Remote Sensing and GIS for assessment of land use change and deforestation in Sri Lanka

K.U.H. Prasadi Thilanka Senadeera

NOVA Information Management School
Universidade NOVA de Lisboa, Campus de Campolide, 1070-312, Lisboa, Portugal
Tel.: + 94712617955
m20190645@novaims.unl.pt; Prasadisenadeera1991@gmail.com

Abstract

Being a small Island of 65610 sq. km, Sri Lanka faces a major issue with the scarcity of land for its ever-growing population and for its recent developments. These unprecedented developments and growing human population ultimately caused forest cover loss for the country. When in view of the current situation of Sri Lanka, sudden change of weather patterns around the country has leads to frequent natural disasters such as thundershowers, landslides, and heavy winds. Deforestation can be identified as one of the major human factors leading to natural ecosystem imbalances that cause various types of disasters around the world. Therefore, timely and accurate data on forest cover change within the country is essential to improve forest management in order to preserve the natural ecosystem in the country. Recent studies show that Earth Observation (EO) data and GIS technology offers new opportunities for fast, reliable and accurate deforestation detection at smaller scales with robust and continuous data with large area coverage and repetitive observations. This study examined the potential use of remote sensing and GIS to assess and monitor changes in forest cover in Sri Lanka. Each of these methods has advantages and disadvantages, but moderately they all help to assess and monitor deforestation over time.The scope reviewed in the study confirms the severity of deforestation in Sri Lanka, and there were three areas identified as prone to the above problems: Wilpattu National Park, located on the north eastern border, the western border of the Kanneliya Forest Reserve and the other in the centre of the island are a bit north. East of the Knuckles Conservation Forest also it is confirming that, the rate of deforestation in Sri Lanka has increased over the past few years

Keywords: Forest cover, Deforestation, Deforestation rate, Remote Sensing, GIS, Sri Lanka.

1 Introduction

1.1 Forest

The forest is peculiar organism of unlimited kindness and benevolence that makes no demands for its sustenance and extends generously that produce of life activity; it affords protection to all beings, offering shade even to the axe man who destroy it. ~Gautama Buddha~

Forests provide several ecologically, economically and social perspective functions to life viz., water supplies, soil conservation, nutrient cycling, species and genetic diversity and greenhouse gases regulation (Chineke, 2011) Forest is not just a combination of several trees. It is a complex ecosystem composed mainly of trees that buffer the earth and support countless life forms. Trees help create a special environment that affects the types of animals and plants that can exist in the forest. The tree is an important component of the environment. They clean the air, cool on hot days, save heat at night, and serve as an excellent sound absorber. The importance of forests cannot be underestimated. We rely on the forest for our survival, from the breathing air to the foods we eat. Forests play a major role in maintaining environmental balance on the earth. They have a prominent role in global carbon cycle, exchanging large fluxes of carbon with the atmosphere through the processes of photosynthesis, respiration and decomposition (P. Senadeera,2018).

1.2 Deforestation

Deforestation is the conversion of forested areas to non-forest land use such as arable land, urban use logged area or wasteland. According to World Food and Agriculture Organization (FAO), deforestation is the conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10% threshold (GIRI TEJASWI, 2007). Deforestation and forest degradation are the biggest threats to forests worldwide (IUCN). The 15^{th} United Nations' Sustainable Development Goal mentions that at the current time, 13 million hectares of forests are being lost every year and even though up to 15% of land is currently under protection, biodiversity is still at risk. The reasons behind this phenomenon are various, from timber trade to providing new lands for agriculture and farming as well as for the exploitation of natural resources by the opening of new mines. Moreover, natural disasters such as fire forests, floods, pathogens and parasites, as well as climate change and wars, have an impact on the current situation of forests worldwide.

The strength and importance of forests lies in the services and goods that they provide to both humans and nature. Over 80% of the world's terrestrial biodiversity can be found in forests; the degradation and loss of forests threatens the survival of many species and reduce their ability to provide essential services such as clean air and water, healthy soils for agriculture, and climate regulation (FAO). Other than its role on biodiversity, healthy forests take part to sustainable livelihoods of the world's poorest communities and have a crucial role in climate change adaptation efforts (IUCN). UN 15^{th} Sustainable Development Goal states that by protecting forests, we will also be able to strengthen natural resource management and increase land productivity. Moreover, the United Nations are not the only ones setting goals in terms of forest protection: the SDGs, together with Aichi Biodiversity Targets, Paris Climate Change Agreement, Land Degradation Neutrality (LDN) and many others, are all aimed to lead the planet towards a sustainable development.

