Democratic less-developed countries cause global deforestation

M. LARJAVAARA

Finnish Forest Research Institute BOX 18, FI-01301 VANTAA, Finland
and
Department of Forest Sciences BOX 27, FI-00014 University of Helsinki, Finland

Email: markku.larjavaara@gmail.com

SUMMARY

The role of democracy on deforestation has been analysed previously but the results have been contradictory. In this study, FAO statistics on forest area change in countries of the world from 2000 to 2010 were compared with three independent democracy indices. Democratic less-developed countries caused 55%–74% of the net global forest area decrease and non-democratic less-developed countries caused 66%–67% of the net forest increase. When the relative forest area change weighted with forest area in the country was plotted against the level of democracy in 121–131 less-developed countries the slopes of fitted linear regressions were statistically significant for all three democracy indices, linking positive forest area change and non-democracy. The potential mechanisms causing these trends are unclear but nevertheless the vigorous promotion of democratic methods by donors in high-income countries should be questioned.

Keywords: afforestation, autocratic, deforestation, forest transition, reforestation

Les pays démocratiques en développement provoquent la déforestation mondiale

M. LARJAVAARA

L'influence de la démocratie sur la déforestation a été analysée précédemment, mais les résultats ont été contradictoires. Dans cette étude, les statistiques de la FAO sur le changement de la superficie forestière entre 2000 et 2010 dans les pays du monde ont été comparées avec trois indices de démocratie indépendants. Les pays démocratiques en développement ont causé entre 55% et 74% de la diminution nette mondiale des forêts, et les pays non-démocratiques en développement, pour leur part, ont causé entre 66% et 67% de l'augmentation nette des forêts. Lorsque le changement de la superficie forestière, pondéré par rapport à la superficie forestière totale dans le pays, a été étudié en relation avec le niveau de la démocratie dans les 121–131 pays les moins développés, les pentes de régression linéaire étaient statistiquement significatives pour les trois indices de démocratie, associant le changement négatif de la superficie forestière et la démocratie. Les mécanismes potentiels qui causent ces tendances ne sont pas clairs, mais néanmoins la promotion vigoureuse des méthodes démocratiques par les donateurs des pays de revenu élevé devrait être remise en question.

Países democráticos menos desarrollados causan la deforestación global

M. LARJAVAARA

El papel de la democracia en la deforestación se ha analizado anteriormente, pero los resultados han sido contradictorios. En este estudio, las estadísticas de la FAO sobre cambios en cubierta forestal por países entre el año 2000 y el 2010 fueron comparados con tres índices de democracia independientes. Los resultados demuestran que países democráticos y menos desarrollados causan el 55%–74% de la disminución global neta en cubierta forestal y que países no democráticos y menos desarrollados causado el 66%–67% del incremento global neto en cubierta forestal. Cuando se estudió la relación entre el cambio en cubierta forestal, normalizado en base a la superficie forestal total del país, y el nivel de democracia en 121–131 países con menos desarrollo, las pendientes de los modelos de regresión resultantes fueron estadísticamente significativas para los tres índices sobre la democracia, vinculando el cambio negativo entre área de bosque y democracia. Los posibles mecanismos que causan estas tendencias no están claros, sin embargo, la promoción intensa de métodos democráticos por donantes de países ricos debería ser cuestionada.

INTRODUCTION

Economic development and deforestation

Deforestation can be disastrous to societies using forest products for construction, food and medicine. According to Diamond (2005), in historical societies that he examined, such as the Maya Empire, "Deforestation was a or the major factor in all the collapses . . . .". It is therefore no surprise that deforestation is one of the most discussed areas of environmental degradation and has been widely researched. Many have argued that local motives for deforestation and forestation (defined here to include both reforestation and afforestation) vary significantly and global analyses should not be attempted. Despite of this numerous authors have had a global focus.

Perhaps the most extensively studied variable that has been linked with deforestation is economic development. The theory of environmental Kuznets curves suggests that the environment deteriorates in the early stages of industrialization and economic development, but improves with further development (Ehrhardt-Martinez *et al.* 2002). This theory has been supported by, for example, data on air pollutants (Selden and Song 1994). However, the phenomenon of deforestation differs from air pollution, because deforestation can continue only as long as there are forests. In addition, deforestation can be reversed, unlike emissions, which can only be stopped. Fitting the environmental Kuznets curve to forest data has been further confused by uncertainty over whether economic development should be compared with deforestation (Ehrhardt-Martinez *et al.* 2002) or a given forest area at a given time (Uusivuori *et al.* 2002). Despite this ambiguity, numerous studies have been conducted in the search for evidence on the environmental Kuznets curve. Some studies support the theory (Bhattarai and Hammig 2001), but others do not (Koop and Tole 1999). A less confusing theory of forest transition developed by Mather (1990) and others and recently applied e.g. by Kastner *et al*. (2005), focuses on the turning-point from national net deforestation to forestation and its causes. Rudel *et al*. (2005) argue that causes of forest transition are either related to human migration to urban areas, when decreasing agricultural activity releases land for trees, or to rising prices for timber, leading to establishment of new plantations. Both causes are linked to economic development, and most research on the topic has produced evidence that high-income countries have a more positive trend in forested area than less-developed countries (Kauppi *et al.* 2006).

Democracy and deforestation

Forests provide goods and services, some of which mainly benefit the individuals harvesting e.g. forest fruit or timber. Some services, however, such as carbon sequestration and biodiversity conservation, benefit people all over the globe. In general, since it is in the interest of large groups to conserve forests, while individuals living in or next to the forest, or at intermediate distances away in the case of industrial logging, might benefit most if they were allowed to indulge in unsustainable exploitation, ruling parties need to exert control for the benefit of society. Their main tools are regulatory, economic and information policy instruments (Krott 2001).

"Democracy" is strictly defined as "a system of government by the whole population, usually through elected representatives" (Concise Oxford dictionary 1995). However, democracy and its derivatives such as "democratic" are often used in a wider context and include civil liberties and sometimes (although not in this paper) even a market-based economic system. In forest conservation and forestation projects, the impact of laymen in terms of democracy is possible to varying degrees. On the largest scale, the national level, elected representatives promote the interest of potential voters. On the smallest scale, that is, the implementation of individual projects, participation in decision-making by locals in participatory planning, community and family forestry is considered democratic (Buchy and Hoverman 2000; Carr and Halvorsen 2001). In an extreme non-democratic hypothetical situation, leaders make decisions based on considerations of their own and implement projects via ministries and regional units without feedback from them or from experts or laymen.

