Forest Policy and Economics 76 (2017) 35–44

Contents lists available at ScienceDirect

Forest Policy and Economics

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

Assessment of bio-physical, social and economic drivers for forest transition in Asia-Pacific region☆

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ARTICLE INFO

Article history:
Received 18 April 2015
Received in revised form 20 July 2016
Accepted 23 July 2016
Available online 9 August 2016

Keywords:
Agricultural production
Discriminant analysis
Forest carbon
Forest transition pathways
Forest transition theory

ABSTRACT

Forest transition (FT) has taken place in many developing countries in recent decades. Analysis of developing countries FT is mostly based on case studies and exploring a limited set of drivers that result in forest cover change. This paper attempts to identify and explain trends in forest cover change across nine countries of the Asia Pacific based on panel data of a period of over 50 years (1962–2011). We used discriminant analysis to identify relationships between bio-physical variables (forest cover area and land under cultivation) and socioeconomic variables (GDP, assets and infrastructure), and the transition status (transition vs. no transition) of the countries. The results show a net increase in forest cover in China, India (with consistent increase in the area of agricultural land in both), Philippines and Vietnam; and a decrease in Indonesia, Laos, and Malaysia (with a consistent decrease in the area of agricultural land). They also show a decrease of forest cover and area of agricultural land in both Japan and South Korea. The discriminant analysis results suggest that FT is linked to variation in area of agricultural land (Indonesia, Japan, Malaysia, Philippines, Vietnam), livestock population (China, Indonesia, South Korea, Laos, Malaysia), urban population (India, Laos, Philippines, Vietnam), cereal production (Indonesia, Japan, Philippines), and area of arable land (China and Japan). The results concur with FT predictions of forest cover change in relation to bio-physical and socioeconomic dynamics, with heterogeneity in rates of change across the nine countries. The results have implications for existing FT models. We conclude that there is opportunity for a refinement of analyses and explanations of FT by considering the effect of precise bio-physical and socioeconomic drivers.

1. Introduction

Forest transition (FT) is a possible forest development paths, where direction, magnitude, and speed is influenced by societal factors or drivers (Lambin and Meyfroidt, 2010). FT relates to land use transition, which is a broader change in land use. FT was initially discussed in the early 1990s by Alexander Mather who analyzed recurring patterns of forest cover changes in European countries (Mather, 1990; Mather, 1992; Mather and Fairbairn, 2000). Subsequently, Foster et al. (1998) presented empirical evidence of FT in North America. FT refers to a transition from decreasing (deforestation) to expanding forest cover (reforestation) at a geographical scale (Lambin and Meyfroidt, 2010). FT in a confined geographical region occurs when reforestation begins or increases and exceeds deforestation, which declines or stops (Grainger, 1995). FT also concurs with land use transition, as land used for non-forest purposes becomes designated for forest land use (Barbier et al., 2010). Incorporating land use transition into a FT model implies a delay between the deforestation decline and forest cover increase (Grainger, 1995). After an initial focus on Europe and North America, FT analysis was extended into low per capita GDP countries such as China, India, Vietnam, and Costa Rica and elsewhere (Meyfroidt and Lambin, 2008, 2011; Rudel et al., 2009; Grau et al., 2003; Mather, 2007; Bae et al., 2012).

Many countries are now recognized to have experienced FT, but the conditions under which transition occurs varies from place to place. FT was noticed in northern Europe between 1850 and 1980, but until 1990, FT was not observed in southern Europe (Mather, 1990; McNeill, 1992). European countries had experienced a reversion of deforested lands to forest during the 14th century when the continent suffered from the pneumonic plague (Herlihy, 1997; Poos, 1991), but the majority of them experienced a second wave of FT during the 19th and 20th century. Scotland and Denmark, for instance, experienced FT in early 20th century. As per FAO statistics on forest cover for the past decades, a turnaround of forest cover has occurred in Bangladesh, China, Costa Rica, Cuba, Denmark, Dominican Republic, France, Gambia, Hungary, Ireland, Peninsular Malaysia, Morocco, New Zealand, Portugal,

☆ This article is part of a special issue entitled "Forest transition in Asia: Trends and some theoretical implications".

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http://dx.doi.org/10.1016/j.forpol.2016.07.008
1389-9341/

Puerto Rico, Rwanda, Scotland, South Korea, Switzerland, and the United States (Rudel et al., 2005). China experienced a forest cover turnaround in the second half of the 20th century and other countries much more recently. The majority of countries experienced FT with very low remaining forest cover, however, New Zealand, South Korea, and the United States are exceptions, as these countries had comparatively large areas still under forest when turnarounds occurred. If viewed at a regional scale, forest cover has been expanding in counties in Europe, North America, countries in the Caribbean, East Asia, and Western-Central Asia. Forest cover is still declining in most of Central America, South America, South and Southeast Asia and regions in Africa. Between 1990 and 2015, tropical countries such as India, Bhutan, Laos, Philippines, Vietnam did experience FT and converted net forest loss to net forest expansion (Keenan et al., 2015).

The drivers responsible for FT in developed countries are mostly related to land use transition. The latter, in turn, is causally linked to the increase of production costs and enhanced agricultural technology (Foster, 1992; Andre, 1998; Mather et al., 1999). During the early phases of land use transition, demand for agricultural land and timber along with timber products caused forest clearing and deforestation (Culas, 2012). When economic development progresses, agricultural production costs increase, and agro-technology improves. These two processes result in the abandoning of agricultural lands which then reforest. In addition, demand for forest products may also contribute to reforestation on marginal agricultural land. The two processes have been identified as the economic development and forest scarcity FT pathways (Rudel et al., 2005).

Recent studies recognized the need to draw upon additional reforestation drivers to explain FT in several of the developing countries where FT has been observed (Castaneda, 2009; Perz and Skole, 2003; Mather, 2007; Xu et al., 2007; Sloan, 2015). These include agriculture sector development (Perz and Skole, 2003; Rudel et al., 2005), rural-urban migration, use of new energy sources (DeFries and Pandey, 2010; Tiwari and Bhattarai, 2011), and legislation and policies (Foster and Rosenzweig, 2003). FT in many developing countries can be linked to socioeconomic development, such as rural exodus, agricultural intensification, the establishment of extensive tree plantations, economic industrialization, enhanced education and technical knowledge, and the strengthening of socio-political institutions (Yackulic et al., 2011; Nagendra and Southworth, 2010; Farley, 2010; Rudel, 2009).

In developing countries the drivers themselves are unique, or they may have typical characteristics. For instance, people migrate from rural to urban areas but continue to support the relatives who stay behind through remittances (Rudel et al., 2009). Modest intensification of smallholder agricultural production assures the provision of food crops at relatively low prices, but also may lead to shifts in the overall land use pattern. Lambin and Meyfroidt (2010) and Meyfroidt and Lambin (2011) recognized this and that, therefore, explanations of FT in European countries may not be valid for developing countries. Policies that give higher priority to forests over other land use may be triggered by forest scarcity, but also be inspired by land use modernization efforts, the integration of marginal social groups into mainstream society, or the promotion of culture or ecotourism (Lambin and Meyfroidt, 2010).

Recognizing of at least some unique features of FT in tropical countries has led to the proposal of three additional FT pathways: state forest policy; globalization; and smallholder, tree based land use intensification FT pathways. The state forest policy pathway is defined as FT resulting from policies designed specifically to that end. These policies may also be motivated to achieve objectives other than increasing the provision of forest goods and services (Lambin and Meyfroidt, 2010). The globalization pathway is a modern version of the economic development pathways, which is influenced by the integration of the national economy with global markets and trade, but also economic priorities of multinational players, or development cooperation actors. Developing countries are strongly affected by globalization and neo-liberal economic reforms, labor out-migration, international conservation priorities, and international tourism. This may positively affect national forest cover (Kull et al., 2007). The last pathway, generally poorly accounted for in land use statistics, is a significant increase in tree cover on smallholders' farmland, pastures and fallows in the form of orchards, agroforestry, gardens, and secondary successions. Smallholders may reduce vulnerability to economic and environmental shocks, but they may also intensify land use in some parts of their estates and increase tree cover on others (Ashraf et al., 2015; Lambin and Meyfroidt, 2010). With the identification of multiple pathways it also has become evident that various pathways may be followed concurringly or sequentially. The drivers of FT may vary over time, space and location (Kant and Wu, 2013; Rudel et al., 2010) because of wider economic, social and biophysical changes (Rudel et al., 2005; De Jong, 2010).