1.3 Sri Lanka

The Democratic Socialist Republic of Sri Lanka is an island nation with a total land area of 65,610 km^2, located in the Indian Ocean just off the southeastern tip of India. The country got independent from the British in 1948 after a long history of colonial rule (Lindström, 2011). Sri Lanka is one of 25 biodiversity hotspots in the world. Although the country is relatively small, it has the highest biodiversity density in Asia (R. Mittermeir,2000).

1.4 Forest cover, Deforestation and Consequences of Deforestation in Sri Lanka

About 400 years ago Sri Lanka was almost entirely covered by tropical forests; some figures estimate that the forest cover was as high as 90 percent of the total land surface and there were eight national categories of natural forest defined according to the elevation and rainfall (Kariyawasam & Rajapakse, 2014) However, for decades, forests have been cleared both legally and illegally for various purposes.

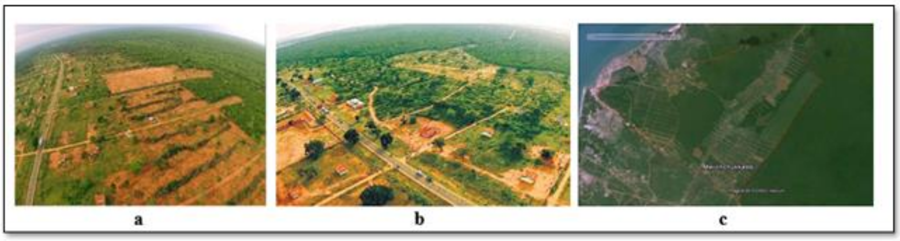

Figure 1. Aerial photos of deforested areas in Sri Lanka. Source: News1st (media organization).

From ancient times, between the 16^{th} and 20^{th} centuries, the country was governed by Dutch, Portages, and English, began deforestation process to plant commercial agriculture such as tea, coffee and rubber. Then, after independence in 1948, deforestation was again carried out for settlement purposes, timber production, economic purposes, agricultural activities, and mainly because of weak implementation of land use policies.

Because of this false environmental practices, sudden changes in national weather patterns lead to frequent natural disasters such as thunderstorms, landslides, and strong winds. According to the Disaster Management Centre (DMC) of Sri Lanka, total affected population by all disasters is approximately 2.7 million including 154 deaths in the year of 2019 in addition to much loss of infrastructure and housing. Even at this moment (31.10.2019), early landslide warnings occupy in the country. Deforestation can be identified as one of the major human factors leading to natural ecosystem imbalances that cause various types of disasters around the world. Therefore, in order to design the meaningful conservation strategies, comprehensive information and current status of forest cover/forest types on the basis species composition as well as information of changes in forest cover with time, is required (Chineke, 2011). Recent studies show that Earth Observation (EO) data and GIS technology offers new opportunities for fast, reliable and accurate deforestation detection at smaller scales with robust and continuous data with large area coverage and repetitive observations. The most cost effective and accurate way of keeping a check on land use change is by remote sensing and GIS technology (Sharma, 2012).

1.5 Importance of Geospatial technologies (GST) in Forest Studies

The Global Positioning Systems (GPS), Remote Sensing and Geographic Information Systems (GIS) are commonly referred to as the three sciences and technologies often applied in a geographical information project. Geospatial technology can be applied to almost every field of engineering, natural sciences, and social sciences, providing an accurate, efficient, and reproducible way to collect, display, and analyze spatial data. In particularly, it provides opportunities to assess and monitor deforestation using spatial data. These three sciences are working in a variety of ways to make a successful geographic information project.

Remote sensing involves measuring or acquiring information about surface properties using sensors typically found onboard aircraft or satellites (Chineke, 2011). Remote sensing provides a systematic, synoptic view of earth cover at regular time intervals and useful for changes in land cover and to revels aspect of biological diversity directly. Satellite image classification change detection analysis (Armenteras et al., 2004) and econometric modelling are extensively used to identify the rates and drivers of deforestation in global hotspots of biodiversity and tropical ecosystems.

