APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

What Drives Deforestation? A Case of Deforestation Drivers in Sri Lanka

Manuri Gamage, Shashika Guruge*, Menuka Udugama, Mohamed Iffam and Ishara Anjalee

Abstract

Background: Sri Lanka has a striking variety of forest types brought about by spatial variations that can be simply classified as tropical rain forests. Forests account for removal of 17–25% of annual greenhouse gas emissions at the global level. State of deforestation in Sri Lanka is controversial in both scope and quantity. Therefore, understanding the drivers of deforestation is fundamental to the development of policies and measures that can incorporate to amend the current status of deforestation activities, toward more favourable environment-friendly outcome. Aim of this study is to assess the determinants of deforestation to better understand the patterns and intensity of deforestation in Sri Lanka, during the past three decades.

Methods: Data were acquired through two secondary sources; Food Agriculture Organization of the United Nation (FAO) and Department of Census and Statistics for the period from 1990 to 2016. A structural model was used to approximate the causes of deforestation and burnt forest area.

Results: Results reveals that the forest area has been decreased from 1990 to 2010 and remains nearly at a steady level, which shows the success of national wide reforestation and afforestation programmes. Interestingly, income, agricultural gross domestic products, crop production, crop production area, poverty, population, literacy rate, agricultural labour force and agricultural land area showed significant impacts (at 95% confidence level) on the forest cover change, while none of the factors denote any significant impact towards burnt tropical forest cover.

Conclusions: Study reveals the factors that are significantly affect the forest cover change. Interestingly none of the factors had any significant impact towards burnt tropical forest cover and yet to be studied in future. Study provides clues of the success of some reforestation programmes which need to be studied further.

Keywords: Deforestation, Drivers of Deforestation, Structural Model, Tropical Forests

Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila, Sri Lanka

* Correspondence: guruge84@yahoo.com

https://orcid.org/0000-0002-7073-673X

INTRODUCTION

Forests are a central part of terrestrial ecosystems with multiple definitions made to fit specific purposes, based on views, concepts, and priorities [1]. Forest classification system includes forest vegetation group and non-forest vegetation group that provide multiple benefits on life of the earth, including protecting of watersheds, providing habitats for animals, reducing Green House Gas (GHG) emission, preventing soil erosion, and mitigating climate changes. World's forests amount has been continuously declining as a result of increase of human population and the increase of demand for food and land.

Forest resources are the home of multiple ecological services fundamentally important to human wellbeing. Further it regulates the climate and water resources, while providing habitats for plants and animals. Forests are under constant threat of degradation or destruction due to increasing human interactions. Deforestation or the forest degradation crisis accounts for significant, yet disputed portion of human induced greenhouse gas emissions. Therefore, the studies related to forest cover change are a central component in developing strategies for management of natural resources. Further the community is seeking to design mechanisms to reduce forest-related carbon emissions through promoting the enhancement of carbon stocks via reforestation.

Deforestation is an incidence of removal of trees and the conversion from forest vegetation into non-forest vegetation and other land uses. Deforestation has many definitions and most of them have been compiled and classified by Lund [2] either as a change in land cover or a change in land use. By supporting all those literature, Lund [2] has defined deforestation as "the act or process of changing forest land to non-forest land". Further, more often deforestation has been defined as the transformation from forested land to non-forested land during a certain time [3]. Deforestation is responsible for 17–25% of annual greenhouse gas emissions that is a principal factor in global warming [4-5]. International bodies have been developing numerous policies for strengthening carbon sequestration by forests, through reducing deforestation to encourage the developing countries to identify drivers of land use change, including deforestation.

Climate change is a pressing global issue and it negatively affects many developing countries. As a response to this pressing challenge, many countries have been introducing major programmes to reduce deforestation and forest degradation. However, these programmes are hindered by limited understanding of the extent of deforestation and forest degradation and their underlying causes [6]. As countries that are moving towards the implementation phase of their national REDD+ (Reducing Emissions from Deforestation and forest Degradation) programmes, it is crucial to better understand what drives deforestation. This will assist in identifying policy responses which remains challenging because, while the number of scientific assessments of deforestation drivers is increasing, they often reach diverging conclusions [7].