Research on FT and FT theoretical development has thus (Rudel et al., 2010) shifted from a focus on developed countries (e.g. Denmark, France, Switzerland, the USA, and Scotland and Austria (Houghton and Hackler, 2000; Mather, 2007; Mather et al., 1998; Mather et al., 1999; Krausmann, 2006) to a focus on less wealthy countries, like Puerto Rico, Dominican Republic, El Salvador, Vietnam, China and India (Aide and Grau, 2004; Grau et al., 2003; Hecht et al., 2006; Mather, 2007; Meyfroidt and Lambin, 2009; Rudel et al., 2005). FT, furthermore, can be analyzed at different scales. It is most commonly analyzed at national scale but can also be analyzed at sub-national and multi-national scales (e.g. Meyfroidt and Lambin, 2011). However, cross-national studies which might empirically support the FT theory are less common. Drivers and underlying causes of deforestation have been evaluated for multiple countries (e.g. Angelsen, 1999; Angelsen and Kaimowitz, 1999; Geist and Lambin, 2001; Grainger, 1995; Lambin et al., 2003; Vanclay, 2005; Redo et al., 2012). Studies attempting cross-national analyses of FT include, for instance Rudel et al. (2005), Mather (2007) and Meyfroidt et al. (2010).

The expanded scope of FT research has reconfirmed that elements of social and economic development affect land use and have a subsequent bearing on forest cover (Bhojvaid et al., 2016). Changes in forest cover have major ecological consequences by directly affecting biodiversity, carbon budget, and soil and watershed conservation (MEA, 2005). Understanding patterns and drivers of forest cover change and possible FT trajectories may contribute to achieving broader societal goals of land-use sustainability in the face of rapid global environmental and socioeconomic changes (Redo et al., 2012). FT is increasingly common, but global deforestation still exceeds forest recovery (Damette and Delacote, 2009; Ewers, 2006; Karsenty, 2008). We postulate here that consideration of more factors based on country circumstances, keeping in mind the discrepancies in growth, development and demand and supply of resources, may result in a better explanations of FT (e.g. Mather, 1992; Grainger, 1995; Mather et al., 1999). It may also lead to the proposition of new FT pathways (Lambin and Meyfroidt, 2010).

In summary, prevailing FT explanations may not be sufficient to understand FT in countries where the process is much more recent, especially when it concerns developing countries with their current pace and pattern of development and industrialization, and employment. We concur with Southworth et al. (2011) that there is need for scrutiny of land and forest use in recent FT countries and to expand the explanations of the process. This is an important reason why we implemented a study on FT in nine countries in Asia: China, Indonesia, India, Japan, Laos, South Korea, Malaysia, Philippines and Vietnam, incorporating social and biophysical factors that are expected to cause FT. The number of cases is too low to definitely establish differences in FT, comparing developing and developed countries. However, we aim to reveal the relative importance of various social and bio-physical factors that explain FT in the nine countries and also to note differences between the countries. Our specific objective is to identify the potential drivers or combination of drivers of FT in each of the case countries, and that way contribute to the further development of the FT theory.

In Section 2 of the paper we briefly summarize relevant information on the Asia-Pacific region necessary for understanding the subsequent analysis. In Section 3, we explain the analytical approach, including a listing of drivers and how they relate to FT. In Section 4 we explain how the model was built, and also discuss how FT can be explained based on aggregation of factors, for instance change in overall dependency on land. We also try to distinguish and link national domestic drivers, or those operating at household, sub-national and national levels and extra-national drivers (Nair, 2013). Section 5 discusses the result of our analysis and Section 6 draws conclusion. In the conclusions we also reflect on the value of FT to plan forest policies, or land use policies and climate change mitigation policies.

2. The Asia-Pacific region

In the recent past, economic growth of Asia-Pacific countries has been much higher than the rest of the world. The region has also seen the highest expansion of tree plantations (FAO, 2010). The nine countries of this study share 45.88% of the world's population and their combined GDP increased from 17.32% in 1985 to 25.89% in 2012 of world's GDP (Liu et al., 2014). Japan and South Korea are high income countries; Malaysia, Indonesia, China, Philippines and India are medium-income countries, while Laos, and Vietnam are considered poor countries (Liu et al., 2014). The nine countries have quite different geographic and socio-economic realities. They followed differentiated economic and political responses to forest and land scarcity, economic growth, and international market integration (Liu et al., 2014), and also varied responses to the perceived consequences of forest area change. For instance, China, India and Vietnam have in recent years witnessed a halt to dramatic deforestation and forest expansion due to large scale forest plantations, while Indonesia and Malaysia still experience the reduction of their tropical forests.

The Asia-Pacific region accounts for around 37% of the global agricultural land area with an annual growth rate of 0.8% over the last two decades (FAO, 2009). This growth rate accounts for the agricultural land expansion in the Asia-Pacific region from 47% of the region's total land area in 1970 to 53% in 2007. The total area of agricultural land is 1.8 billion ha or around 0.5 ha per capita (FAO, 2009), and it concurred with a rapid economic development, technological progress, infrastructure expansion and population growth and mobility (Schandl et al., 2009).

The region's extraordinary economic growth combined with a continuing population growth results in production and consumption demands that outstrip the sustainable production levels of the region's natural resources. These demands have resulted in the expansion and intensification of agriculture and rapid urbanization and in dramatic changes in forest area and composition. Population growth has decreased the agricultural land availability per capita and per agricultural worker (ADB, 2008). In this regard, Japan and the Republic of Korea are industrialized and high population density countries with a long history of agricultural production and industrialization, with limited natural resources. China, India and Indonesia are high population density developing countries with yet substantial agricultural sectors, but which are becoming increasingly urbanised.

3. Analytical approach

The empirical studies on FT for developed as well as developing countries established the relationship between deforestation and Gross Domestic Products (GDP) using cross country data and applying panel ordinary least square (OLS), fixed and random effects models. The estimated models for different locations were found to be linear, quadratic and cubic (Culas, 2012). Encouraged with this, we attempted to establish empirical relationships between forest area change with various country level factors responsible for these changes. Based on the deforestation and reforestation literature, as well as the first author's previous experience with FT in India (Bhojvaid et al., 2016), we consider and hypothesize the factors that are major drivers of deforestation and reforestation. These include various bio-physical, ecological and social drivers such as *agricultural production, agricultural land, arable land, GDP* per capita, *and total, rural and urban population, livestock and poultry population, government policies, infrastructure and industrial growth.*

For the present study, we collected data for 1961 to 2011 for all the above mentioned factors from secondary sources specifically from FAO and the World Bank. We also collected information from the country reports submitted to APAFRI, based on the project Transition to Sustainable Forest Management (APAFRI, 2013). We estimated the few missing data points using the TRAMO method (Gómez and Maravall, 1992, 1994). The statistics of all the factors are reported and represented in Table 1. All these factors are hypothesized to have association with forest cover change, and this association is briefly explained in the following paragraphs.

3.1. Forest cover

Forest cover includes forests and woody vegetation that is within the definition of forest as applied in each of the nine countries. It covers closed and open forest, woodlands and plantation. If the actual area of deforestation and reforestation in a given year is more than the average annual value of deforestation and reforestation over a period of time, then this is expressed as FT, else there is no FT (Table 2). This logic considers that while the country overall forest cover development may not yet reverse the decrease in forest cover, in parts of the country this actually may be happening. Hence we consider FT to start when a persistent reduction in forest cover decline is reflected in national statistics. In addition countries hold a diversity in terms of resources, culture and enforcement of rules and regulation that are valid for the whole country, but they may also be valid for some part of the country. These considerations imply that FT is not immediately evident from the overall national forest statistics. This is reflected in Table 2 that include periods of FT and non FT, as reflected in decreasing and increasing forest cover change status. Rather than considering annual forest cover change as FT, we rely on a broader perspective of FT, as most of the drivers may potentially impact forest cover gradually over a multiannual period. The definition of FT status that we use for our discriminant analysis allows the consideration of the actual scenario of forest cover change over a longer period, but as being triggered by time-bound drivers.