Theories explaining the lower probability of democratic countries to engage in a war are well known (De Mesquita *et al.* 1999). Various authors have also advanced theories about the mechanisms by which the degree of democracy affects environmental degradation. Most of the benefits advanced for having a non-democracy are actually the benefits of a socialist economic system. However, since nearly all democratic and non-democratic countries nowadays have a more or less market-based economy, these mechanisms are no longer relevant. Mather (2007) writes that "Strong states, even if not democratic, are almost by definition better able to bring about FTs than their weaker counterparts", where "FT" refers to forest transition from net deforestation to net reforestation. Non-democracy is often associated with strong states in which the leaders change rarely. Diamond (2005) discusses the influence of the dynastic periods on deforestation. Extreme examples include the single family regimes in Asia and Europe that in many cases have lasted for centuries. The inheritance of power provided an extra incentive for long-term planning, since emperors wanted to avoid environmental collapse during the reigns of their descendants.

The economic success of western societies was generally based on democratic systems in the 20th century, and "democratic" is often considered intrinsically good. This thinking, common among laymen and politicians, might have influenced scientists as most seem to assume that democracy is beneficial to the environment. Didia (1997) disagrees with Diamond (2005), arguing that dictators have had a shorter planning time horizon than have democratic leaders. This disagreement could be explained by the more recent and more tropical focus of Didia, who claimed that dictators have continually been afraid of coups d'état and have exploited resources not for the benefit of the country but only to secure their positions. Didia (1997) states that leaders and the associated elite in non-democracies have been less pro-environment than the masses in a democracy, because such leaders

benefit more from the unsustainable exploitation. An open democracy on the other hand allows environmental activism, to which political leaders are more responsive than those in non-democratic states (Ehrhardt-Martinez *et al.* 2002; Buitenzorgy and Mol 2011). Furthermore, activism raises public awareness in a democracy, which is then noted by responsive political leaders (Li and Reuveny 2006). Freedom of the press reduces the corruption that undermines the power of legislation passed to minimize environmental degradation (Ehrhardt-Martinez *et al.* 2002). In addition, Midlarsky (1998) and Gleditsch and Svendrup (2002) argue that leaders in open democracies interact more with scientists and leaders of other countries, leading to a better understanding of environmental problems and internationally negotiated solutions.

Some earlier studies of democracy and change in forest area are summarized in Table 1. Their conclusions are confusing. Four of the six studies have been based on a similar methodology, including control variables such as GNP, but have still produced contradictory results. Unfortunately, the authors do not discuss the possible causes of the contradictions, and the complexity of the models and lack of graphical presentation makes it difficult to know whether the statistically significant results are also practically significant. On the other hand, Mather and Needle (1999) rely on a simple approach based on tables and excluding the least forested countries from their analysis. Didia (1997) focuses only on tropical countries but strangely does not base his analysis on absolute deforestation divided by forest area (i.e., relative forest area change) as do all the others, but rather on absolute deforestation divided by GNP and, in a second analysis, by population.

Objectives

Despite the confusing results of earlier studies of democracy and forest area change, (Table 1), foresters and environmentalists in international organizations vigorously promote democratic, bottom-up methods including participatory planning and community forestry for rehabilitation and conservation in less-developed countries (Mansourian *et al.* 2005; Economist 2010). For example, Vietnamese forest rehabilitation has been criticised for ". . . government actors . . . still dominating decision making" by de Jong *et al*. (2006). It is therefore important to shed more light on the influence of democracy on forest area change.

First, the impact of GDP per capita on forest area change is examined for all countries. Then high-income countries are excluded from further analysis and the effect of population density and level of democracy on forest area change are analyzed. The approach in general is graphical with the emphasis is on figures enabling visualization of patterns, and associated discussions.

TABLE 1 *Summary of earlier empirical studies of democracy and forest area change*

Author	Countries	Forest data	Democracy data	Dependent variable	Control variables	Results
Didia 1997	55 all tropical	FAO 1981–1985	An index developed by the author	Absolute forest area change divided by GNP and population	None	Non-democracy and deforestation associated when deforestation divided by GNP used
Midlarsky 1998	77	World Resources Institute 1981–1990	Polity III -index and indices developed by Bollen and Gastil	Relative forest area change	5	Democracy and deforestation associated with 2 of the 3 democracy indices
Mather and Needle 1999	104	FAO 1980–1990	Index developed by Gastil	Relative forest area change	None	Most democratic countries had the least deforestation and intermediately democratic countries had the most
Ehrhardt-Martinez *et al*. 2002	74	FAO 1980–1995	Polity II -index	Relative forest area change	19	"Weak democratic states might be associated with higher rates of deforestation"
Li and Reuveny 2006	134	FAO and World Resources Institute 1980–2000	Polity IV -index	Relative forest area change and proportion of land area forested	5	Non-democracy, deforestation and low proportion of land area forested associated
Buitenzorgy and Mol 2011	177	FAO 1990–2000	Polity index (and 2 others not reported as results similar)	Relative forest area change	5	Forest area change is most negative at intermediate levels of democracy

MATERIAL AND METHODS

Data

The abundance of forests has normally been expressed either as the area covered by forests or the total volume (i.e., growing stock). Volume is a better measure than area if the interest is in carbon sequestration or harvestable timber. However, forest area is more relevant in considering non-timber forest products, biodiversity or soil conservation. The FAO (2010) published data on both volume and area, but for many countries either the volumes are missing or the estimated volumes are biased and unreliable (FAO 2010). This study thus concentrates only on forest area. The FAO defines forest as "Land spanning more than 0.5 ha with trees higher than 5m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ" excluding agricultural and urban areas (FAO 2010). Despite this global definition of forests, the FAO statistics are based on national reports, and national datasets may be based on other definitions, causing inaccuracy when comparisons between countries are made (FAO 2006). However, temporal trends in a particular country are not influenced by the variability in definitions between countries and the temporal variability in definitions has probably been relatively unimportant. The precision of forest resource assessments has increased with greater efforts and better techniques (Mather 2005). The assessment of 1990 was based on a different general FAO definition of forest than the 2000, 2005 and 2010 assessments, making examination of temporal trends before 2005 difficult (Mather 2005). The period from 2000 to 2010 offers more reliable data on changes in forest area than was available previously and was used in this study even though significant uncertainty remains. The forest area was published for the 231 "countries / areas" (referred in this article: "countries") (FAO 2010).