Over the last few decades there have been a considerable number of deforestation studies conducted in the world, with compared to Sri Lanka. According to the literature, countries in Latin America have recognized, the access to markets and agricultural and forest activities as the main causes of deforestation, that may subject to the forest types too [8]. Further above study has identified that deforestation measurements focused at different scales and on different forest types would help governments to improve their reports for international initiatives and more importantly, for developing local policies for the sustainable management of forests in Latin America.

In another study, Trigueiro *et al.* has used a Geographically Weighted Regression (GWR) approach to assess the spatial variability of deforestation drivers in Brazil [9]. The results show that, to effectively reduce deforestation, public policies should integrate strategies focusing not only at national and biome levels, but also at the regional level. In Myanmar, a number of spatially explicit potential drivers of deforestation such as infrastructure, elevation, slope, deforested land, and population, have been identified [10].

Although the effects of deforestation are well known, the understanding of its drivers across regions and countries is crucial. Further there are many studies, which consider that certain driving factors influence deforestation equally in all regions. Yet, deforestation has a strong spatial structure that can lead drivers to vary their influence on deforestation in different regions [9]. Van Khuc *et al*. has used Geographic Information System (GIS) tools, structural regression models (structural model), and a regression tree method to quantify the extent, as well as the approximate causes of deforestation and forest degradation in Vietnam [6]. Results have concluded initial forest cover, per capita income, agricultural production, governance, population growth, food, and poverty as drivers of deforestation and forest degradation.

One of the South Asian studies has analysed the land cover and investigated the spatial patterns of deforestation and forest fragmentation in South Asian region since the 1930's. The study covered eight countries of the region including; India, Bangladesh, Bhutan, Nepal, Pakistan, Afghanistan, Sri Lanka and Maldives [11]. In South Asia, agricultural lands are predominant (43%) of the total geographical area followed by barren lands (20.0%) and forests (14.7%). The long-term change analysis has indicated a loss of 29.6% of the forest cover. Forest fragmentation had denoted significant spatial-temporal variations. The large core forests in South Asia have denoted significant decrement over last eight decades [11].

Xu *et al.* quantifying the dynamics of forest and agricultural lands and the spatially explicit drivers of their changes, provides a solid foundation for land use and land cover change modelling and projection in South and Southeast Asia [12]. Laurance, highlights the pattern and pace of tropical forest destruction in the Americas, Asia, and Africa [13]. He recognizes Asian forests as the most immediate less surviving forests, than the other two regions, along with higher relative rates of deforestation and logging. This study has further identified human population pressure, weak government institutions and poor policies, increasing trade liberalization, and industrial logging as the four main emerging key drivers of forest destruction [13].

Sri Lanka has a striking variety of forest types brought about by spatial variations in rainfall, altitude and soil [14-15]. The Sri Lankan forests have been categorized broadly as tropical wet lowland evergreen forests; wet sub-montane forests; wet montane forests; tropical dry mixed evergreen forests in the dry lowlands, with riverine vegetation along river banks; tropical moist evergreen forests in the intermediate zone; thorny scrublands in the arid areas; and mangrove forests in the coastal areas, lagoons and at the river mouths [14-15]. Just due to the complexity of classification, the forests were simply classified as “tropical” and “other forests”, in the current study. The tropical rain forests are evergreen, luxuriant and rich in tree species as well as in other plant and animal life and a major source of the world's hardwoods, which are used in fine furniture and other high-grade uses too. Only a small proportion of the world's tropical forests are under management in any meaningful sense and often confined to the collection of revenue from logging operations or the protection of national parks by government forest services.

State of deforestation in Sri Lanka is controversial in both scope and quantity. Therefore, understanding the drivers of deforestation is fundamental to the development of policies and measures that can incorporate to amend current status of deforestation activities, toward more favourable climatic and biodiversity-friendly outcomes. Aim of this study was to assess the determinants of deforestation to better understand the patterns and intensity of deforestation in Sri Lanka, during the past three decades.

