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# Drivers of deforestation and forest degradation in Vietnam: An exploratory analysis at the national level

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ABSTRACT

Climate change is a pressing global issue and it negatively affects many developing countries, including Vietnam. To help Vietnam effectively respond to this pressing challenge, the country has recently introduced a major program for reducing carbon emissions arising from deforestation and forest degradation, fostering conservation, managing forests sustainably, and enhancing forest carbon stocks (REDD+). Current policies in Vietnam provide a sound platform for the development of REDD+, and REDD+ can potentially greatly contribute to the reduction of deforestation and forest degradation. However, these policies and the REDD+ program are hindered by limited understanding of the extent of deforestation and forest degradation and their underlying causes. This study employed geographic information system (GIS) tools, a structural regression model (structural model), and a regression tree method to quantify the extent as well as the approximate causes of deforestation and forest degradation in Vietnam. Results show that around 1.77 and 0.65 million ha of forests were lost and degraded, respectively, between 2000 and 2010. Deforestation and forest degradation were most notable in the north central, northeast, central highland, and northwest areas of the nation. There were several underlying indicators of deforestation and forest degradation including initial forest cover, per capita income, agricultural production, governance, population growth, food, and poverty. Our results illustrate several important policy implications for forest restoration and the REDD+ program in Vietnam: Vietnam should focus most strongly on reducing poverty, preserving existing forests, improving provincial-level governance, and controlling population growth.

## 1. Introduction

Land use and land cover change (LULCC), mainly deforestation and forest degradation, are responsible for 17–25% of annual anthropogenic greenhouse gas emissions that are a principal factor in global warming (Bernstein et al., 2008; Le Quéré et al., 2015). Although deforestation and forest degradation have declined, they are still serious in scope and quantity, especially in developing countries (Calle et al., 2016; Hansen et al., 2013; Köthke et al., 2013). Understanding drivers of deforestation and forest degradation is fundamental to and necessary for the development of policies and measures that allow humans to modify current trends in forest activity toward a more climate- and biodiversity-friendly outcome (Hosonuma et al., 2012; Kissinger et al., 2012).

International bodies have developed various policies for reducing carbon emissions related to deforestation and forest degradation. Many challenges remain for implementing programs to reduce forest degradation and deforestation, particularly monitoring projects and improving developing countries' capacity for ensuring compliance (Hosonuma et al., 2012; Kissinger et al., 2012; Pham et al., 2012). Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have developed a mechanism for reducing emissions resulting from deforestation and forest degradation. The UNFCCC has encouraged developing countries to identify drivers of land use change, including deforestation and forest degradation (Hosonuma et al., 2012).

Vietnam has reputation for tropical forest ecosystems with high diversity and uniqueness. Vietnam's forests have undergone a transition from net deforestation to net reforestation since the 1990s (Meyfroidt and Lambin, 2008a). Although forest cover has increased in Vietnam, deforestation and forest degradation continues (JICA, 2012). In the beginning years of the 21st century, Vietnam was one of the top nations for gross tree cover loss (Hansen et al., 2013). How to help control this emerging issue and contribute to climate change mitigation has been a central question for Vietnam recently, motivating this study to

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determine why forest loss and forest degradation occur and to better understand patterns and intensity of deforestation and forest degradation in Vietnam during the past decade.

In an effort to halt deforestation and forest degradation, Vietnam is participating in the REDD + (Reducing Emissions from Deforestation and Forest Degradation project, fostering conservation, sustainably managing forests, and improving forest carbon stocks) (Pham et al., 2012). Although current policies in Vietnam have provided a sound platform from which REDD + can develop, and REDD + can potentially contribute significantly to initiatives battling deforestation and forest degradation, current policies are incomplete. This is due to lack of information on the extent of forest loss and forest degradation and their drivers on a national scale. Current information on this topic in Vietnam comes mainly from research that was derived from small-scale (e.g., village, commune) (Khang and Bao, 2015; Meyfroidt, 2013; Muller and Zeller, 2002) and annual forest development reports (FSSP, 2014, 2015) that were not adequate to assist in policy formation. In many cases, the current policy is either out of date or incomplete to some degree since the input for policy formulation lacks updated and large-scale (i.e., province-level) information.

In this study, our goal was to overcome those shortcomings by determining the extent of forest loss and forest degradation and their approximate drivers based on cross-province data gathered between 2000 and 2010. To clarify to what extent drivers influence forest loss and forest degradation, we tested some key variables—income, population, poverty, food security, and governance—in a structural model and a regression tree model. We employed an interdisciplinary method that combines GIS tools and econometrics to compute and analyze a newly updated province-scale database.