A geographic information system (GIS) is a computerized information system that collects data, stores it, processes it and helps with the analysis and visualization of the results (Lindström, 2011). GIS combines spatial data (maps, aerial photographs, satellite images) with other quantitative, qualitative and descriptive information databases, making it easy to analyze spatial connections. Using GIS in a research project should not be seen as a methodology by itself, but rather as a tool to use in combination with other methods to enhance and emphasize the results.

GPS is a satellite and ground-based radio navigation and locational system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The GPS has been found very useful in gathering all-weather locale-specific information (Kushwaha, 2005). In forestry, GPS helps determine the geographic coordinates of various forest features and helps map forest areas through field-based approaches. It can also be used significantly to verify the accuracy of geographic information projects using ground truth collection and mapping.

In the field of deforestation, GST offers several applications such as:

- Time series analysis of deforestation
- Forest cover mapping
- Analyses of land cover and land use changes
- Estimation of deforestation rates and forest fragmentation rates

- Examination of the spatial correlation of forest loss and the socioeconomic drivers of land use change
- Modeling of deforestation
- Analysis of the consequences of land cover and land use change in the form of climate change and change in distribution biodiversity
- Biomass estimation
- Gap analysis of effectiveness of the protected area network in conserving areas of importance for biodiversity conservation (Sharma, 2012).

The purpose of this study is to investigate the applications of remote sensing and GIS technology focused to study of deforestation and its impacts in Sri Lanka as well as to understand the methodologies behind those studies.

2 Forest cover mapping

Forest cover mapping provides a static depiction of land cover. It does not on its own indicate changes within forest area. However, forest cover maps fulfil several functions in monitoring changes in forest cover (Chineke, 2011). The need for information on the extent of forest cover is essential as a baseline for monitoring future changes and for planning and managing the forest resources (N. JEWELL and C.A. LEGG, 1993) The mapping of forests for their status is of increasing importance (Sudhakar Reddy, Manaswini, Jha, Diwakar, & Dadhwal, 2017)

Land cover classes of Sri Lanka was mapped by N. JEWELL and C.A. LEGG in 1993 using Landsat thematic mapper (TM) imageries. They were able to classify images into a total of nine classes, including natural and plantation types (Table 1). The procedure consists of several steps, such as download free Landsat TM cloud free images and IRS-1 images for which cloud free TM images were not available, Geometric correction of images to convert to Sri Lankan National Grid (SLD99) using ground control points, Display colour composition on a high-resolution colour monitor and finally, on screen digitizing along the forest boundaries by visual interpretation.

Table 1. Nine categories of natural and planted forest types.

Natural Forest classes	Plantation classes
Closed canopy natural forest	Conifers
	Eucalyptus
Spare	Teak
Dry Zone riverine forest	Mahogany
Mangroves	
Montane forest	

As the next step in the study, researchers were able to generate a forest cover map for each district by overlaying the district boundaries with digitized forest cover. The extracted area statistics were then compared with the same information collected from previous forest surveys to obtain deforestation rates. The results showed that deforestation rates are increasing in some areas.

Consequently, in year 2016, C. Sudhakar Reddy, G. Manaswini, C. S. Jha, P. G. Diwakar and V. K. Dadhwal used satellite remote sensing and GIS techniques to generate a nation-wide database on forests, forest types and land use/land cover of Sri Lanka based on hybrid classification technique and spatial grid cell analysis. In hybrid classification technique, conjunctive use of visual interpretation, Normalized Difference Vegetation Index and unsupervised classification were used in view of phenological variations and topography to be incorporated in terms of context, association and texture to delineate different land cover classes (Sudhakar Reddy et al., 2017). The resulted map displayed seven land use/landcover classes such as Forest, Grass land, Plantations, Agriculture, Wetland, Barren land and Settlements.

3 Forest cover change detection

Remote Sensing and GIS can assess and monitor two broad categories of forest cover changes: categorical vs. continuous (GIRI TEJASWI, 2007). There are two main approaches to assessing this categorical and continuous forest cover change. Here, the wall-to-wall mapping method focuses on mapping the entire earth, and the sampling strategy specifies the portion of the entire region of interest that needs to be analysed, and the results for the whole is derived from the samples. The map of the main areas of forest-cover changes is based on three types of data sources: expert opinion gathered through formal procedure (NRCS, 2001), remote sensing-based products and national statistics (FAO, 2001). Most of these data directly measure deforestation and forest degradation [4]. Change detection methods can be grouped into seven categories: (1) algebra, (2) transformation, (3) classification, (4) advanced models, (5) Geographical Information System (GIS) approaches, (6) visual analysis, and (7) other approaches (GIRI TEJASWI, 2007)

Dilanjani H.U.K. and Ranagalage M.M used GIS and remote sensing to investigate changes in forest cover in Minneriya National Park from 2000 to 2014 and found that the forest area has decreased from 42 square kilometers to 36.5 square kilo meters over the past 14 years (H.U.K. & M.M., 2017).