Numerous indices have been developed to describe the level of democracy in a given country. Because these indices are mainly based on relatively subjective assessments by experts, a combination of indices should preferably be used to understand the uncertainty on how the indices are able to quantify the actual level of democracy. The time period 2000–2010 offers an opportunity to compare three widely recognized indices (presented in the following three paragraphs) for the first time. Matching the time of the forest area, democracy and other data is challenging. As the forest area change is reported from 2000 to 2010 (the month of the year is not specified but presumably the numbers correspond to the mid-year situation), an average democracy index from mid-2000 to mid-2010 should ideally be used assuming no or the same time lag from the actual level of democracy to the value of the indices and the impact of the level of democracy on forest area change. In practice, some time passes from actual changes in the level of democracy to changes in the values of the indices and impacts on the forest area. However, currently available data is probably not sufficient to investigate these time lags, and the best practical option is simply to assume the same lags for impact on values of the indices and impacts on forest area and use the average 2000–2010 GDP per capita, population density and of democracy index values. Because of the uncertainty in the time lags, analysis taking temporal trends into account was not attempted.

The *Economist* Intelligence Unit's "index of democracy" (Kekic 2007) covers the widest range of indicators and is the only one of the three that includes public opinion surveys in addition to expert assessments. This index, called the "Economist index" in this study, includes the electoral process and pluralism, civil liberties, the functioning of government, political participation and political culture and therefore measures a wider range of indicators than what is included in the other indices. The Economist index was first produced in 2006 and only this first version was used because of the absence of earlier indices. The 2006 index, which covers 167 countries and areas, is based mainly on the situation in 2006 but includes information on elections since 2000 (Kekic, 2007).

A non-governmental organization called Freedom House publishes a "Freedom in the world" index or simply "Freedom House index" (Freedom House 2011). The index is based on political rights and civil liberties that include the freedom to develop opinions, institutions and personal autonomy without interference from the state. Since 2000 and 2001 were not available, the mid-term year of 2005 was used. The index covered 192 countries, which is the largest number among the three indices.

The academic Polity IV project has published "Political Regime Characteristics and Transitions, 1800–2010," including an index, Polity2, that will be referred to hereafter as the "Polity index" (Polity 2011). This index includes fewer aspects than the other two not, for example, including data on civic liberties. An average of data from 2000 to 2010 was used, covering 158 countries. As the Polity index was the only of the three to cover the whole 2000–2010 period, it was possible to assess the potential error caused by using Economist and Freedom House data from only a single year. For the 158 countries for which the Polity index was quantified in 26 countries (none of the top 20 in 2010 forest area), the average value from 2000–2010 differed more than 1 unit (range from –10 to 10) and in only 1 country (Nepal) by more than 5 units from the 2005 value. This indicates that the use of the Economist and Freedom House indices from a single year is not likely to cause significant uncertainty. All three indices were normalized to range from 0 to 100.

World Bank GDP per capita and population density data was used (World Bank 2011); as with the Polity index, the average from 2000 to 2010 GDP was reported for 201 countries and population density for 215. All data, with the exception of countries not having forest in 2000 and/or 2010, is reported in Appendix 1. As can be seen, adequate data was available for large countries, those with the most forest appearing at the top of the table.

Methodology

The global analysis in this paper differs significantly from most earlier studies, in which a larger number of variables are

used in the analysis. Since the main aim of the present analysis was to present the data in figures, only five main variables were used and three of them shown in a given bubble scatter plot. In all the figures relative forest area change is shown in the y-axis and the bubble size is directly proportional to forest area. The variables shown in the x-axis are GDP per person, population density and three democracy indices. This simple analysis, avoids problems related to collinearity, enabling rapid absorption by other scientists and perhaps also by policy-makers. OLS linear regressions were fitted to the data with R software (R Development-Core-Team 2008). All reported p-values are based on a two-tailed test, since democracy can influence the change in forest area in both directions. Based on earlier studies on importance of the level of economic development on forest area change (Mather 1990), the countries studied were stratified into high-income and less-developed and the focus was only on the latter (with the exception of Figure 1 showing GDP – forest area change relation). High-income countries were defined applying the World Bank definition for high-income countries, but using GDP per person instead of GNI per person normally used by the World Bank (World Bank 2011). The average GNI threshold from 2000 to 2010 of US$ 10,065 was used (World Bank 2011).

All countries were considered equal in five of the six earlier studies of democracy and changes in forest area irrespective of the forest area (all in Table 1 except (Mather and Needle 1999)). This is the simplest and perhaps the most natural approach for political scientists interested in the impact of governance on the environment. Brazil, with a forest area of 546,000,000 ha in 2000, would then be weighted equal to the Netherlands Antilles in the same region with 1000 ha and countries with only a little forest dominate the analysis. Only 5 of 140 less-developed countries contain 58% of forests among these countries.

There are three reasons why weighting the influence of the country with the forest area is done in this study. Firstly, one may be interested in global forest area changes and want simply to know about the level of democracy in countries undergoing important changes without interest in potential causality. This thinking has probably been the reason for some authors to exclude countries with a small forest area from their analysis forests (Mather and Needle 1999; Kauppi *et al.* 2006). Secondly, the mechanism by which democracy influences forest area change could be different in countries with a large absolute forest area, which are always large, and countries with little forest, which are typically small. This could be the case for example if the leaders in a small non-democratic country know the environmental condition of their country better than their colleagues in large countries, so that a non-democratic system would thus work better in a small country. Analysing by weighting by forest area first would therefore reveal potentially significant causal effects of the level of democracy on forest area change in countries with a large forest area. Thirdly, weighting countries according to their forest area can also be justified when decisions influencing forest area are taken by provincial governments (as is often the case; see, for instance, (Chokkalingam *et al.* 2006). As the provincial governments are more numerous in countries with a large forest area, the data points from these countries can be considered as an average of thousands of provincial data points and must therefore carry more weight than data points from countries with a small forest area. However, there is no certainty about how well the level of democracy in the central government is reflected in the provinces or how far decisions influencing forest area change are implemented there.