3.2. Agricultural production

Agriculture production refers to the total production of agriculture crops. Agriculture provides employment and contributes to exports. The major strategy in developing counties to increase agricultural production is the expansion of agriculture land into forestland (Angelsen, 1999; Culas, 2012). A large proportion of the population of Asia Pacific still lives in rural areas, and relies on agriculture as a primary livelihood source (FAO, 1998; FAO, 2012). However, forests remain an important source for products and services that contribute to households' livelihoods and emergency safeguards (Angelsen et al., 2014). Based on this, we hypothesize that the increase in *agriculture production*, measured by two proxy variables i.e. *agriculture land (total recorded land under agriculture)* and *arable land (land under cultivation)*, has an important functional link to FT. These two variables vary, as per the recorded data, especially in the developing countries, due to the continued economic progress. The overall contribution of the two proxy variables determine the agricultural production, especially the total annual absolute cereal production of a country, which also contributes to the total GDP of a country. The contribution of agriculture to a country's economy can be measured by the *percent share of agriculture in a country's GDP.* This variable also reflects the contribution of farm mechanisation and technological inputs as the main driver of the increase of agricultural production. Considering the rural settings of developing countries, we hypothesize that a higher share of agriculture to GDP reflects better

Table 1
Descriptive statistics of the drivers of FT.

		FA	GDP	AGA	ARL	AGCONT	CP	LP	PP	SGP	TP	UP	RP
Country	Descriptive statistics	Million ha	Current US$	Million ha	Million ha	% of GDP	M Tonnes	Millions	Millions	Millions	Millions	Millions	Millions
China	Mean ± SE	153.4 ± 4.1	794.3 ± 166.6	459.5 ± 9.21	110.7 ± 1.44	25.6 ± 1.39	331.8 ± 15.6	94.7 ± 3.7	2683.1 ± 274.0	216.2 ± 11.3	1095.1 ± 31.3	329.1 ± 25.4	765.9 ± 12.4
	Min	110.2	69.8	346.0	96.9	10.0	120.4	55.4	679.5	124.0	686.3	121.8	564.5
	Max	209.6	5447.3	527.3	124.4	42.2	520.6	145.0	6486.1	372.9	1399.3	716.7	867.5
India	Mean ± SE	63.6 ± 0.4	394.7 ± 47.1	179.9 ± 0.1	160.9 ± 0.3	173.4 ± 8.3	30.9 ± 1.2	267.7 ± 3.9	314.5 ± 28.9	152.5 ± 5.4	820.3 + _32.7	209.5 + _12.5	610.8 ± 20.3
	Min	59.75	91.68	176.18	156.70	79.70	17.74	225.33	114.50	102.18	467.96	85.25	382.71
	Max	68.58	1539.60	182.57	163.64	287.86	44.53	323.74	968.50	231.50	1221.16	381.93	839.23
Indonesia	Mean ± SE	130.4 ± 4.1	812.1 ± 109.2	42.4 ± 0.5	19.3 ± 0.3	44.4 ± 2.8	26.9 ± 1.9	11.8 ± 0.3	564.8 ± 68.1	16.3 ± 0.74	166.8 ± 6.4	54.7 ± 4.8	112.1 ± 1.9
	Min	93.7	56.6	37.1	17.1	14.0	13.0	8.5	66.0	9.7	93.1	14.0	79.1
	Max	188.6	3471.4	54.6	24.7	84.8	56.3	16.1	1491.7	28.9	243.8	123.6	125.1
Japan	Mean ± SE	24.9 ± 0.1	19,727.7 ± 2155.2	5.8 ± 0.1	4.8 ± 0.05	2.5 ± 0.1	12.1 ± 0.3	4.2 ± 0.1	265.8 ± 9.4	0.1 ± 0.1	116.8 ± 1.5	90.9 ± 2.1	25.8 ± 0.7
	Min	24.9	633.6	4.6	4.3	1.1	8.9	2.9	90.7	0.0	94.3	61.4	11.1
	Max	25.1	46,134.6	7.1	5.6	5.1	16.6	5.0	345.4	1.1	127.4	116.2	32.9
Korea	Mean ± SE	6.4 ± 0.1	6552.3 ± 967.8	2.1 ± 0.1	1.9 ± 0.1	14.3 ± 1.6	7.8 ± 0.1	2.1 ± 0.5	66.3 ± 2.5	0.32 ± 0.1	39.7 ± 0.1	26.1 ± 1.5	13.6 ± 0.6
	Min	6.22	103.57	1.76	1.49	2.64	5.90	1.21	10.44	0.10	26.50	7.81	8.18
	Max	6.60	22,388.20	2.34	2.20	39.36	10.54	3.40	163.61	0.68	48.73	40.56	19.33
Laos	Mean ± SE	17.6 ± 0.1	457.6 ± 52.9	1.7 ± 0.1	0.84 ± 0.1	46.8 ± 2.1	1.6 ± 0.1	1.7 ± 0.1	11.9 ± 0.1	0.11 ± 0.1	4.1 ± 0.1	0.77 ± 0.1	3.3 ± 0.1
	Min	15.67	149.56	1.45	0.64	29.52	0.53	0.75	4.31	0.03	2.22	0.18	2.04
	Max	19.53	1265.71	2.38	1.40	61.81	4.28	2.74	30.31	0.43	6.52	2.23	4.29
Malaysia	Mean ± SE	22.5 ± 0.1	2824.6 ± 344.0	6.3 ± 0.1	1.4 ± 0.1	19.2 ± 1.1	1.9 ± 0.1	0.82 ± 0.1	105.7 ± 10.6	0.44 ± 0.1	17.4 ± 0.9	9.3 ± 0.8	8.1 ± 0.1
	Min	20.37	292.03	4.25	0.84	8.01	1.12	0.62	26.30	0.35	8.71	2.43	6.28
	Max	24.46	10,058.04	7.89	1.91	33.81	2.64	1.02	281.77	0.65	28.76	20.93	9.25
Philippines	Mean ± SE	6.3 ± 0.1	771.3 ± 74.6	10.3 ± 0.2	5.1 ± 0.1	22.2 ± 0.1	12.9 ± 0.8	5.2 ± 0.5	91.6 ± 5.7	3.6 ± 0.1	58.4 ± 2.9	25.7 ± 1.7	32.7 ± 1.1
	Min	5.03	156.69	7.79	4.64	12.31	5.14	4.31	49.85	0.51	28.08	8.65	19.43
	Max	7.72	2357.57	12.10	5.49	31.06	23.74	7.04	173.91	6.73	95.05	46.42	48.63
Vietnam	Mean ± SE	8.5 ± 0.5	536.3 ± 74.2	7.5 ± 0.2	5.8 ± 0.5	27.8 ± 1.7	21.6 ± 1.7	5.7 ± 0.2	126.9 ± 10.4	0.49 ± 0.1	63.6 ± 2.4	14.2 ± 0.1	49.4 ± 1.5
	Min	2.66	97.16	6.30	5.34	18.66	8.63	3.66	53.10	0.16	34.95	5.37	29.58
	Max	13.94	1543.03	10.84	6.65	46.30	47.24	9.72	322.60	1.78	89.91	27.90	62.01

FA = forest area, GDP = GDP per capita, AGA = absolute agricultural area, ARL = absolute arable land, AGCONT = agricultural contribution to GDP %, CP = absolute cereals production, LP = livestock population, PP = poultry population, SGP = sheep and goats population, TP = total population, UP = urban population, RP = rural population,
SE = standard error, Min = minimum, Max = maximum.

Table 2
Country wise period of forest cover change based on annual average forest cover change for 1961–2011.
Source: Elaborated by the authors, based on Bhojvaid et al. (2013), Carandang et al. (2014), Damayanti et al. (2014), Liu et al. (2014), Park and Youn (2014), Tachibana et al. (2014), Razali and Mohd Shahwahid (2014) and Wanneng (2014).

Country	Period of forest cover change status	
	Decreasing	Increasing
China	1962–1985	1986–2011
India	1962–1984; 1991–2000; 2006–2011	1985–1990; 2001–2005
Indonesia	1985–2011	1962–1984
Japan	2001–2011	1962–2000
South Korea	1987–1990; 2001–2011	1962–1986; 1991–2000
Laos	1984–2011	1962–1983
Malaysia	1962–1990	1991–2011
Philippines	1991–2011	1962–1990
Vietnam	1975–2000; 2006–2011	1962–1974; 2001–2005

employment opportunities for rural households. This may concur with agricultural intensification, and subsequently a lower pressure on the forests and thus a moving forward toward FT.