K.U.J. Sandamali and D.R. Welikanna sought to identify and analyse forest cover and its changes in Wilpattu National Park, where deforestation has grown to a critical level. This study showed how to extract surface features using vegetation indices (Normalize Difference Vegetation Index (NDVI), Normalize Difference Water Index (NDWI) Green Normalize Difference Vegetation Index (GNDVI)) to detect changes over time (K.U.J. Sandamali, 2018). This study shows that reforestation is taking place in the national park, and there is deforestation near the border.

4 Rate of Deforestation

“Tropical moist forests, which are estimated to contain over half of the global biodiversity, are being destroyed at an alarming rate (Chineke, 2011).” Understanding dynamic for forest loss is critical for the management and maintenance of biodiversity time (K.U.J. Sandamali, 2018) Forest loss can be measured using spatial analysis (Reddy, Jha, & Dadhwal, 2013) Understanding the rate of change in deforestation is important not only for estimate the amount of loss, but also for predicting the future. It also provides important insights for biodiversity management and maintenance. These dynamic rates of change are usually calculated by comparing the forest cover area of the same region at two different times. According to FAO, the annual rate of forest cover change is derived from the compound interest formula in which the rate of forest change is calculated using the following formula:

$$r = \frac{1}{(t_1 - t_2)} * \ln \frac{a_2}{a_1} \qquad (1)$$

where,

r is the annual rate of change (percentage per year),

a_1 and a_2 are the forest cover estimates at time t_1 and t_2 respectively.

The annual rate of deforestation is also calculated according to Menon and Bawa

$$\frac{1}{t_2 - t_1} * \frac{a_2 - a_1}{a_2} \qquad (2)$$

where,

r is the annual rate of change (percentage per year),

a_1 and a_2 are the forest cover estimates at time t_1 and t_2 respectively

It is known in various terms such as “Deforestation rate”, “Annual deforestation (%)”, “Annual change rate” (K.U.J. Sandamali, 2018).

Two studies are concerned about estimating the rate of deforestation in Sri Lanka using the above compound interest formula. K.U.J Sandamali discovered that during the subsequent decline in the forest area of Wilpattu National Park, the annual deforestation rate was -0.17% and the deforestation area was

203.72 hectares / year. And (Sudhakar Reddy et al., 2017) also another study found national annual deforestation rates in four different periods from 1976 to 2014, with the highest deforestation rate of 0.45% observed in the 1976-1994 period.

5 Modeling of deforestation

Simulation of future land use/cover maps helps to assess the impact of land use/cover change in a global environment. Modelling deforestation is an economic issue, as it deals with human activities producing land use changes, as well as an object of interest for geographers, dealing with spatial organization of the territory, or environmental scientists, concerned about the human impact on ecosystems (Dez, 2015) It also has political implications as well as historical aspects that can be identified as long-term causes of deforestation. Economic models of deforestation fall into categories based on the scale (household, subnational or national) and on the methodology used (analytical, simulation or regression models). However, these classifications are general and the choice of model relevant to the study must be consistent with the scale and the objective of the project indeed (D. & A., 1998). K.U.J. Sandamali 2018 used Markov Chain analysis to model the deforestation at Wilpattu National Park, Sri Lanka in 2050 was able to identify a significant change with more deforestation along the western boundary of the study area.