RESULTS

In the 138 less-developed countries (GDP per capita below US $10,065), the forest area was increasing in 38 countries and decreasing in 72. In the 50 high-income countries (GDP per capita above US $10,065), the forest area was increasing in 28 and decreasing in only 7, all of which are either close to the GDP limit of a less-developed country, have a very small forest area, or have a slow relative change in forest area. Therefore, it can be generalized that forest area has been increasing, is stable, or is decreasing in less-developed countries and increasing or stable in high-income countries (Figure 1). Forest area changes are much more significant in less-developed countries. Only 6.0% of the total loss in countries with decreasing forest area and 17.9% of the total gain in those with increasing forest area are reported to be in high-income countries.

When only less-developed countries are analyzed, human population density does not significantly influence the average change in forest area in less-developed countries, yet few of the sparsely-populated countries are undergoing a rapid

FIGURE 1 *GDP per capita and change in forest area from 2000 to 2010 in 179 countries in which change in forest area was between –2% and 2% and GDP was reported and was below 65,000 US$. The 52 countries not included represent 2.4% of global forest area (in 2000). The vertical dotted line is the divider between less-developed and high-income countries at GDP US$10,065 per capita. The names of the seven countries with over one million km² of forest are shown. The area of the circles is directly proportional to the forest area of the countries in question*

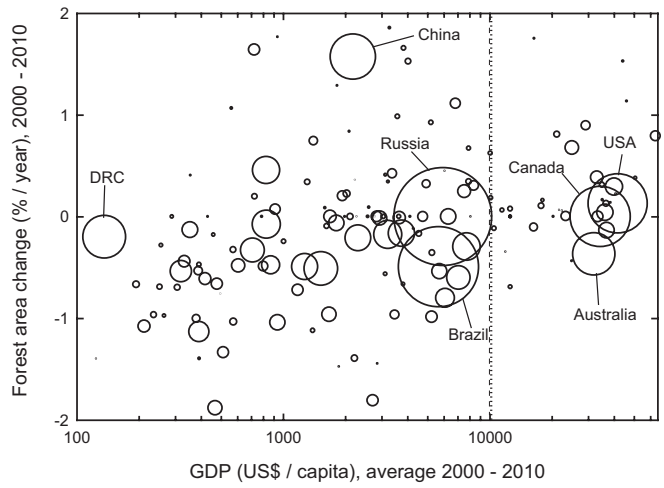
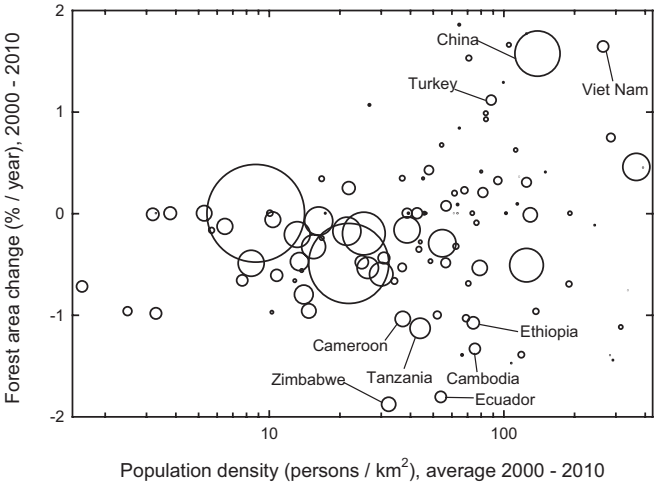


FIGURE 2 *Population density and change in forest area from 2000 to 2010 in 124 less-developed countries in which change in forest area was between –2% and 2%. The 14 other less-developed countries represent 1.0% of the global forest area (in 2000). The 37 countries for which GDP was not reported and could not be classified as less-developed or high-income country represent 1.4% of the global forest area (in 2000). The area of the circles is directly proportional to the forest area of the countries in question*



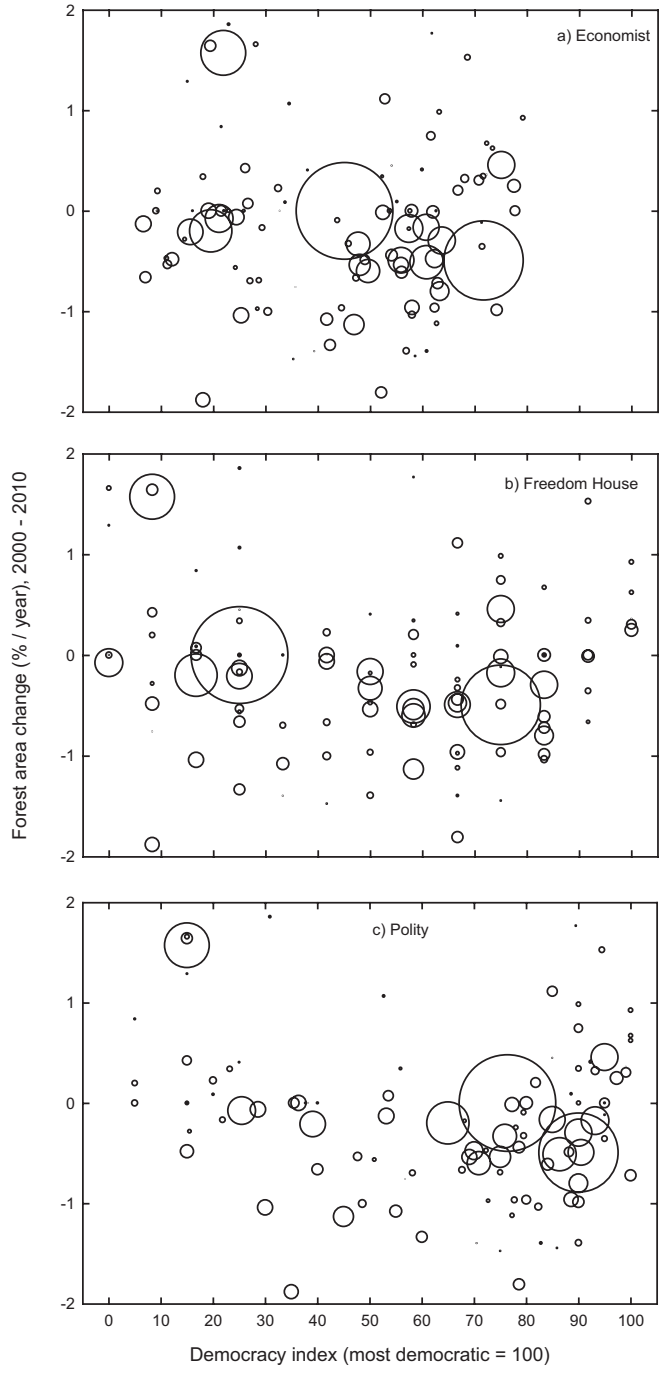
change in forest area (Figure 2). In other words, there is no rising or falling trend but the scatter increases with increasing population density.