3.3. Economy and population

A high share of absolute rural population residing in poverty ridden rural communities is detrimental to forest cover and forest condition. When incomes increase, demand of agricultural and forest products may increase and this can cause deforestation to accelerate. Higher incomes, however, can reduce pressure on forests as it commonly concurs with an increase in demand for nature values of forests, i.e. scenic beauty or biodiversity protection (Culas, 2012). Consumers progressively seek to improve the quality of life (e.g. Maslow, 1943) and this result also in a demand for services that were less relevant when survival or economic improvement were priorities (Redo et al., 2012). GDP increase will also lead to demand for better quality resources, including wood products, which may result in demand for timber or wood that can only be obtained through imports. When this happens, this may result in an overall reduction of pressure on forests or more support for the protection of forests (Kant and Redantz, 1997), which will have positive impacts on forest cover.

Growth in national population and affluence, therefore, does not necessarily mean continued deforestation, while the economic, social, political and technological progress can contribute to reforestation and related forest recovery (Mather and Fairbairn, 2000). A growing population, however, may also affect the labor market and may push down wage rates and increase unemployment. Unemployment may increase pressures on forests and population pressure may contribute to reduced deforestation when it concurs with and triggers innovation, technological progress and institutional strengthening in the agricultural and forestry sectors (Culas, 2012). Moreover, urban bound migration because of differentiated economic opportunities may also reduce pressure on forests.

3.4. Livestock and poultry

Livestock rearing is an important livelihood opportunity for rural populations and it does reflect land use intensification. Livestock rearing involves the collection of fodder from forests and agricultural fields, and grazing in forests lands (Pandey, 2011). Livestock and poultry therefore may have a negative influence on forests transition. Livestock production, including poultry, may also represent the opportunity to improve income, and reduce dependence on forests, which in turn may facilitate transition. The complexities of the relationship at a broader spatial scale between livestock demand and forest contribution to livelihoods within a wider context of economic development can be considered to favour FT. However, an increase of livestock and poultry production is not likely to reduce pressure on forests when it concerns poor rural agricultural producers.

3.5. Government forest policies and programs

Government device policies and programs to support tree planting including through incentives for local residents (Mukherjee, 1997; Zhang et al., 2000). Forest policies promote forest rehabilitation on poor grasslands, brush lands, scrublands or barren lands, through planting or assisted natural regeneration to produce industrial timber, sustain livelihoods or restore forest ecosystem function (Chokkalingam et al., 2005). Forest policies have been designed to provide economic incentives to villages and for small landowners to produce forest products on their lands resulting in FT (Foster and Rosenzweig, 2003; Mather, 2007; Rudel, 2012). Forest policies also may support conservation forestry, which changes attitude toward forests, forest products use, again contributing to FT (Lambin and Meyfroidt, 2010; Bhojvaid et al., 2016). Forest polices in support of reforestation or forest conservation are an important contribution to FT.

3.6. Infrastructure and industrial growth

Infrastructure development has an indirect link to forest cover, because it influences economic growth. The economic growth resulting from infrastructure development and industrial expansion facilitates FT in a two ways. It improves incomes (Rudel, 1998; Culas, 2012) and thus increases a demand for intangible forest ecosystem services, while it also causes a shift away from livelihoods that rely on forests and forest products. The growth in infrastructure and industrial expansion facilitate globalization that may lead to FT due to labor out migration, growing tourism and land acquisition for the sake of conservation (Lambin and Meyfroidt, 2010). Hence, we hypothesize that infrastructure development and industrial expansion are conducive to FT.

4. Building the model

FT is influenced by a wide array of drivers, including social, economic factors, government forest policies and infrastructure development and industrial expansion. To develop the model, we categorized a dynamic process of related and interacting forest cover decline as FT and no FT. The distinction is that transition countries have passed the FT inflection point and forest cover increase continues to exceed forest cover reduction. Non-transition countries have not yet reached this stage. In a first step to develop the model we undertook a regression analysis to establish statistical relationships between forest areas of individual countries and the drivers of FT in Table 1. The models that emerge from regression analysis demonstrate the complexities of explaining forest area changes based on single contextual variables in the nine countries (Table 2). Based on this analysis and reviewing relevant literature (Cropper and Griffiths, 1994; Koop and Tole, 1999; Shafik, 1994; Antle and Heidebrink, 1995), we conclude that for a better understanding of the complex relationships between drivers and FT a more appropriate approach is to use logistic discriminant functions to analyze multiple contextual variables. We distinguish cases into two statuses, i.e. with or without FT status, and explain the status relying on contextual variables and using discriminant analysis.

4.1. Discriminant function analysis

Discriminant analysis (DA) is a multivariate parametric statistical technique commonly used to build a predictive model of group discrimination based on observed predictor variables (factors), and classifying each observation into one of the groups that are discriminated. The analysis creates a discriminant function, which is a linear combination of the weightings and scores of variables that are considered

(Ramayah et al., 2010). DA also helps to identify important discriminating variables (Khattree and Naik, 1995; Lachenbruch and Mickey, 1968).

Discriminant analysis involves deriving a variate, the linear combination of the independent variables that will discriminate best between the defined groups to be discriminated. The linear combination for a discriminant analysis, also known as the discriminant function (Hair et al., 2005), is derived from an equation that takes the following form:

$D = a + W_1X_1 + W_2X_2 + W_3X_3 + \cdots + W_iX_i$
$D =$ discriminant function (or classification function)
$W_t =$ discriminant coefficients or weights for variable i
$X_i = i^{\text{th}}$ independent variable
$a =$ a constant (intercept)

The case that is subjected to DA is more likely to belong to the group or category for which the classification score is highest. In the present study, we classified FT into two groups: group 1 as cases without FT and group 2 as cases with FT. We used SPSS 16.0 to analyze the data (Agresti, 1996). In the present case, DA is aimed at determining how independent variables as agricultural productivity, livestock and poultry, economy and population, infrastructure and industrial growth discriminate among the members of the two groups, the status of FT i.e. FT and no FT.

5. Results

The summary statistics reflect very diverse developments of the various variables across the countries of the Asia Pacific region. The forest areas of China, India, Philippines and Vietnam show an increase over the last five decades, whereas Indonesia, Laos and Malaysia show a continuing decrease. Japan demonstrates a marginal increment in forest area and the forest area of Korea has declined slightly.

The cereal production of China, India, Indonesia, Laos, Malaysia, Philippines and Vietnam has consistently increased during the last few decades. Japan and Korea, on the other hand, show a decline in cereal production. The agricultural area of China, India, Indonesia, Laos, Malaysia, Philippines and Vietnam increased consistently, while they decreased in Japan and South Korea. The GDP per capita for all the developing economies started to increase slowly during the early 1960s and 1970s, but a rapid growth rate is observed during the last two decades. The population is growing consistently in all the nine countries, as is the urban population. The rural population of China, Indonesia, South Korea and Malaysia dropped consistently with a deep drop in Japan, whereas the rural population of India, Laos, Philippines and Vietnam increased in parallel with the overall population.

FT is the result of an individual factor or the aggregation of several factors. We first explored if individual factors might explain FT by regressing factors with the forest area as the indicator of FT, and assessing the relationship based on a curve fitting module and selected through model statistics. We tested different functions like linear, quadratic, cubic, exponential and logarithmic for factors identified above. We selected simple regression models with value > 0.80 to define the relationship of the driver with FT. The most suitable models that account for the variation of forest area are listed in Table 3, but the exact models were not all reported due to their limited use in the paper. The models reflect the tentative trend of individual factors in relation to FT. We discuss the individual models separately to arrive at our concluding remarks on the contextual drivers that explain FT.

The per capita GDP shows a linear relationship with forest areas in all countries except Japan, where it has a cubic relationship. This indicates that with the increase of per capita GDP, transition remains i.e. if a country experiences a growing per capita GDP, the forest area may also increase, provided other factors don't affect the phenomenon. China, Japan, Laos, Philippines and Vietnam have cubic relationships between forest area and agricultural area. India has an exponential relation between the two variables while Indonesia has a quadratic relationship and South Korea and Malaysia a linear relationship between the two variables. These results indicate that the agriculture area determines the forest area. However, the relationship varies between countries, probably due to the different shares of land under other activities, out of the total fixed area of the country.

Japan and South Korea have quadratic relations between forest area and arable land, whereas Laos and Malaysia have cubic functions between forest area and arable land. The rest of the countries do not demonstrate any functional relationship between the two variables. This increases the understanding of the complexities of the role of arable land in the processes of FT and the low technical inputs for the development of fertile lands in the majority of the economies reviewed.

