Land Use Policy 71 (2018) 395–408

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Using the forest-transition model and a proximate cause of deforestation to explain long-term forest cover trends in a Caribbean forest

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A R T I C L E I N F O

Keywords:
Forest transition
Land cover change
Deforestation
Reforestation
Proximate causes
Caribbean
Jamaica

A B S T R A C T

Jamaica experienced net deforestation during the period 2001–2010. Yet, the proximate causes of deforestation and the reasons why a forest transition might be absent, particularly at the local-level, which can explain national scale changes, have been little studied. Long-term changes in socio-economic and land cover data over 68-years, for the moist forest of the Cockpit Country, Jamaica, and predictors of land cover change, were assessed using generalized linear and non-linear regression models. These were used to determine if the classic theorized determinants of a forest transition were present at different spatial scales and to identify the proximate cause(s) of deforestation. Some theorized determinants were present (improvements in national and sub-national economic development, and a decline in agricultural production); however, rural/local scale population density and growth rates were stable. As such, pressure on the unprotected (non-reserves) marginal/agricultural lands in the Cockpit Country was not reduced and this prevented them from reverting to forest. Forest cover for the entire Cockpit Country and the non-reserves therefore fluctuated significantly over time (nonlinear trend), peaking twice (1980 and 2002). The implementation of trade liberalization policies in the 1980s resulted in increased yam cultivation, which was the proximate cause of forest cover change in the non-reserves (a significant non-linear relationship). As a result, deforestation increased significantly during this period and again during the 2000s, at which time it was driven largely by other factors. A forest transition is unlikely to occur via an economic pathway, but it can possibly be achieved via the enforcement of existing forest protection laws and active promotion of forest cover expansion.

1. Introduction

Forest transitions – long-term shifts from net deforestation to net reforestation within a defined territory (Mather, 1990, 1992; Rudel et al., 2005; Rudel et al., 2010; Yackulic et al., 2011) – involve an initial stage with high deforestation rates and large losses in forest cover, followed by a reduction in rates of forest loss, eventual forest cover stabilization, and a final period of overall forest growth (Angelsen, 2007). Initial forest loss has largely been attributed to drivers of deforestation. These drivers are varied and complex but are commonly categorized as proximate and underlying causes and spatial pattern drivers (Geist and Lambin, 2001; Mitsuda and Ito, 2011; Meyfroidt, 2016). Proximate causes are anthropogenic activities that directly modify the landscape, such as wood extraction and the expansion of agriculture and infrastructure, (Geist and Lambin, 2001). In the tropics, agricultural expansion of high value commercial crops is the leading proximate cause of deforestation (Geist and Lambin, 2001). The underlying causes are the economic, cultural and sociopolitical influences that form the basis for proximate causes (Geist and Lambin, 2001). Spatial pattern drivers are the landscape biophysical characteristics that determine where change will occur (Echeverría et al., 2008; Mitsuda and Ito, 2011). These three classes of drivers are often interlinked and operate at several different levels of aggregation or spatial scales (Geist and Lambin, 2001; Lambin et al., 2003; Lambin and Meyfroidt, 2010), although proximate causes generally operate at the local scale (Geist and Lambin, 2001).

The forest transition (FT) model provides a conceptual framework for understanding the underlying processes that lead to these changes in forest cover. The FT model posits that driving forces, such as economic development, especially industrialization and urbanization, initially cause large-scale forest clearance, but eventually lead to rural depopulation, farm abandonment and ultimately forest re-growth on marginal lands (Rudel, 1998; Perz, 2007). This process has been referred to as “the economic development pathway” to a forest transition (Rudel et al., 2005). An alternative pathway to forest expansion that has been observed in some countries was termed ‘the forest scarcity

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https://doi.org/10.1016/j.landusepol.2017.11.056
Received 22 May 2017; Received in revised form 10 September 2017; Accepted 29 November 2017
Available online 21 December 2017
0264-8377/

pathway' (Rudel et al., 2005). This occurs when areas have experienced particularly drastic declines in forest cover (due to the three categories of deforestation drivers) that prompt management decisions to increase forest extent due to rising prices of forest products, or in response to real or perceived negative effects of deforestation (e.g., severe soil erosion, landslides, or increased flooding) on local populations (Rudel et al., 2005; Angelsen, 2007; Lambin, and Meyfroidt, 2010). Applications of the FT model to forests in tropical developing countries have yielded mixed results (Perz, 2007; Rudel et al., 2010). This was perhaps due to the smaller spatial and temporal scales of analysis used in those studies (e.g., Perz and Skole, 2003; Perz, 2007; Izquierdo et al., 2008; Meyfroidt and Lambin, 2008; Rudel et al., 2010), in contrast to the original observations of forest transitions in very large North American and European nation states over hundreds of years (Mather, 1990, 1992, 2001, 2004; Mather et al., 1999). Perz (2007) further criticized the apparent limited utility of the theory to explain the occurrence (or non-occurrence) of transitions in tropical developing countries with colonial pasts, that are currently impacted by important exogenous forces such as globalization and international trade agreements. As such, with a wider range of processes linked with FTs in the tropics, Meyfroidt and Lambin (2008) proposed three additional FT pathways: 1) the state forest policy pathway (e.g., the establishment of parks and protected areas), 2) the globalization pathway (e.g., where neo-liberal economic restructuring, labour out-migration, local implementation of international conservation ideologies, ecotourism and acquisition of land by expatriates improve the quality and quantity of forest cover) and 3) the smallholder, tree-based land use intensification pathway (e.g., tree cover increase associated with the expansion of fruit orchards, wood lots, agroforestry systems, gardens, hedgerows and secondary forests on abandoned pastures).