Less-developed countries that have a democracy index value of 50 or above cause 55%–74% of the net global forest area decrease (depending on the index), but only 15%–16% of the net forest area increase. By contrast, less-developed non-democratic countries with a democracy index value below 50 cause only 15%–35% of the total loss but 66%–67% of the total gain.

Figure 3 shows somewhat decreasing trends. The main difference among the democracy indices is that none of the less-developed countries has a democracy level of 80 or more based on the Economist index, while 35 countries based on the Freedom House index and 48 based on the Polity index surpass this number. However, the locations of data points relative to other countries remain similar for countries with a large forest area; only the circles in panel c in Figure 3 have shifted right compared to panels a and b in Figure 3. The most significant exception is that Russia (the largest circle in the Figures) is relatively more democratic based on the Polity index than based on Economist and especially Freedom House index (Figure 3).

Linear regression models weighted with the forest area of the country in 2000 were fitted into the datasets shown in Figure 3, including the 11 countries that could not be shown in the diagrams because of rapid change in their forest area. The model parameters are shown in Table 2. All three main models (in bold) show statistically highly significant decreasing trends, indicating correlation between democracy and deforestation, but the Economist index explains less of the variation.

FIGURE 3 *The three adjusted democracy indices and change in forest area from 2000 to 2010. The number of less-developed countries of all 138 and proportion of global forest area (in 2000) of countries excluded because of forest area change being faster than 2% or democracy index not available was: a) 28 countries and 1.0%; b) 12 countries and 0.9%; c) 28 countries and 1.4%. The area of the circles is directly proportional to the forest area of the countries in question. The Economist index is based on 2006, the Freedom House on 2005 and the Polity on the average from 2000 to 2010*



Since the definition of a less-developed country was arbitrary, a sensitivity analysis with regression models with the upper GDP limit of countries shifted 50% from US $10,065

TABLE 2 *Linear regression weighted with forest area based on Economist, Freedom House and Polity democracy indices and forest area change from 2000 to 2010 in less-developed countries. R^2 is the coefficient of determination, p the probability value (or p-value) and n the number of countries included in the analyses. Countries with no forest in 2000 or 2010 or both were not included. Models on which conclusions are mainly based are in bold*

Democracy index	Upper GDP limit	Weighting with forest area in 2000	R^2	Regression intercept	Regression slope	p –value for slope	n
Economist	***10065***	***X***	**0.078**	**0.29**	**–0.0098**	**0.002**	**121**
Economist	*5033*	*X*	0.043	0.22	–0.0092	0.038	101
Economist	*15098*	*X*	0.077	0.28	–0.0096	0.002	129
Economist	*10065*		0.010	–0.64	0.0067	0.267	121
Freedom House	***10065***	***X***	**0.154**	**0.25**	**–0.0095**	**0.000**	**137**
Freedom House	*5033*	*X*	0.125	0.33	–0.0115	0.000	111
Freedom House	*15098*	*X*	0.150	0.25	–0.0094	0.000	148
Freedom House	*10065*		0.000	–0.35	0.0008	0.832	135
Polity	***10065***	***X***	**0.168**	**0.64**	**–0.0115**	**0.000**	**121**
Polity	*5033*	*X*	0.189	0.68	–0.0137	0.000	100
Polity	*15098*	*X*	0.165	0.63	–0.0114	0.000	129
Polity	*10065*		0.009	–0.06	–0.0044	0.312	121

to US $5033 and to US $15,098 was also computed. The results are similar with the exception of the US $5033 limit and Economist index leading to a worse fit (Table 2).

Previous studies have either excluded countries with a small forest area from the analysis or treated all countries equally in analyzing the data. To facilitate comparison, regression models without weighting countries based on forest area were also computed. None of the three models showed significant correlations (Table 2).

DISCUSSION

During the 2000 to 2010 period, global forest area decreased over 5.2 million hectares annually (FAO 2010). Most of the net loss occurred in democratic less-developed countries, while the net gain occurred in non-democratic and less-developed countries. China and Brazil dominate global forest area change but in opposite directions. China is very large and non-democratic and has experienced an exceptionally rapid forest area increase (Shi *et al.* 2011). Brazil is also large but is democratic and its forest area has been shrinking. The trend of an increase in total forest area in non-democratic countries and a decrease in democratic countries seems to be caused by countries with a large forest area. Such a trend cannot be found if countries with a small forest area only are considered. Weighting countries with their forest area in this analysis was a novel approach and naturally lead to results that are difficult to compare to earlier studies. This study did not find most negative forest area change with intermediate levels of democracy as did Mather and Needle (1999) and Buitenzorgy and Mol (2011). Instead Figure 3 indicates a clearly visible trend of more negative forest area change with increasing level of democracy.

Three varying indices were used in order to understand the role of the methodology in developing the democracy index when studying forest area change. The definition of democracy in the Introduction was left on purpose vague and there is no intention to discuss which of the three indices corresponds best to a given definition of democracy. However, a comparison of the panels a, b and c in Figure 3 potentially reveals the variables in the society that impact forest area change. The regression models based on the three different indices are similar. The Economist index includes the widest range of indicators of the three and explained least the variation in forest area change (Table 2). At the other extreme is the Polity index, which focuses only on political regime characteristics and explained most of the variation in forest area change. However, the differences are so small that making deductions on the exact mechanisms how democracy influences forest area change are not possible.