Korea, Malaysia and Vietnam have a linear relationship of agricultural contribution to GDP and forest area. India, Indonesia, Laos and Philippines demonstrate a quadratic relationship, while China has a logarithmic function between the two variables. The latter because of China's capacity to sustain food production for its population. The role of population in FT varied also between countries. However, more important than population appears to be population density (Table 3).

In summary, our findings suggest that forest area of any country is not pre-determined by any single factor that overly determines FT. Neither is the relative importance of single variables the same in each country, given the variation in magnitudes of single variables. Therefore, assessing the importance of individual factors is not sufficient to explain the complex phenomenon of FT. Rather, FT is defined by an aggregate role of FT factors, while variables have their own precise characteristic. This conclusion warrants the application of multivariate techniques that actually can assess the combined role of the drivers of FT.

The discriminant function analysis results in a non-multicolinearity for selected independent variables. This was judged based on the matrix of average correlations within groups, which was < 0.54 for all combinations of the variables for all countries. The results of the stepwise discriminant analysis distinguish between the two groups, i.e. FT and no FT, judged by the significance of Wilks` lambda for all countries. The model is constituted of two to five variables at the most for different countries, and this allows the classification of groups. The basis of the

Table 3
Functional relationship of forest area with potential drivers for nine developing economies.

Parameters	China	India	Indonesia	Japan	South Korea	Laos	Malaysia	Philippines	Vietnam
GDP per capita	LIN	LIN	LIN	CUB	LIN	LIN	LIN	LIN	LIN
Agricultural area	CUB	EXP	QUAD	CUB	LIN	CUB	LIN	CUB	CUB
Arable land	NA	NA	NA	QUAD	QUAD	CUB	CUB	NA	NA
Agriculture contribution to GDP %	LOG	QUAD	QUAD	CUB	LIN	QUAD	LIN	QUAD	LIN
Cereal production	QUAD	EXP	QUAD	LIN	LIN	CUB	QUAD	CUB	CUB
Livestock population	CUB	EXP	EXP	CUB	LIN	EXP	QUAD	QUAD	CUB
Poultry population	CUB	CUB	LIN	NA	CUB	NA	CUB	LOG	LOG
Sheep and goats population	CUB	QUAD	CUB	LOG	QUAD	QUAD	NA	LIN	CUB
Total population	EXP	CUB	CUB	QUAD	QUAD	CUB	LIN	QUAD	LIN
Urban population	CUB	CUB	QUAD	QUAD	CUB	CUB	QUAD	QUAD	CUB
Rural population	NA	QUAD	QUAD	NA	LIN	CUB	NA	CUB	LIN

CUB = cubic, EXP = exponential, LIN = linear, LOG = logarithmic, QUAD = quadratic, NA = no relationship (weak relationship).

Table 4
Fisher's linear discriminant functions and associated statistics.

Country	Significant variables	Standardized coefficients	Structured coefficients	Wilks' lambda	Eigen value	Canonical correlation
China	Arable land (ARL)	0.95	0.62	0.08*	10.96	0.96
	Livestock population (LP)	0.96	0.53			
India	Agriculture contribution to GDP % (AGCONT)	5.10	0.61	0.72*	0.34	0.53
	Urban population (UP)	4.56	−0.46			
Indonesia	Cereals production (CP)	−1.26	0.38	0.05*	18.72	0.97
	Agricultural area (AGA)	−1.32	0.26			
	GDP per capita(GDP)	2.29	0.16			
	Livestock population (LP)	1.32	0.55			
	Rural population (RP)	1.14	0.33			
Japan	Cereals production (CP)	−0.66	0.10	0.02*	62.78	0.99
	Agricultural area (AGA)	11.10	0.23			
	Arable land (ARL)	−3.90	0.20			
	GDP per capita(GDP)	2.72	−0.10			
	Total population (TP)	4.22	−0.10			
South Korea	GDP per capita(GDP)	−0.72	−0.53	0.24*	3.25	0.87
	Livestock population (LP)	0.91	−0.17			
	Sheep and goat population (SGP)	1.48	−0.02			
	Rural population (RP)	1.87	0.43			
Laos	Livestock population (LP)	1.00	0.84	0.15*	5.50	0.92
	Urban population (UP)	−0.84	0.44			
	Rural population (RP)	0.62	0.85			
Malaysia	Agricultural area (AGA)	1.97	0.73	0.11*	8.37	0.97
	Livestock population (LP)	−0.48	0.37			
	Rural population (RP)	−1.10	0.24			
Philippines	Agricultural area (AGA)	−1.12	0.36	0.12*	7.40	0.94
	Cereals production (CP)	−1.36	0.51			
	Urban population (UP)	2.95	0.71			
Vietnam	Agricultural area (AGA)	−1.87	0.10	0.32*	2.14	0.84
	Poultry population (PP)	−4.68	0.11			
	Urban population (UP)	6.68	0.25			

* Significant at 5%.

values of Wilks` lambda for particular variables allowed the determination of the relative contribution of each individual variable to discrimination between groups. We also estimated structured and standardized coefficients to define relative strength of the discriminant variables and for evaluating the unique contribution of independent variables to the discriminant function, respectively. We discuss the emerging potential factors that shape FT for each country.

China's economic development, industrialization, and urbanization have led to some of the most significant land use changes observed in the Asia-Pacific region, including the largest net annual gains in both forest and agricultural areas. The discriminant function analysis reveals that arable land and livestock population explain correctly the transition, as evident by the structured function. The canonical correlation of 0.96 suggests the model explains 92% of the variation in defining transition and no transition (Table 4). This can be explained based on the apparent increase in the overall agriculture productivity against the increase in arable land (Jianga et al., 2013). China has expanded its agricultural land significantly between 1970 and 2005 (ADB, 2008). Moreover, intensification of agricultural land use occurred due to high agricultural investments in China during recent decades (Jianga et al., 2013). The livestock contribution to FT may be explained based on its added value of household productive activities, which results in improved land use efficiencies. For instance, ADB (2008) reports that rural land use has intensified from 22.7 m^2 per US$ GDP in 1990 to 15.4 m^2 per US$ GDP in 2005.

India, is a food self-sufficient country, which because of the ‘green revolution’ witnessed very little change in agriculture land area, but with notable alterations in cropland and continued industrialization and urbanization. Agricultural GDP has grown since 1970, but the share of agriculture in the country's total GDP has declined from 39% in 1970 to 17% in 2005. The discriminant function based on two variables namely agricultural contribution to GDP % (+ve) and urban population (−ve) attributed to 0.53 canonical correlation which explained 28% of the variation (Table 4). Though relatively the share of agriculture in GDP is decreasing, the absolute volume of agriculture GDP is increasing (ADB, 2008). Agricultural land conversion has become a serious issue in the country and resulted into a decrease in the net sown area by about 1.8 million ha between the triennium ending 1991–92 and 2011–12, contrary to an increase of about 5 million ha of land during the same period for non-agricultural uses, especially urbanization, road infrastructure expansion and industrial development (Sharma, 2015). The forest cover is steady since the last few decades and therefore increase in agriculture GDP is attributed to agriculture intensification. Rural land use efficiency has improved, intensifying from 28.0 m^2 per US$ GDP in 1990 to 18.8 m^2 per US$ GDP in 2005 (ADB, 2008). The inverse relationship of urban population and FT may be understood as that household welfare requirements are not met, resulting in more forest extraction to meet daily needs. Extractive pressures on the environment would be expected to maintain the pace of a transitional economy to attain an industrialized one (UNEP, 2013).

Indonesia, richly endowed with natural resources, supporting a large and growing population faces significant and continued deforestation with low changes of the agricultural land area. The discriminant function attributed the five major factors of the transition. Intensity wise, the factors of influence are respectively livestock population, cereals production, rural population, agricultural area, and per capita GDP (Table 4). In Indonesian scenarios, the contribution of these variables for transition is apparent. The statistics also support this view as they report the expansion occurred in both arable land and cropland areas. Cash cropping, specifically oil palm, the increase in per capita GDP as well as improved rural land use efficiency, intensified rural land use from 44.8 m^2 per US$ GDP in 1990 to 28.2 m^2 per US$ GDP in 2005 (ADB, 2008).

Japan is the country that has the most intense land use in the Asia-Pacific region, with a total managed land use intensity of 0.09 m^2 per US$ GDP in 2005. The country has a stable forest land area (ADB, 2008). The strong significant canonical correlation (0.99) of discriminant function reflects a correlation between the discriminating variables and transition and no transition group. Based on the structure coefficient value, it can be concluded that transition is mainly determined positively by agricultural area, arable land, and cereals production. However GDP per capita, and total population adversely impact FT (Table 4). The results suggest that in industrialized Japan, the transition may be facilitated by improving overall agriculture productivity. The relative importance of Japan's agricultural sector has declined from a contribution of around 5% to the country's total GDP in the 1970s to approximately 1% by the late-1990s (World Bank, 2009).