## 2. Method and materials

### 2.1. Conceptual framework

#### 2.1.1. Forests

Forests are a central part of terrestrial ecosystems and have been the subject of interest for scholars and scientists around the world. There have been around 1500 definitions of the term *forest* on many levels, including at the local, state, provincial, national, and international scale (Lund, 2014). Generally, definitions of *forest* are made to fit specific purposes, based on views, concepts, and priorities (Chazdon et al., 2016). In Vietnam, *forest* has been clearly defined and used officially in forest protection and development law for several years. In this study, we adopted the definition presented in Vietnamese Circular Number 34/2009/TT-BNNPTNT. Forest is an ecological system which mainly consists of long term wood trees, coco species with a height of 5.0 m or more (excluding new plantation forest and mangrove forest), and bamboo species that can provide timber, non-timber forest products, and direct or indirect value such as biodiversity and landscape conservation. Areas considered to be forests include newly planted forests with woody trees, regenerating forests after harvesting, plantation forests with an average tree height of > 1.5 m for slow-growing species and > 3.0 m for fast-growing species with a density of 1000 trees per hectare or more. Canopy cover of the main tree species of the forest is 10% or more. The forest has a minimum block area of 0.5 ha. In the case of trees strips, a minimum width is 20 m and there must be at least 3 rows of trees in a strip. In addition to the term “forest” in legal documents, it is important to define the forest classification system that was developed for forest inventory by the Forest Inventory Planning Institute (FIPI) in 2008. There are 17 land use types in the forest classification system. They are classified into forest vegetation group and non-forest vegetation group. The forest vegetation group includes 12 forest vegetation types such as evergreen forest (rich, medium, poor), rehabilitated forest, deciduous forest, bamboo, mixed bamboo, coniferous forest, mixed evergreen and deciduous, mangrove forest, limestone forest, and plantation forest. The non-forest vegetation group consists of five non-forest land use types: limestone, bare land, water body, residential, and other land (JICA, 2012).

#### 2.1.2. Deforestation and forest degradation

*Deforestation* is a well-defined term that has been widely used for some years. Hosonuma et al. (2012) referred to deforestation as the removal of trees and the conversion from forest vegetation into non-forest vegetation and other land uses such as agriculture, mining, etc. Remarkably, Lund (2014) compiled > 250 definitions of deforestation and classified them as a change in land cover, a change in land use, or both. He concluded his study by defining deforestation as “the act or process of changing forest land to non-forest land”. In this study, we used the definition proposed by FAO (2010): Deforestation is the transformation from forested land to non-forested land during a certain time.

Forest degradation is more difficult to define, as it may refer to several dimensions in terms of state and process that are difficult to observe and quantify. Various definitions of forest degradation have recently been proposed (FAO, 2011; IPCC, 2003; ITTO, 2002; Putz and Redford, 2010; Thompson et al., 2013). Thompson et al. (2013) proposed five criteria with which to assess the degree of forest degradation such as productive functions, biodiversity, unusual disturbances, protective functions, and carbon storage. In this study, we define forest degradation as a decline in forest production capacity that is indicated by several measures including (i) forest quality (i.e., reduced tree density), (ii) carbon stock (i.e., reduced carbon stocks), and (iii) type of forest vegetation (i.e., evergreen forest turns into bamboo).

#### 2.1.3. Theoretical model of deforestation and forest degradation

There are many models of drivers of deforestation in the literature. In this study, we adapted the widely-used framework for tropical forest deforestation proposed by Kaimowitz and Angelsen (1998). This framework is built on three levels of drivers that are associated with deforestation and forest degradation. The first level is agents of deforestation and forest degradation (i.e. small farmers, ranchers, plantations, loggers, etc.). The decision parameters and agent characteristics belongs to the second level while the last level is those factors that can be considered the underlying drivers of deforestation and forest degradation such as the broader economic, political, cultural, demographic, and technological forces, which determine the agents' characteristics and decision parameters.

To build a general model of deforestation and forest degradation in Vietnam, we employed a literature review-based approach. We first reviewed numerous relevant publications on deforestation and forest degradation and their models, and we then narrowed down to several publications that are closely associated with Vietnam. There are many factors reported to influence forest loss and forest degradation; we ultimately selected seven groups of factors that can affect forest loss and forest degradation in Vietnam. Those groups include agricultural production, income, poverty, population, forest capital, food, and province-scale governance. The following is our justification for selecting these factors.

As in many developing countries, the expansion of agricultural land is a principal driver of deforestation and forest degradation, driven by continuous increase in demand for agricultural products. Up to now, the majority of agricultural land has been transformed from previous forestland (DeFries et al., 2010; Kissinger et al., 2012; Meyfroidt et al., 2013). Agricultural expansion occurs for both subsistence-oriented production, such as through shifting cultivation, as well as for commercial agriculture destined both for domestic and international markets. Therefore, agricultural production is assumed to play an important role in promoting deforestation and forest degradation in Vietnam.

The causal relationship between income and deforestation has been documented in several studies (Kaimowitz and Angelsen, 1998). As income grows, investment in forests increases as well. As a result, newly planted forests can compensate for forest loss (Bhattarai and Hammig,