It is important to note that the discussion has been based simply on changes in forest area and that it is possible that the level of democracy also influences the quality of forests and the way forests benefit people e.g. due to the origin of the species (Lamb *et al.* 2005) or the level of species diversity (Larjavaara 2008). Unfortunately the data (FAO 2010) used in this study is unsuitable to study compare the quality of forests globally and better alternatives do not exist. It is possible that, for example, bottom-up approaches create forests that people want, whereas non-democratic leaders are interested only in statistics on forest area, which leads to monocultures ravaged by pests and which local people might not even be allowed to enter. Furthermore, people might derive satisfaction simply

from participation in national elections and community forest meetings, even though these activities may not improve forest management.

When focusing again in forest area only, the greatest forestation success stories of the recent years are from non-democratic China and Viet Nam. If more distant history is examined more success stories are found from the same region. Tak *et al*. (2007) have formulated the recent forest history of the Republic of Korea in these terms: "In what was probably the best orchestrated and publicly cohesive reforestation event in world history, the people of South Korea came together in the 1970's and 1980's and reforested the country . . . ." and Bae *et al*. (2012) conclude their summary by writing that "The case of South Korea shows that FTs (forest transitions) can be cultivated in a relatively short period of time by a central authority, even with imperfect governance and low economic development." During this time, the country was non-democratic (the adjusted average on the Polity index of 27) with a very strong government and, like Viet Nam and China in recent years had a young market-oriented and rapidly-growing economy. A rapid forestation happened also in Japan but already in the first half of the eighteenth century under strong leaders who planned for the long-term future as Diamond explains (2005). The Japanese reforestation was organized during a time of extreme political stability, the same Tokugawa family having ruled for centuries. It is possible that millennia of wet rice cultivation in this region provided the foundations for rapid forestation by favoring cultures in which people obey autocratic leaders and are ready to work unselfishly to benefit all in projects such as digging irrigation canals for the whole community or planting trees on deforested and eroding hills. Countries such as Myanmar and North Korea demonstrate how rice cultivation based culture and a stable non-democratic leadership do not always lead to a positive forest area change (Appendix 1). A strong non-democratic state allows the leaders to transform the country rapidly and one could expect more variation in forest area change in non-democratic countries, but surprisingly this cannot be seen in Figure 3.

The list of ways in which democracy decreases environmental degradation is long (see Introduction). However, only Diamond (2005) has pointed out that in many cases non-democratic regimes have longer planning-time horizons, thereby enabling investment in forestation. It is probable that democracy influences the forest area negatively in other ways as well. Perhaps democratic voters do not understand the benefits of the forests as well as non-democratic leaders do. Obviously non-democratic leaders are also potentially quicker in responding to emerging environmental threats, since only the leaders need to be convinced and not the majority of the voters in a process that could take decades, especially if the situation is complex. Interestingly, democracy and deforestation are correlated only in large countries, possibly indicating that voters in these countries are not able to interpret the complex problem of deforestation correctly, perhaps because they might live far away from the deforested areas. These mechanisms are all linked to the objectives of the central governments. However, governments also act differently depending on the level of democracy. Perhaps democratic, bottom-up forest management does not work as expected because it is mainly locals who are involved, although forests also benefit people further away.

When interpreting the results of this study one needs to be cautious on whether they represent causalities or non-causal correlations. Would for example Brazil and Indonesia start reforesting soon after a significant drop in their level of democracy? This seems unlikely as longer time periods are needed for the regimes to secure their positions and expand their planning time horizons which makes foresting a more attractive investment. With better forest area data a study focusing in addition to variation among countries in temporal variation within countries would become possible. Meanwhile the role of the level of democracy on forest area change remains uncertain but this does not mean that the vigorous promotion of democratic bottom-up means of managing of natural resources by donors from high-income countries (Poffenberger 2006) should be continued.

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APPENDIX 1 *Basic data and the three democracy indices of 216 countries for which a forest area of greater than none was reported for both 2000 and 2010. The data is provided here for easy reference only. If data is analysed original publications listed in section "Data for global analysis" of the article should be cited*

Country/Area	Forest area in 2000 (1000 ha)	Forest area in 2010 (1000 ha)	Forest area change per year (%)	GDP per capita (US$)	Population density (inhabitants / km^2)	Econ-omist	Free-dom	Polity
Russian Federation	809269	809090	–0.002	5935	8.8	45.1	25	76.4
Brazil	545943	519522	–0.495	5652	21.9	71.7	75	90
Canada	310134	310134	0	34318	3.6	90.8	100	100
United States of America	300195	304022	0.127	41729	32.3	81.2	100	100
China	177000	206861	1.571	2174	139.6	21.9	8.3	15
Democratic Republic of the Congo	157249	154135	–0.2	136	25.4	19.5	16.7	65
Australia	154920	149300	–0.369	31947	2.7	91.1	100	100
Indonesia	99409	94432	–0.512	1523	125.3	60.8	58.3	86.4
Sudan	70491	69949	–0.077	829	16.3	21.1	0	25.5
Peru	69213	67992	–0.178	3213	21.5	57.4	75	93.2
Mexico	66751	64802	–0.296	7726	54.8	63.7	83.3	90
India	65390	68434	0.456	827	368	75.1	75	95
Colombia	61509	60499	–0.165	3738	38.8	60.7	50	85
Bolivia (Plurinational State of)	60091	57196	–0.493	1270	8.4	55.9	66.7	90.5
Angola	59728	58480	–0.211	2304	13.2	15.6	25	39.1
Zambia	51134	49468	–0.331	710	15.5	47.7	50	75.9
Venezuela (Bolivarian Republic of)	49151	46275	–0.601	7062	30.1	49.6	58.3	70.9
Mozambique	41188	39022	–0.539	320	26.4	48	58.3	75
United Republic of Tanzania	37462	33428	–1.133	391	44.1	46.9	58.3	45
Myanmar	34868	31773	–0.925	NA	71	8.4	0	14.5
Argentina	31861	29400	–0.801	6087	14.1	63.3	83.3	90
Papua New Guinea	30133	28726	–0.477	870	13.5	62.3	66.7	70
Sweden	27389	28203	0.293	40025	22.1	100	100	100
Japan	24876	24979	0.041	36183	349.9	80.4	91.7	100
Central African Republic	22903	22605	–0.131	354	6.5	6.6	25	53.2
Congo	22556	22411	–0.064	1810	10.4	24.4	41.7	28.6
Finland	22459	22157	–0.135	36848	17.3	92.9	100	100
Cameroon	22116	19916	–1.042	939	37.2	25.3	16.7	30
Gabon	22000	22000	0	6301	5.3	19.1	41.7	36.4
Malaysia	21591	20456	–0.539	5707	79.2	55.9	50	69.1
Paraguay	19368	17582	–0.963	1667	14.8	58	66.7	88.6
Thailand	19004	18972	–0.017	2936	130.1	52.4	75	77.3
Zimbabwe	18894	15624	–1.882	468	32.4	18	8.3	35
Spain	16988	18173	0.677	24990	86.9	82.6	100	100
Lao People's Democratic Republic	16532	15751	–0.483	606	24.9	12.1	8.3	15