METHODOLOGY

This study followed a framework, which is built on three levels of drivers that are associated with deforestation [16]. The first level consists of agents of deforestation, and second stage with decision parameters and agent characteristics, while the last level considers a broad set of socio-demographic characters, such as economic, political, cultural, demographic, and technological factors. Following the literature review, four broader categories were selected as the causes of deforestation. Those categories include agricultural and food production (AFP), socio-economic factors (SEF), human resource factors (HRF), land use changes (LUC). Therefore, a general model of deforestation was formed as follows;

$$DF|BFT|BFO = f(AFP, SEF, HRF, LUC) \quad (1)$$

DF : Deforestation
BFT : Burnt forest tropical
BFO : Burnt forest others

As presented above, deforestation can be shaped by many wide-ranging factors that are complex with interactions to be disentangled. A new integrated model was derived to build up the structural model of drivers of deforestation [12-17] as follows;

AFP : f (AGGDP, CRPD)
SEF : f (IN, POV, POP)
HRF : f (LIT, LAB)
LUC : f (AGLA, CROPLA)

$$DF|BFT|BFO = f(AGGDP, CRPD, IN, POV, POP, LIT, LAB, AGLA, CROPLA) \quad (2)$$

AGGDP : Agricultural Gross Domestic Products
CRPD : Quantity of crop production
IN : Income
POV : Poverty
POP : Population
LIT : Literacy rate
LAB : Labour force in agriculture
AGLA : Agricultural land area
CROPLA : Crop production area

Burnt forest tropical and burnt forest others were included in the above model. Income, poverty and population were included to epitomize the socio-economic factors. Change in AGGDP and change of quantity of crop production were used to describe the agricultural and food factors. Meanwhile, change of labour force in agriculture and change of literacy rate were included in to exemplify the human resource factors. In addition, the change in agriculture land share from total land share (%) and change of crop production area (ha) were included to represent land use changes.

Data Collection and Analysis

Data were acquired from two secondary sources; Food Agriculture Organization of the United Nation (FAO) and Department of Census and Statistics for the period from 1990 to 2016. All the potential variables were included and tested to find the best model. Collinearity was tested using Variance Inflation Factors (VIF) and the final model was derived using a stepwise method, which retains only the statistically significant variables. Finally, STATA (version 14) was employed to re-examine the reliability and validity of the final model, using the Shapiro-Wilk test for normality ($P>0.1$). Then the structural model was used to derive the explanatory relationships between the deforestation and their drivers.

RESULTS AND DISCUSSION

Table 1 shows the descriptive statistics of all potential variables that were used to select the best model.

Figure 1 shows the changes in forest cover, while figure 2 shows the burnt forest area of both tropical and other forests.

Table 1: Descriptive Statistics for Potential Variables in the Integrated System

Variables		Mean	Std. Dev.	Min	Max
FCOVER	Total forest cover change (ha)	138.95	40.93	89.34	174.75
PFCOVER	Percentage of total forest cover change (ha)	0.01	0.01	0.00	0.01
FTBURNT	Burnt forest area (T) (ha)	20100.36	5588.34	14961.52	29601.43
PFTBURNT	Percentage of burnt forest area (T)(ha)	0.90	0.29	0.66	1.41
FOBURNT	Burnt forest area (O)(ha)	10328.05	5060.54	3828.96	17924.00
PFOBURNT	Percentage of burnt forest area (O) (ha)	0.47	0.24	0.17	0.84
Socio Economic Factors					
INCOME	Change of Per capita income (Billion PPP dollar)	45.06	35.20	18.53	102.00
PINCOME	Percentage of per capita income change(Billion PPP dollar)	46.42	9.84	37.02	61.11
POVERTY	Change of Annual poverty rate (%)	-9.12	5.64	-19.00	-5.40
PPOVERTY	Percentage of Annual poverty rate change (%)	-14.64	11.69	-35.19	-6.70
POP	Change of Population (Unit 1000)	760.45	148.90	534.69	917.14
PPOP	Percentage of Population (Unit 1000) change	4.05	0.86	2.93	5.29
Agricultural and Food					
AGGDP	Change in AGGDP (Rs/$)	0.94	1.05	-0.37	2.02
PAGGDP	Percentage of AGGDP (Rs/$) change	29.28	30.95	-11.37	67.14
CROPPROD	Change of Quantity of crop production (Tonnes)	220518.2	985031.1	-950755.0	1747071.0
PCROPPROD	Percentage of Quantity of crop production change (Tonnes)	4.40	15.20	-12.15	28.74
Human Resource Factors					
LITRATE	Change of Literacy rate (%)	0.77	0.55	0.28	1.68
PLITRATE	Percentage of Literacy rate change (%)	0.86	0.62	0.31	1.88
LABOUR	Change of labour force in agriculture (%)	-4.19	3.50	-7.43	1.68
PLABOUR	Percentage of labour force in agriculture change (%)	-10.78	8.95	-18.07	4.25
Land Use Changes					
AGRILAND	Change in agriculture land share from total land share (%)	1.46	1.33	-0.21	2.82
PAGRILAND	Percentage of change in agriculture land share from total land share (%)	3.68	3.35	-0.56	6.83
CROPPRODAR	Change of Crop production area (ha)	-12144.8	172236.0	-250623.0	207575.0
PCROPPRODAREA	Percentage of crop production area (ha) change	-0.40	10.29	-14.03	13.15