South Korea has made larger improvements in land use efficiency with a stable forest land area, and a decline in agricultural land area, agricultural land per capita, and overall importance of the agricultural sector to the country's economy (ADB, 2008). The four variable model derived from discriminant analysis identifies the transition with positive influence of rural population and adverse impact transition due to GDP per capita, livestock population, and sheep and goat population (Table 4). Probably, the cattle population may be highly dependent on forests fodder leading to loss of forest areas. The results suggest that a reduction of the population of livestock, sheep and goat would support FT. South Korea recorded an increase in the amount of GDP generated by the sector, demonstrating the presence of a greater ability for efficiency improvements with the continuing industrialization of its agricultural sector (ADB, 2008).

The Lao People's Democratic Republic (*Laos*), with a densely forested mountainous landscape, has a low population density with a high share of the agricultural sector in GDP. The agricultural land area has steadily risen since 1970, initially resulting in an increase in agricultural GDP. This increase was reversed with the growth in the country's industry, manufacturing, and services sectors. The agricultural GDP relative importance declined from a 56% share in 1984 to 37% in 2005. The three main variables that explain transition are in order of importance: rural population, livestock population, and urban population (Table 4).

Malaysia, facing an annual forest area declining rate of 1.94%, with a slow increase of arable land has a high constant rate for population growth and a growing GDP. The rate of urbanization is also very high and the rural population has decreased consistently (Razali and Mohd Shahwahid, 2014). The discriminant analysis leads to a three variables model with agricultural area, livestock population and rural population that explain FT in Malaysia (Table 4). The increase in agriculture area, in combination with a growing GDP are linked to employment improvement and value adding of raw materials from the livestock sector that are produced domestically. This can be linked to lowering of forest extraction and this has a positive influence on FT.

Philippines' commercial logging and conversion of forest to agricultural land are the main factors causing a decline of forest area in the country, as the country shows consistent growth in agricultural and arable land. The population of the country has demonstrated a linear increase, but only a marginal growth in GDP (Carandang et al., 2014). The urban population, cereals production and agricultural area are the main factors that influence FT (Table 4). The improved status of cereals production and agricultural area coupled with the urban population lead to the lowering of the dependency on the forests, and this causes the path that FT has followed.

Vietnam is a small country with a growing economy of 7.5% average annual GDP growth rate. The growth resulted in a dramatically decrease in natural forest area (MARD, 2008). The decrease in forest area caused serious economic, social and environmental consequences resulting in poor supply of forest product, more frequent and destructive flooding and draughts, decreasing agricultural productivity because of land degradation, and acute shortage of water supply (Hoang et al., 2009). The natural forest cover and total forest cover area have reversed since about the mid-1990s (e.g. De Jong et al., 2006). The discriminant analysis leads to define transition based on urban population, poultry population, and agricultural area with high canonical correlation (Table 4). The link between FT and the increase in urban population and agriculture area is apparent. Urban migration and concurring increase of agriculture area lead to better household economic status and a resulting lower dependency on forests. The contribution of the poultry sector can be explained that it improves rural incomes, which further reduces reliance on forests.

6. Conclusions

The fundamental cause of deforestation and then reforestation relates to the change in society's dependence on land. The direct causes of deforestation are fairly well known and understood: the conversion of forested land to agricultural land by shifting cultivators, conversions to commercial agriculture, plantations, commercial logging and forest destruction for roads, mining and hydropower dams (Myers, 1994). Developing countries are not in a position to reduce deforestation activities without compensation of developed economies due to economic pressure (Culas, 2012). High population pressure leads to high demand of agricultural land and timber requirement resulting into deforestation. FAO's Global Forest Resources Assessment (FAO, 2005), for instance, suggested the linkage of forest-cover with population and proved that population growth has a link with historical decline of forests, but the relationship between population and forests transition is poorly understood.

The result of the analysis of the nine countries in this paper is being reinforced by the conclusion reported in UNEP's “Resource Efficiency: Economics and Outlook for Asia and the Pacific” (UNEP, 2011). The report highlights that the Asia-Pacific's transition from an agrarian socio-ecological regime into an industrialized one is still in the early phases, and agricultural land expansion has occurred at 6% rates from 1970 to 2007, while a net decline in forest area ceased between 2000 and 2005, primarily because of large-scale reforestation activities. The analysis of land cover change in the Asia Pacific region during the past half century provides an excellent example of the association between bio-physical and socioeconomic variation and forest cover change. Although undoubtedly there are divers acting at transnational influences on land-use change that are not captured by our indicators, we have been able to provide a deeper understanding of FT complexities by showing the importance of the heterogeneity of influencing patterns of forest cover change, with implications for countries' overall FT pathways.

Forest cover and population are inversely related, however only up to a certain point and the relationship is mitigated by other factors. Theoretically, rapid increase in population might exert pressure on forests, especially through expansion of the arable area, while a dwindling population leads to forest recovery, especially if agricultural land is abandoned (Mather et al., 1999). Additionally, the scarcity of timber and industrialization are generally viewed as accounting for FT (Rudel, 1998). The asymmetry in patterns between neighbouring countries, described here, based on bio-physical and socio-economic indicators has implications both for the refinement of the FT model particularly for the countries reviewed in this paper, and the drivers of forest cover change. It also has implications for understanding the consequences of forest cover change in relation to bio-physical and socioeconomic adaptations and adjustments for a country's development and globalization. There are also practical implications of these asymmetric patterns of forest cover change that should be evaluated when developing strategies that aim to address forest-based solutions for climate mitigation, conserving biodiversity and boosting environmental services. In addition, ‘forest’ is not a homogenous category and countries experience different rates and trajectories of land use change because of different demand led variability in bio-physical and socioeconomic factors.

Demographic changes, particularly population growth, its density and distribution greatly influence the quality and extent of forests, especially in the Asia-Pacific region. Few developing economies have very high population densities with a large proportion of people living in rural areas relying on farming, animal husbandry, fishing and such other activities with land and labor as key factors of production (Nair, 2013). Industrialisation along with urbanization need not always reduce the dependency on land as the increasing demand for food and fuel will have to be provided by the rural economy. This is especially the case when income increases enhance the demand for food and other products (Nair, 2013).

With their fast growing economies, China' India and Vietnam have addressed deforestation and have a relatively stable land cover configuration. These patterns, however, vary significantly among developing economies. The countries with stabilized economies such as Japan, and South Korea early on addressed forest loss without prioritizing agriculture and rural development, but still managed to revert forest covers. On the other hand, the countries with a long history of deforestation and land use change such as Indonesia, Malaysia, and Philippines have optimized agriculture productivity based on a feed materials use from feed based on marine products to agriculture products. FT pathways in developing economies are complex, need to be explained using a combination of drivers, and overarching patterns or FT pathways do not seem the most appropriate explanatory models.

Acknowledgements

We are thankful to anonymous reviewers for their thoughtful comments about the earlier version of this article. The authors also thank APFNet for its support to the India study that was part of the project: Transition to sustainable forest management and forest rehabilitation in the Asian region.