APPENDIX 1 *Continued*

Country/Area	Forest area in 2000 (1000 ha)	Forest area in 2010 (1000 ha)	Forest area change per year (%)	GDP per capita (US$)	Population density (inhabitants / km^2)	Econ-omist	Free-dom	Polity
Chile	15834	16231	0.248	7529	21.9	77.5	100	97.3
France	15353	15954	0.385	33033	114.9	79.5	100	95
Guyana	15205	15205	0	1688	3.8	57.9	83.3	80
Suriname	14776	14758	–0.012	3651	3.2	62	91.7	NA
Ethiopia	13705	12296	–1.079	212	74.3	41.7	33.3	55
Mali	13281	12490	–0.612	419	10.8	56	83.3	84.1
Nigeria	13137	9041	–3.668	818	154.1	28.1	50	70
Madagascar	13122	12553	–0.442	332	30.9	54.1	66.7	78.6
Botswana	12535	11351	–0.987	5234	3.3	74.2	83.3	90
Chad	12317	11525	–0.662	477	7.7	7	25	40
Ecuador	11841	9865	–1.809	2712	54	52.1	66.7	78.6
Viet Nam	11725	13797	1.641	723	265.4	19.4	8.3	15
Mongolia	11717	10898	–0.722	1175	1.6	62.9	83.3	100
Cambodia	11546	10094	–1.335	512	75.5	42.3	25	60
Germany	11076	11076	0	33334	235.9	88	100	100
Iran (Islamic Republic of)	11075	11075	0	2834	42.8	21.5	16.7	35.5
Côte d'Ivoire	10328	10403	0.072	915	56.9	26.6	16.7	53.6
Turkey	10146	11334	1.113	6819	88.6	52.8	66.7	85
Ukraine	9510	9705	0.203	1934	81.6	66.8	58.3	81.8
Norway	9301	10065	0.793	63451	15.3	96.3	100	100
South Africa	9241	9241	0	4739	38.8	77.7	91.7	95
Poland	9059	9337	0.303	8364	125.3	70.8	100	99.1
Senegal	8898	8473	–0.488	800	56.7	49	75	88.2
Italy	8369	9149	0.895	29184	199.1	75.7	100	100
Belarus	8273	8630	0.423	3370	48.1	26.1	8.3	15
New Zealand	8266	8269	0.004	23320	15.6	90.2	100	100
French Guiana	8118	8082	–0.044	NA	NA	NA	NA	NA
Namibia	8032	7290	–0.965	3463	2.5	62.3	75	80
Somalia	7515	6747	–1.072	NA	13.3	NA	8.3	50
Philippines	7117	7665	0.745	1401	286.5	61.6	75	90
North Korea (shortened from FAO)	6933	5666	–1.998	NA	196.8	0	0	5
Guinea	6904	6544	–0.534	388	37	11.2	25	47.7
Honduras	6392	5192	–2.058	1508	61.6	59	66.7	85
Romania	6366	6573	0.321	4926	94.5	68.1	75	93.2
Republic of Korea	6288	6222	–0.105	16325	495.7	77.4	91.7	90
Burkina Faso	6248	5649	–1.003	379	52.2	30.4	41.7	48.6
Ghana	6094	4940	–2.078	702	95.3	48.8	83.3	84.5
Benin	5061	4561	–1.035	574	69.2	58	83.3	82.3
Morocco	5017	5131	0.225	2031	68.1	32.4	41.7	20

APPENDIX 1 *Continued*

Country/Area	Forest area in 2000 (1000 ha)	Forest area in 2010 (1000 ha)	Forest area change per year (%)	GDP per capita (US$)	Population density (inhabitants / km^2)	Econ-omist	Free-dom	Polity
Liberia	4629	4329	–0.668	194	34.3	47.3	41.7	67.7
Guatemala	4208	3657	–1.394	2214	119	56.9	50	90
Turkmenistan	4127	4127	0	2110	10.1	9	0	5
Nepal	3900	3636	–0.698	307	190	27	33.3	58.2
Uganda	3869	2988	–2.551	345	145	46.4	41.7	38.2
Austria	3838	3887	0.127	36605	99.6	86.6	100	100
Nicaragua	3814	3114	–2.007	924	45.1	52.5	66.7	91.8
Greece	3601	3903	0.809	21135	86.2	80.2	91.7	100
Kenya	3582	3467	–0.326	572	62.7	45.8	66.7	79.5
Malawi	3567	3237	–0.966	236	137.4	44.5	50	77.7
Portugal	3420	3456	0.105	17729	114.7	80.6	100	100
Bulgaria	3375	3927	1.526	4027	71.1	68.6	91.7	94.5
Panama	3369	3251	–0.356	5256	43.6	71.4	91.7	95
Kazakhstan	3365	3309	–0.168	4541	5.7	29.3	25	21.8
Latvia	3241	3354	0.343	7909	37	71.6	91.7	90
Uzbekistan	3212	3276	0.197	726	61.8	9.3	8.3	5
Bhutan	3141	3249	0.339	1307	16.8	18	25	23.2
Sierra Leone	2922	2726	–0.692	252	70.8	28.7	58.3	75
United Kingdom	2793	2881	0.311	34980	249.5	79.7	100	100
Georgia	2768	2742	–0.094	1622	76.7	43.7	58.3	79.5
Czech Republic	2637	2657	0.076	12571	133.4	80.7	100	95.5
Serbia	2460	2713	0.984	3575	84	63.2	75	90
Cuba	2435	2870	1.657	3826	105.3	28.1	0	15
Costa Rica	2376	2605	0.924	5197	84.2	79.2	100	100
Solomon Islands	2268	2213	–0.245	1005	16.8	NA	66.7	78
Estonia	2243	2217	–0.117	10502	31.8	75.8	100	95
Bosnia and Herzegovina	2185	2185	0	3055	73.6	53.7	58.3	NA
Guinea-Bissau	2120	2022	–0.472	391	48.8	11	50	72.3
Pakistan	2116	1687	–2.24	725	206.1	32.7	25	41.4
Sri Lanka	2082	1860	–1.121	1389	316	62.7	66.7	77.3
Lithuania	2020	2160	0.672	7900	54.5	72.3	83.3	100
Dominican Republic	1972	1972	0	3630	191.7	57.6	83.3	90
Slovakia	1921	1933	0.062	11484	112.2	72	100	97.3
Hungary	1907	2029	0.622	10057	112.7	73.4	100	100
Croatia	1885	1920	0.184	10120	79.3	67.9	83.3	92.7
Equatorial Guinea	1743	1626	–0.692	12569	21.7	12	8.3	25
Algeria	1579	1492	–0.565	3117	13.8	24.2	25	50.9
Eritrea	1576	1532	–0.283	256	44.2	14.5	8.3	15.5
Belize	1489	1393	–0.664	3806	12.9	NA	91.7	NA
Bangladesh	1468	1442	–0.179	459	1074.9	57.4	50	68.2