Despite the recent application of FT models to tropical developing countries, very few studies have applied FT model to the Caribbean region (e.g., Crk et al., 2009; Yackulic et al., 2011), in spite of the region's colonial past, and the general expansion in forest cover it has experienced since at least the mid-20th century. Documented increases in total forest cover have occurred on the islands of Puerto Rico (Thomlinson et al., 1996; Yackulic et al., 2011), Barbados, St. Kitts, Nevis and Grenada (Helmer et al., 2008), and more recently in Cuba, Puerto Rico and Hispaniola (FAO, 2010; Aide et al., 2012; Álvarez-Berríos et al., 2013). Furthermore, very few studies have sought to explain the absence of forest transitions on other Caribbean islands, such as Jamaica, which experienced net deforestation during the last three decades (Eyre, 1987; Aide et al., 2012; Álvarez-Berríos et al., 2013). This occurred despite an overall increase in real GDP per capita and improvements in living standards, reduced population growth rates, and declines in agricultural production. Additionally, in Jamaica, local-level land use changes, which can explain the changes observed at the national scale, have remained understudied.

Recent attempts at applying the FT model or assessing drivers of change at the local level in Jamaica, have yielded disparate results. Timms et al. (2013), using data from a Forest Reserve (protected area) in the moist tropical forest of the Cockpit Country, Trelawny, and a 1500 m buffer of unprotected forest surrounding the reserves, reported that net forest cover was stabilizing during a possible turnaround phase (net deforestation to net reforestation) in a forest transition between 1987 and 2011. However, Timms et al. (2013) used only low resolution, national scale process data and no data on smaller scale processes (aside from their forest cover data, which was inadvertently generated using inaccurate forest reserve boundaries) in their assessment of possible explanatory factors for a localised forest transition. In contrast, other studies that used a larger study area that incorporated both non-reserve areas and the correct forest reserve boundaries (Newman et al., 2014a, 2014b) reported that while deforestation rates fluctuated, and the net rate was relatively low over a 68-year period (1942–2010: – 0.04% yr), exceedingly high net deforestation rates were recorded in the 1980s and more recently (2001–2010: – 0.25%/yr). Additionally, forest fragmentation, including within the forest reserves, also increased during that final decade (2001–2010; Newman et al., 2014a). Furthermore, the underlying causes and spatial pattern drivers of deforestation (identified using a spatial analysis) fluctuated over the 68 year period (Newman et al., 2014b). These results, when coupled with the growing importance of high-earning export crops (yams) cultivated in the Cockpit Country, which also occurred during the last three decades (1980–2010) (Beckford et al., 2011), indicate that yam cultivation was possibly a proximate cause of forest loss during this period. Consequently, a turnaround phase is either not occurring, is less smooth than previously thought, or the extent of the study area influenced the results of the studies. Moreover, scale is not often incorporated into FT model evaluations, and context is often ignored or not addressed when the FT model is applied to developing countries (Perz, 2007; Walker, 2008), especially at smaller spatial scales (regional and local), due to a sole focus on national scale processes (Bray, 2010).

In this study, we used the FT model to explain long-term forest cover trends and to determine if the classic theorized determinants of a forest transition were present at different spatial scales in the Cockpit Country. Additionally, we incorporated scale and context into our model evaluation. We postulated that if socio-economic conditions were improving, there should be national (a significant increase in GDP) and sub-national (the parishes/sub-national political administrative divisions where the Cockpit Country is located) economic development (improvement in living standards), but marginal or no development in the communities surrounding the Cockpit Country. This would lead to a general decline in rural population and agricultural production, and as marginal lands in the non-reserve (unprotected) areas in and around the Cockpit Country were no longer used for agriculture, they would revert to forest (Rudel, 1998; Perz, 2007). This should result in a sustained increase in forest cover and a forest transition in the Cockpit Country. If a forest transition did not occur, this may have been due to the increased cultivation (proximate cause) and importance of yams as an export crop since the 1980s (Beckford et al., 2011), influenced by trade liberalization and devaluation policies (FAO, 2003) (context). We therefore used key socio-economic data closely related to observed and theorized forest transitions (population density, overall agricultural production, the yam production, and measures of economic growth and living standards) and forest cover/change data for the years 1942, 1961, 1980, 1985, 1989, 1995, 2001, 2008 and 2010 obtained from two studies (Newman et al., 2011, 2014a), to determine:

1) Whether the socio-economic conditions posited by the FT model were actually present at the national, sub-national or local (Cockpit Country) scales.
2) Whether forest cover in the reserves, non-reserves or the entire Cockpit Country varied significantly over time or showed a smooth incremental change (an inverted bell (bowl-shaped) curve over time (Mather, 1992; Grainger, 1995)), indicative of a forest transition.
3) Whether yam cultivation was a major proximate cause of past or recent forest cover change, and if so, identify the aggregate level at which it was operational.

2. Materials and methods

2.1. Study site

There are currently no geo-political boundaries for the area known as the Cockpit Country, in west-central Jamaica. The boundaries used for the present study are those of a proposed conservation area (68,024.40 ha) for Cockpit Country biodiversity that encompasses 17 individual forest reserves (designated in the 1950s and 1960s), the largest of which is the Cockpit Country Reserve (24,340 ha) (Fig. 1). Our Cockpit Country study site is centred in the parish of Trelawny and extends into four additional parishes, namely St. James, St. Elizabeth,