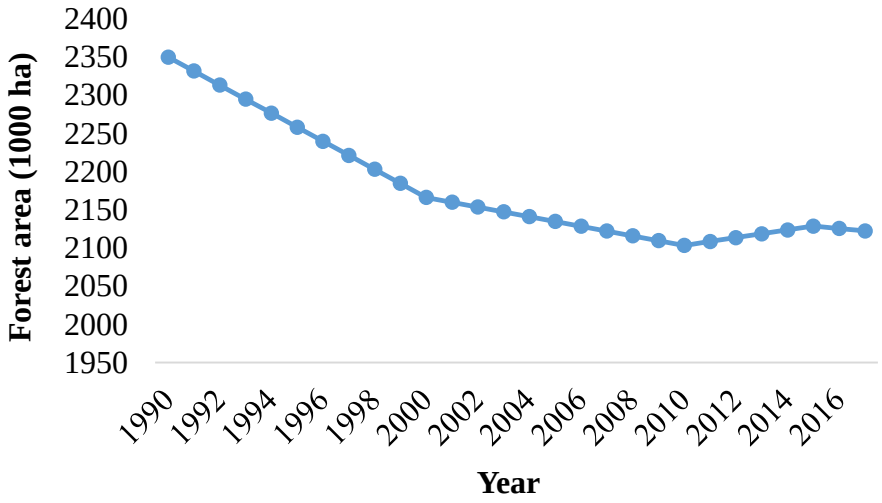

Figure 1: Temporal Variation of the Forest Area in Sri Lanka

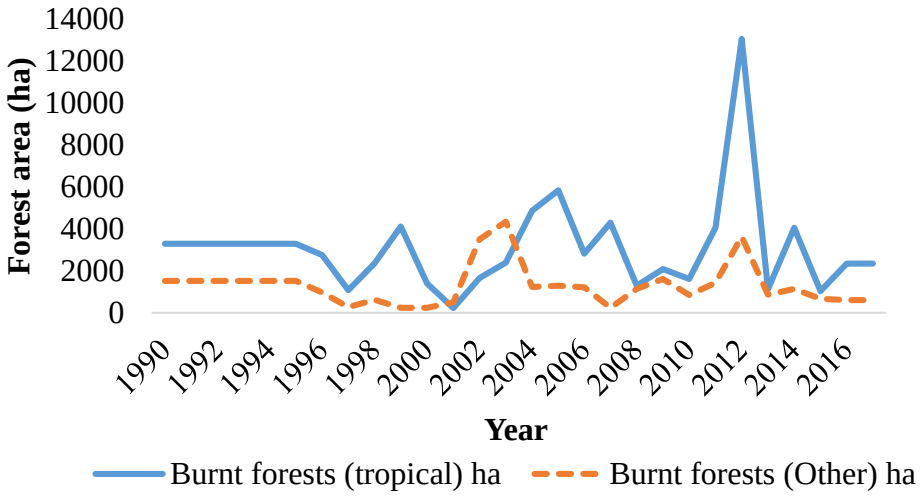

Figure 2: Temporal Variation of the Burn Forest Area in Sri Lanka

Forest cover in Sri Lanka has been declining from 1990 to 2010 and then remains at a stable phase with very minor changes. Tropical forests have been burnt drastically with respect to the other forests. As shown in the Table 2, the total forest cover changes in the period 2010 to 2017 had been smaller, than the 1990 to 2005 period. This is due to the succession of previously deforested areas during the second period. The total burnt forest area was approximately 39346.94 ha in 2016. Tendency of forest burning has been increased, causing a huge impact on tropical forests.

According to the results of the structural regression model used to identify the approximate drivers of deforestation, all the variables have remained significant (P<0.05). Therefore, all the variables significantly affect the forest cover change. The respective R^2 values of all the variables are also >70%, depicting a good fitness level. According to the Table 3, per capita income and crop production denote negative relationships with the forest cover change,

Table 2: The Extent of Deforestation in Sri Lanka during 1990 to 2017

Year	Unit	Total Forest Cover Change	Deforestation		
			Burnt Forest Area (Tropical)	Burnt Forest Area (Others)	Total Burn Forest Area
1990-1995	ha	165.91	19753.97	9063.96	28817.93
	%	0.01	0.84	0.39	
1995-2000	ha	165.14	14961.52	3828.96	18790.48
	%	0.01	0.66	0.17	
2000-2005	ha	174.75	18260.88	11077.82	29513.44
	%	0.01	0.84	0.51	
2005-2010	ha	89.34	17924.00	17924.00	35937.34
	%	0.00	0.84	0.84	
2010-2017	ha	99.62	29601.43	9745.50	39446.56