References

ADB, 2008. Toward Resource-Efficient Economies in Asia and the Pacific. Asian Development Bank, Manila, Philippines/Kanagawa, Japan.
Aide, T.M., Grau, H.R., 2004. Globalization, migration, and Latin American ecosystems. Science 305, 1915–1916.
Agresti, A., 1996. An Introduction to Categorical Data Analysis. John Wiley and Sons.
Andre, M., 1998. Depopulation, land-use change and landscape transformation in the French Massif Central. Ambio 27 (4), 351–353.
Angelsen, A., 1999. Agricultural expansion and deforestation: modeling the impact of population, market forces and property rights. J. Dev. Econ. 58, 185–218.
Angelsen, A., Kaimowitz, D., 1999. Rethinking the causes of deforestation: Lessons from economic models. World Bank Res. Obs. 14 (1), 73–98.
Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N., Bauch, S., et al., 2014. Environmental income and rural livelihoods: A global-comparative analysis. World Dev.
Antle, J.M., Heidebrink, G., 1995. Environment and development: theory and international evidence. Econ. Dev. Cult. Chang. 43, 603–625.
APAFRI, 2013. Transition to sustainable forest management. The enabling roadmap. Available at http://www.apafri.org/publications/Forest%20Transition%20Extended%20Abstracts.pdf.
Ashraf, J., Pandey, R., De Jong, W., 2015. Factors influencing farmers' decision to plant trees on their farms in Uttar Pradesh, India. Small Scale For. 14 (3), 301–313.
Bae, J., Joo, R., Kim, Y., 2012. Forest Transition in South Korea: Reality, path and drivers. Land Use Policy 29, 198–207.
Barbier, E.B., Burgess, J.C., Grainger, A., 2010. The forest transition: towards a more comprehensive theoretical framework. Land Use Policy 27, 98–107.
Bhojvaid, P.P., Singh, M.P., Ashraf, J., Reddy, S.R., 2013. Country Report on 'Transitions to Sustainable Forest Management and Rehabilitation in Asia-Pacific Region - INDIA'. Forest Research Institute, Dehradun.
Bhojvaid, P.P., Singh, M.P., Reddy, S.R., Ashraf, J., 2016. Forest transition curve of India and related policies, acts and other major factors. Trop. Ecol. 57 (2), 133–141.
Carandang, A. P., Pulhin, J. M., Camacho, L. D., Camacho, S. C., Paras, F. D., Peter Jerome B. Del Rosario, P. J. B. D. and Tesoro, F. O. 2014. Transition to sustainable forestry management and rehabilitation in Philippines. Unpublished country report, APAFRI.
Castaneda, H. 2009. Analysis of the spatial dynamics and drivers of forest cover change in the Lempa river basin of El Salvador. Unpublished D. Phil Dissertation, University of Florida, Florida.
Chokkalingam, U., Sabogal, C., Almeida, E., Carandang, A.P., Gumartini, T., De jong, W., Brienza, S., Meza, A., Murniati, Nawir, A., Rumboso, L., Toma, T., Wollenberg, E., Zhou, Z., 2005. Local participation, livelihood needs and institutional arrangements: three keys to sustainable rehabilitation of degraded tropical forestlands. In: Mansourianm, S., Vallauri, D., Dudley, N. (Eds.), Forest Restoration in Landscapes. Springer, New York, pp. 405–414.
Cropper, M., Griffiths, C., 1994. The interaction of population growth and environmental quality. Am. Econ. Rev. 84, 250–254.
Culas, R.J., 2012. REDD and forest transition: tunnelling through the environmental Kuxnet curve. Ecol. Econ. 79, 44–51.
Damayanti, E. K., Prasetyo, L. B., Kartodiharjo, H. and Purbawiyatna, A. 2014. Transitions to sustainable forest management and rehabilitation in the Asia Pacific region, Indonesia. Unpublished country report, APAFRI.
Damette, O., Delacote, P., 2009. The environmental resource curse hypothesis: the forest case. Working Paper INRA-LEF.
De Jong, W., 2010. Forest rehabilitation and its implication for forest transition theory. Biotropica 42 (1), 3–9.
De Jong, W., Ruiz, S., Becker, M., 2006. Conflicts on the way to communal forest management in northern Bolivia. Forest Policy Econ. 8, 447–457.
DeFries, R., Pandey, D., 2010. Urbanization, the energy ladder and forest transitions in India's emerging economy. Land Use Policy 27, 130–138.
Ewers, R.M., 2006. Interaction effect between economic development and forest cover determinate deforestation rates. Glob. Environ. Chang. 16, 161–169.
FAO, 1998. Sustainable development dimensions special: biodiversity for food and agriculture. Posted February 1998 and retrieved 3 April 2006 from http://www.fao.org/sd/EPdirect/EPre0043.htm.
FAO, 2005. Global Forest Resources Assessment. Food and Agriculture Organization of the United Nations, Rome.
FAO, 2009. FAOSTAT Data. FAO, Rome.
FAO, 2010. State of the World's Forests. FAO, Rome.
FAO, 2012. State of the World's Forests. Food and Agriculture Organization of the United Nations, Rome.
Farley, K.A., 2010. Pathways to forest transition: local case studies from the Ecuadorian Andes. J. Lat. Am. Geogr 9, 7–26.
Foster, D., 1992. Land-use history (1730–1990) and vegetation dynamics in central New England, USA. J. Ecol. 80, 753–772.
Foster, D.R., Motzkin, G., Slater, B., 1998. Land-use history as long-term broad-scaledisturbance: regional forest dynamics in Central New England. Ecosystems 1 (1), 96–119.
Foster, A.D., Rosenzweig, M.R., 2003. Economic growth and the rise of forests. J. Econ. 118, 601–637.
Geist, H.J., Lambin, E.F., 2001. What Drives Tropical Deforestation? A Meta-Analysis of Proximate and Underlying Causes of Deforestation Based on Subnational Case Study Evidence. Louvain-la-Neuve (Belgium): LUCC International Project Office, LUCC Report Series no. 4.
Gómez, V., Maravall, A., 1992. Time series regression with ARIMA noise and missing observations – program TRAMO. EUI Working Paper ECO No. 92/81.
Gómez, V., Maravall, A., 1994. Estimation, prediction and interpolation for nonstationary series with the Kalman filter. J. Am. Stat. Assoc. 89, 611–624.
Grainger, A., 1995. The forest transition: an alternative approach. Area 27, 242–251.
Grau, H.R., Aide, T.M., Zimmerman, J.K., Thomlinson, J.R., Helmer, E., Zou, X., 2003. The ecological consequences of socioeconomic and land-use changes in postagricultural Puerto Rico. Bioscience 53, 1159–1168.
Hair, J.F., Tatham, R.L., Anderson, R.E., Black, W., 2005. Multivariate Data Analysis. Cornell University, Prentice hall of India.
Hecht, S.B., Kandel, S., Gomes, I., Cuellar, N., Rosa, H., 2006. Globalization, forest resurgence, and environmental politics in El Salvador. World Dev. 34, 308–323.
Herlihy, P., 1997. Indigenous Peoples and Biosphere Reserve Conservation in the Mosquitia Rainforest Corridor, Honduras. In: Stevens, S. (Ed.), Conserva tion Through Cultural Survival. Island Press, Washington DC, USA, pp. 99–129.
Hoang, T.C., Schuler, L.J., Rogevich, E.C., Bachman, P.M., Rand, G.M., Frakes, R.A., 2009. Copper release, speciation, and toxicity following multiple floodings of copper enriched agriculture soils: implications in Everglades restoration. Water Air Soil Pollut. 199, 79–93.
Houghton, R.A., Hackler, J.L., 2000. Changes in terrestrial carbon storage in the United States: 1. The roles of agriculture and forestry. Glob. Ecol. Biogeogr. 9, 125–144.
Jianga, L., Deng, X., Seto, K.C., 2013. The impact of urban expansion on agricultural land use intensity in China. Land Use Policy 35, 33–39.
Kant, S., Redantz, A., 1997. An econometric model of tropical deforestation. J. For. Econ. 3 (1), 51–86.
Kant, P., Wu, S., 2013. Forest transitions across ages and continents: implications for REDD. IGREC Working Paper IGREC 27/2013. Institute of Green Economy, New Delhi.
Karsenty, A., 2008. The architecture of proposed REDD schemes after Bali: facing critical choices. Int. For. Rev. 10 (3), 443–479.
Keenan, R.J., Reams, G.A., Achard, F., de Freitas, J., Grainger, A., Lindquist, E., 2015. Dynamics of global forest area: results fron the FAO global Forest resources assessment 2015. For. Ecol. Manag. 352, 9–20.
Khattree, R., Naik, D.N., 1995. Applied Multivariate Statistics with SAS Software Cary NC. SAS Institute Inc. Chapter 1.
Koop, G., Tole, L., 1999. Is there an environmental Kuznets curve for deforestation? J. Dev. Econ. 58, 231–244.
Krausmann, F., 2006. Forest transition in Österreich: Eine sozialökologische Annäherung. Mitt. Österr. Geol. Ges. 148, 75–91.
Kull, C.A., Ibrahim, C.K., Meredith, T.C., 2007. Tropical forest transitions and globalization: neo-liberalism, migration, tourism, and international conservation agendas. Soc. Nat. Resour. 20 (8), 723–737.
Lachenbruch, P.A., Mickey, M.A., 1968. Estimation of error rates in discriminant analysis. Technometrics 10, 1–10.
Lambin, E.F., Geist, H.J., Lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions. Annu. Rev. Environ. Resour. 28, 205–241.
Lambin, E.F., Meyfroidt, P., 2010. Land use transitions: socio-ecological feedback versus socio-economic change. Land Use Policy 27, 108–118.
Liu, J., Lin L., Hexing, L., Ming, L., Jiayun, D. Minghui, Z. and Ke, W. 2014. Forest transition to sustainable forestry management and rehabilitation in China. Unpublished country report, APAFRI.
MARD, 2008. Minister of Agriculture and Rural Development. Socialist Republic of Vietnam.
Maslow, A.H., 1943. A theory of human motivation. Psychol. Rev. 50 (4), 370–396.
Mather, A.S., 1990. Global Forest Resources. Belhaven Press, London.
Mather, A.S., 1992. The forest transition. Area 24 (4), 367–379.
Mather, A.S., 2007. Recent Asian forest transitions in relation to forest transition theory. Int. For. Rev. 9 (1), 493–502.

