dense forests and open forests) from 1999 to 2010 is 0.23 % of the forest area. Mangrove forests were excluded in this calculation, since some of the mangrove forest areas in northern and eastern parts of Sri Lanka have not been mapped in 1999 due to inaccessibility during this period.

GIS criteria used for the separation of montane and submontane forests were changed in 2010 based on Koelmeyer (1957) classification. Forests located above 1500 m were classified as montane forests in this classification whereby forests located above 2000 m were classified as montane forests in 1999 and in 1992 (Legg & Jwell (1995). Due to this change 45,000 ha forests have been identified as montane forests in 2010 while it was 3100 ha in 1999. Similarly the extent of sub montane forest in 2010 classification was 28,500 ha while the extent of this category is 65,800 ha in 1999 classification. However, total extent of the montane and sub montane forests have not been significantly changed during the two assessments.

The changes in forest area vary in districts. The largest loss in total forest cover has occurred in Monaragala, Hambantota, Ampara, Anuradhapura, Batticaloa and Puttalam Districts. Some districts, conversely, shows slight increases in forest cover. Notable decrease in forest cover has occurred in Dry Zone where slash and burn cultivation is practiced and large scale development programs are implemented.

Natural regeneration over last 10 year period was observed in some districts due to enhanced protection of natural forests. One example is the forest cover increase in Victoria-Randenigala-Rantambe sanctuary due to improved protection.

Commission and omission errors in image interpretation

Visual image interpretation was the main tool used in forest cover classification. Even with available technology, it is difficult to avoid misclassification altogether. Unlike the temperate countries, Sri Lanka harbours many vegetation types including agroforestry systems, home gardens, tea and rubber. Even though these lands are rich with trees, they are not classified as forests. In this situation there is a possibility to misclassify home gardens and tree rich agricultural lands bordering natural forest areas as natural forests. On the other hand isolated forest patches located closer to tree rich home gardens and agricultural lands may have been misclassified as non forests. Despite extensive field verification carried out to avoid these misclassifications, some commission and omission errors can still exist.

CONCLUSIONS

According to the forest cover estimates there are 1.95 Million ha of forests in Sri Lanka and majority of these forests are located in dry zone. According to forest cover estimates of 1999 and 2010 the estimated annual change of forest cover is around 0.23%.The forest cover reduction is observed in the dry zone and intermediate zone while forest cover in the wet zone remains constant.

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