	%	0.00	0.85	0.46	

Table 3: Estimated Results of the Structural Model of Forest Cover Change

Variables	Forest Cover Change	Socio Economic	Crop Production Quantity	Labour Force	Crop Production Area
INCOME	-0.12				
	(-3.49)				
LABOUR	8.96				
	(3.16)				
AGGDP	0.06				
	(0.92)				
CROPPRODAREA	-2.33				
	(-2.38)				
POVERTY		$-9.74*10^{-4}$			
		(-1.66)			
POP		$8.74*10^{-4}$			
		(8.23)			
CROPPROD			44.28		
			(13.78)		
LITRATE				-0.75	
				(-14.95)	
AGRILAND					-0.46
					(-11.05)
P-value	0.00	0.00	0.00	0.00	0.00
Observations	28	28	28	28	28
R-squared	0.83	0.75	0.88	0.90	0.82
Adj. R squared	0.79	0.73	0.87	0.89	0.82

Table 4: Estimated Results of the Structural Model of Burnt Forest Area (Tropical)

Variables	Burnt Forest Area	Socio Economic	Crop Production Quantity	Labour Force	Crop Production Area
INCOME	0.66				
	(0.56)				
LABOUR	-620.37				
	(-0.62)				
AGGDP	-2.56				
	(-0.11)				
CROPPRODAREA	-95.96				
	(0.62)				
POVERTY		$-9.74*10^{-4}$			
		(-1.66)			
POP		$8.74*10^{-4}$			
		(8.23)			
CROPPROD			44.28		
			(13.78)		
LITRATE				-0.75	
				(-14.95)	
AGRILAND					-0.46
					(-11.05)

suggesting that the increase in per capita income and crop production area will subsequently decrease the forest cover change.

Change of labour force in agriculture and change in agricultural GDP shows a positive relationship with the forest cover change. Table 4 shows the relationship of independent variables with the burnt forest area (tropical) and burnt forest area (other). It includes coefficients of variables and t values. All the variables had p-values less than 0.05 with relatively very smaller R^2 values. Thus, although the variables significantly influence the deforestation, their impact towards both burnt tropical and other forest areas are minimum.