Mather, A.S., Fairbairn, J., 2000. From floods to reforestation: the forest transition in Switzerland. Environ. Hist. 6, 399–421.
Mather, A.S., Needle, C.L., Coull, J.R., 1998. From resource crisis to sustainability: the forest transition in Denmark. Int. J. Sustain. Dev. World Ecol. 5 (3), 182–193.
Mather, A.S., Fairbairn, J., Needle, C.L., 1999. The course and drivers of the forest transition: the case of France. J. Rural. Stud. 15 (1), 65–90.
McNeill, J., 1992. The Mountains of the Mediterranean World. Cambridge University Press, Cambridge, UK.
MEA, 2005. Ecosystem and Human Well-Being: Synthesis. Millennium Ecosystem Assessment Island Press, Washington, DC.
Meyfroidt, P., Rudel, T.K., Lambin, E.F., 2010. Forest transitions, trade, and the global displacement of land use. Proc. Natl. Acad. Sci. U. S. A. 107, 20917–20922.
Meyfroidt, P., Lambin, E.F., 2009. Forest transition in Vietnam and displacement of deforestation abroad. Proc. Natl. Acad. Sci. U. S. A. 106, 16139–16144.
Meyfroidt, P., Lambin, E.F., 2008. The causes of the reforestation in Vietnam. Land Use Policy 25, 182–197.
Meyfroidt, P., Lambin, E.F., 2011. Global forest transition: prospects for an end to deforestation. Annu. Rev. Environ. Resour. 36, 343–371.
Mukherjee, S.D., 1997. Is handing over forests to local communities a solution to deforestation? Indian Forester 123 (6), 460–471.
Myers, N., 1994. Tropical deforestation: rates and patterns. In: Brown, K., Pearce, D.W. (Eds.), The Causes of Tropical Deforestation: The Economic and Statistical Analysis of Factors Giving Rise to the Loss of the Tropical Forest. UCL Press, London.
Nagendra, H., Southworth, J., 2010. Reforesting Landscapes: Linking Pattern and Process. Springer, Dordrecht.
Nair, C.T.S., 2013. Societal changes and forest transition: the outlook for the Asia-Pacific region. Pp 1–8 in, APAFRI. International Symposium on Transition to Sustainable Forest Management and Rehabilitation: The Enabling Environment and Road Map Available at: http://www.apafri.org/publications/Forest%20Transition%20Extended%20Abstracts.pdf.
Pandey, R., 2011. Forestry's contribution to livestock feed in Uttarakhand, India: a quantitative assessment of volume and economic value. Folia Forestalia Pol. Ser. A 53 (2), 156–168.
Park, M.S., Youn, Y., 2014. Country Report 'Transition to Sustainable Forestry Management and Rehabilitation in the Republic of Korea', Research Institute for Agriculture and Life Sciences. Seoul National University.
Perz, S.G., Skole, D.L., 2003. Secondary forest expansion in the Brazilian Amazon and the refinement of forest transition theory. Soc. Nat. Resour. 16, 277–294.
Poos, L., 1991. A Rural Society after the Black Death: Essex 1350–1525. Cambridge University Press, Cambridge, UK.
Ramayah, T., Ahmad, N.H., Halim, H.A., Zainal, S.R.M., Lo, M.C., 2010. Discriminant analysis: an illustrated example. Afr. J. Bus. Manag. 4 (9), 1654–1667.
Razali, W.M., Mohd Shahwahid, H.O., 2014. Country Report 'Transitions to Sustainable Forest Management and Rehabilitation in Malaysia'. Universiti Putra Malaysia.
Redo, D.J., Grau, H.R., Aide, T.M., Clark, M.L., 2012. Asymmetric forest transition driven by the interaction of socioeconomic development and environmental heterogeneity in Central America. PNAS 109 (23), 8839–8844.
Rudel, T.K., 1998. Is there a forest transition? Deforestation, reforestation and development. Rural. Sociol. 63 (4), 533–552.
Rudel, T.K., 2009. Tree farms: driving forces and regional patterns in the global expansion of forest plantations. Land Use Policy 26, 545–550.
Rudel, T.K., 2012. The human ecology of regrowth in the tropics. J. Sustain. For. 31, 340–354.
Rudel, T.K., Coomes, O.T., Moran, E., Achard, F., Angelsen, A., Xu, J., Lambin, E., 2005. Forest transitions: towards a global understanding of land use change. Glob. Environ. Chang. 15, 23–31.
Rudel, T.K., Schneider, L., Uriarte, M., Turner II, B.L., DeFries, R., Lawrence, D., Geoghegan, J., Hecht, S., Ickowitz, A., Lambin, E.F., Birkenholtz, T., Baptista, S., Grau, R., 2009. Agricultural intensification and changes in cultivated areas, 1970–2005. Proc. Natl. Acad. Sci. U. S. A. 106, 20675–20680.
Rudel, T.K., Schneider, L., Uriarte, M., 2010. Forest transitions: an introduction. Land Use Policy 27, 95–97.
Schandl, H., Fischer-Kowalski, M., Grunbuhel, C., Krausmann, F., 2009. Socio-metabolic transitions in developing Asia. Tech. Forcasting Soc. Chang. 76, 267–281.
Shafik, N., 1994. Economic development and environmental quality: an econometric analysis. Oxf. Econ. Pap. 46, 757–773.
Sharma, V.P., 2015. Dynamics of land use competition in India: perceptions and realities. W.P. No. 2015-06-02, IIM, Ahmedabad.
Sloan, S., 2015. The development driven forest transition and its utility for REDD+. Ecol. Econ. 116, 1–11.
Southworth, J., Nagendra, H., Cassidy, L., 2011. Forest transition pathways in Asia – studies from Nepal, India, Thailand, and Cambodia. J. Land Use Sci 7, 51–65.
Tachibana, S., Shiga, K., Ota, M., 2014. Country Report 'Transition to Sustainable Forestry Management and Rehabilitation in Japan'. University of Tsukuba, Tsukuba, Japan.
Tiwari, S., Bhattarai, K., 2011. Migration, remittances and forests: disentangling the impact of population and economic growth on forests. Policy Research Working Paper 5907. The World Bank, Washington.
UNEP, 2011. Resource Efficiency: Economics and Outlook for Asia and the Pacific: Key Messages and Highlights. UNEP Regional Office for Asia and Pacific, Thailand.
UNEP, 2013. Recent Trends in Material Flows and Resource Productivity in Asia and the Pacific. UNEP Regional Office for Asia and Pacific, Thailand.
Vanclay, J.K., 2005. Achieving a quiet revolution in forestry education. Aust. For. Grow. 28 (3), 25–26.
Wanneng, P., 2014. Country Report 'Transitions to Sustainable Forest Management and Rehabilitation in Laos' Faculty of Forestry. National University of Laos.
World Bank, 2009. World Development Indicators. World Bank, Washington DC.
Xu, J., Yang, Y., Fox, J., Yang, X., 2007. Forest transition, its causes and environmental consequences: an empirical evidence from Yunnan of Southwest China. Trop. Ecol. 48, 1–14.
Yackulic, C.B., Fagan, M., Jain, M., Jina, A., Lim, Y., Marlier, M., Muscarella, R., Adame, P., DeFries, R., Uriarte, M., 2011. Biophysical and socioeconomic factors associated with forest transitions at multiple spatial and temporal scales. Ecol. Soc. 16 (3), 15.
Zhang, P., Shao, G., Zhao, G., Le Master, D., Parker, G., Dunning, J., Li, Q., 2000. China's forest policy for the 21st century. Science 288, 2135–2136.