6 Conclusion

In the present scenario deforestation is a global issue with many implications and hence constraint in resources leads to exploitation of biological diversity and thereby fulfilment of necessitate, large forest area is being encroached by populace, resultant in the loss of overall environmental conditions including soil quality degradation, surface run off, siltation of river(Chineke, 2011). The literature and case studies presented in this study demonstrate the potential of remote sensing techniques for monitoring land cover to improve our understanding of the spatial and temporal dynamics of forest cover, and the ability to monitor large areas more frequently from the satellite-based observations rather than conventional methods which could consume more time and labour cost. Also, the study addresses the use of GIS to handle and make decisions about the data spatial data. Most case studies were based on classification, digitization, change detection methods (subtraction, correlation, ratio) and visual interpretation. However, each of these methods has advantages and disadvantages and is more or less important depending on the data being analysed, since classifications methods gives more reliable results only when there is sufficient amount of field data is available, the results obtained from digitizing depend entirely on the uncertainty of human elements, the quality and scale of the printed map or image used for digitization, and of course the smallest mappable unit. In time series analysis, multi-image analysis is performed in most situations. registration of one image to another may change due to slight changes in orbit or sensor platforms. which can adversely affect the results. The scope reviewed in the study confirms the severity of deforestation in Sri Lanka, and there were three areas identified as prone to the above problems: Wilpattu National Park, located on the north eastern border, the western border of the Kanneliya Forest Reserve and the other in the centre of the island are a bit north. East of the Knuckles Conservation Forest.

7 Acknowledgements

“True guidance is like a small torch in a dark forest it doesn’t show everything once. But gives enough light for the next step to be safe.” Swami Vivekananda

My deepest sense of gratitude is expressed to professor Marco Painho for his positive encouragement.

8 References

Chineke, U. K. O. W. C. C. O. N. (2011). Monitoring forest cover changes using Remote Sensing and GIS: A Global prospective. *Reseach Journal of Environmental Sciences*, *5*, 105–123. https://doi.org/10.3923/rjes.2015.332.341

D., K., & A., A. (1998). Economic models of tropical deforestation: a review. In *Economic models of tropical deforestation: a review*. https://doi.org/10.17528/cifor/000341

Dez, C. (2015). *Study Report Methodological Approach for Modelling Deforestation in the*. (September).

Food and Agriculture Organization of the United Nations, *accessed 16.11.2019*, *http://www.fao.org/home/en/*

GIRI TEJASWI. (2007). *MANUAL ON DEFORESTATION, DEGRADATION, AND FRAGMENTATION USING REMOTE SENSING AND GIS PREPARED*.

H.U.K., D., & M.M., R. (2017). Spatial and Temporal Changes of Forest Cover in Minneriya National Park Using GIS and Remote Sensing. *Proceedings of International Forestry and Environment Symposium*, *21*(0). https://doi.org/10.31357/fesympo.v21i0.3234

K.U.J.Sandamali, D. R. W. (2018). Deforestation or Reforestation, A Time Series Remote Sensing Perspective of Wilpattu National Park, Sri Lanka. *Journal of Applied Mathematics and Computation*, *2*(10), 473–482. https://doi.org/10.26855/jamc.2018.10.003

Kariyawasam, R., & Rajapakse, C. (2014). Impact of Development on deforestation in Sri Lanka: An analytical study. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *8*(7), 35–39. https://doi.org/10.9790/2402-08723539

Kushwaha, S. P. S. (2005). Geospatial technology for forest resources management. *International Journal of Ecology and Environmental Sciences*, *31*(1), 9–20.

Lindström, S. (2011). *Tropical deforestation in Sri Lanka*. UNIVERSITY OF GOTHENBURG.

N.JEWELL and C.A. LEGG. (1993). A remote sensing / GIS database for forest management and monitoring in Sri Lanka. *ESRI User Conference for South East Asia*, (September), 13–15.

Reddy, C. S., Jha, C. S., & Dadhwal, V. K. (2013). Assessment and monitoring of long-term forest cover changes in Odisha, India using remote sensing and GIS. *Environmental Monitoring and Assessment*, *185*(5), 4399–4415. https://doi.org/10.1007/s10661-012-2877-5

Russell Mittermeier, Norman Myers and Cristina Mittermeier, 2000, *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. Arlington, Virginia: Conservation International. ISBN 978-968-6397-58-1*.

Sudhakar Reddy, C., Manaswini, G., Jha, C. S., Diwakar, P. G., & Dadhwal, V. K. (2017). Development of National Database on Long-term Deforestation in Sri Lanka. *Journal of the Indian Society of Remote Sensing*, *45*(5), 825–836. https://doi.org/10.1007/s12524-016-0636-8

Sustainable Development Goals, accessed 17.11.2019, https://sustainabledevelopment.un.org/?menu=1300

Sharma, S. (2012). *Remote Sensing and GIS for assessment of land use change and deforestation in India*. (December). Retrieved from http://www.globalchange.umich.edu/

The International Union for Conservation of Nature, accessed 14.12.2019, https://www.iucn.org/