CONCLUSION

This study attempted to assess the deforestation drivers in Sri Lanka. Study reveals that overall forest area in Sri Lanka has decreased from 1990 to 2010 and remains nearly at a steady level. This shows the success of some nation-wide reforestation programmes. Interestingly, income, agricultural GDP, crop production, crop production area, poverty, population, literacy rate, agricultural labour force and agricultural land area were found to significantly affect the forest cover change, while none of the factors denote any significant impact towards burnt tropical forest cover. Country's tropical forest cover is still in danger due to some other reasons that were not revealed through this study and yet to be studied in future.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

MG: Designed and implemented the study; SG: Designed and implemented the study and wrote the manuscript; MI: Data collection and analysis; MU and IA wrote and reviewed the manuscript.

FUNDING

Authors received no funding.

REFERENCES

1 Chazdon RL, Brancalion PH, Laestadius L, Bennett-Curry A, Buckingham K, Kumar C, Moll-Rocek J, Vieira IC, Wilson SJ. When is a forest a forest? Forest concepts and definitions in the era of forest and landscape restoration. Ambio. 2016 Sep; 45(5):538-550.

2 Lund HG. A 'Forest' by any other name. Environmental science and policy. 1999; 2(2):125-133.

3 Food and Agriculture Organization of the United Nations. Global Forest Resources Assessment 2015: How are the World's Forests Changing?. Food and Agriculture Organization of the United Nations. 2015.

4 Bernstein L, Bosch P, Canziani O, Chen Z, Christ R, Davidson O, Hare W, Huq S, Karoly DJ, Kattsov V, Kundzewicz Z. Climate change 2007 synthesis report. Intergovernmental Panel on Climate Change. 2008.

5 Quéré CL, Moriarty R, Andrew RM, Canadell JG, Sitch S, Korsbakken JI, Friedlingstein P, Peters GP, Andres RJ, Boden TA, Houghton RA. Global carbon budget 2015. Earth Syst. Sci. Data. 2015 Dec 7; 7(2):349-396.

6 Van Khuc Q, Tran BQ, Meyfroidt P, Paschke MW. Drivers of deforestation and forest degradation in Vietnam: An exploratory analysis at the national level. Forest policy and economics. 2018 May 1; 90:128-141.

7 Wehkamp J, Aquino A, Fuss S, Reed EW. Analyzing the perception of deforestation drivers by African policy makers in light of possible REDD+ policy responses. Forest Policy and Economics. 2015; 59:7-18.

8 Armenteras D, Espelta JM, Rodríguez N, Retana J. Deforestation dynamics and drivers in different forest types in Latin America: Three decades of studies (1980–2010). Global Environmental Change. 2017 Sep 1; 46:139-147.

9 Trigueiro WR, Nabout JC, Tessarolo G. Uncovering the spatial variability of recent deforestation drivers in the Brazilian Cerrado. Journal of Environmental Management. 2020 Dec 1; 275:111243.

10 Sharma P, Thapa RB, Matin MA. Examining forest cover change and deforestation drivers in Taunggyi District, Shan State, Myanmar. Environment, Development and Sustainability. 2020 Aug; 22(6):5521-5538.

11 Reddy CS, Saranya KR, Pasha SV, Satish KV, Jha CS, Diwakar PG, Dadhwal VK, Rao PV, Murthy YK. Assessment and monitoring of deforestation and forest fragmentation in South Asia since the 1930s. Global and Planetary Change. 2018 Feb 1; 161:132-148.

12 Xu X, Jain AK, Calvin KV. Quantifying the biophysical and socioeconomic drivers of changes in forest and agricultural land in South and Southeast Asia. Global change biology. 2019 Jun; 25(6):2137-2151.

13 Laurance WF. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. Conserv. Biol. 2002; 16: 605–618.

14 National Biodiversity Strategic Action Plan 2016-2022. Colombo: Biodiversity Secretariat, Ministry of Mahaweli Development and Environment. 2016.

15 The National Red List 2012 of Sri Lanka. Colombo: Ministry of Environment. 2012.

16 Kaimowitz D, Angelsen A. Economic models of tropical deforestation: a review. 1998.

17 Yin R, Xiang Q. An integrative approach to modeling land-use changes: multiple facets of agriculture in the Upper Yangtze basin. Sustainability Science. 2010 Jan; 5(1):9-18.