APPENDIX 1 *Continued*

Country/Area	Forest area in 2000 (1000 ha)	Forest area in 2010 (1000 ha)	Forest area change per year (%)	GDP per capita (US$)	Population density (inhabitants / km²)	Econ-omist	Free-dom	Polity
Uruguay	1412	1744	2.134	6779	19	78.3	100	100
Afghanistan	1350	1350	0	289	46	22.9	25	15
Niger	1328	1204	–0.975	265	10.3	28.4	66.7	72.7
Slovenia	1233	1253	0.161	18013	99.8	78.3	100	100
Switzerland	1194	1240	0.379	50736	186.6	90.3	100	100
Fiji	980	1014	0.342	3217	45.4	52.3	58.3	55.9
Saudi Arabia	977	977	0	12571	11.9	10.1	0	0
Macedonia (shortened from FAO)	958	998	0.41	3121	80.3	59.9	66.7	92.3
Azerbaijan	936	936	0	2565	102.4	25.8	25	15
Kyrgyzstan	858	954	1.066	561	26.8	34.5	25	52.7
Timor–Leste	854	742	–1.396	392	66.6	60.8	66.7	82.8
New Caledonia	839	839	0	12580	12.8	NA	NA	NA
Tunisia	837	1006	1.856	3273	64.7	22.9	25	30.9
Iraq	818	825	0.085	1593	63.7	33.7	16.7	20
Albania	769	776	0.091	2599	114.5	55.1	66.7	88.6
Western Sahara	707	707	0	NA	NA	NA	NA	NA
Belgium	667	678	0.164	35102	347.4	80.4	100	96.4
Ireland	635	739	1.528	44083	60.5	90.2	100	100
Yemen	549	549	0	787	39.3	22	33.3	40
Montenegro	543	543	0	4110	46.8	62.6	NA	95
Swaziland	518	563	0.837	2086	64.8	21.5	16.7	5
Bahamas	515	515	0	20309	31.9	NA	100	NA
Denmark	486	544	1.134	46025	128	95.9	100	100
Togo	486	287	–5.131	401	99.5	8.1	25	35.5
Puerto Rico	464	552	1.752	16399	440.3	NA	NA	NA
Gambia	461	480	0.405	355	150.7	38	50	25
Vanuatu	440	440	0	1984	17.4	NA	83.3	NA
Syrian Arab Republic	432	491	1.288	1823	99.8	15	0	15
Tajikistan	410	410	0	431	46.3	16	25	37.7
Brunei Darussalam	397	380	–0.437	24929	68.9	NA	25	NA
Netherlands	360	365	0.138	38418	482.7	97.5	100	100
Rwanda	344	435	2.375	325	377.4	31.5	25	33.2
Jamaica	341	337	–0.118	4261	244.7	71.3	75	95
El Salvador	332	287	–1.446	2856	292.4	58.6	75	85.9
Republic of Moldova	324	386	1.766	938	125.2	61.8	58.3	89.5
Mauritania	317	242	–2.664	690	3	23.6	25	30.5
United Arab Emirates	310	317	0.224	40708	55.8	15.7	16.7	10
Armenia	304	262	–1.476	1860	107.9	35.3	41.7	75
Trinidad and Tobago	234	226	–0.347	11924	256.6	69.5	66.7	100

APPENDIX 1 *Continued*

Country/Area	Forest area in 2000 (1000 ha)	Forest area in 2010 (1000 ha)	Forest area change per year (%)	GDP per capita (US$)	Population density (inhabitants / km^2)	Econ-omist	Free-dom	Polity
Libyan Arab Jamahiriya	217	217	0	8070	3.3	9.2	0	15
Burundi	198	172	–1.398	124	284.4	39.3	33.3	70.5
Cyprus	172	173	0.058	22381	111.3	74.2	100	100
Samoa	171	171	0	2267	63.6	NA	83.3	NA
Israel	153	154	0.065	21670	320.9	70.6	83.3	100
Lebanon	131	137	0.449	6048	393	54.1	25	85
Haiti	109	101	–0.759	497	338.7	35.7	8.3	56.8
French Polynesia	105	155	3.971	14508	69.6	NA	NA	NA
Jordan	98	98	0	2784	61.4	32.7	41.7	38.2
Réunion	87	88	0.114	NA	NA	NA	NA	NA
Luxembourg	87	87	0	80819	180.5	91.2	100	NA
Cape Verde	82	85	0.36	2223	116.6	72.3	100	99.1
Guadeloupe	65	64	–0.155	NA	NA	NA	NA	NA
Micronesia (Federated States of)	64	64	0	2331	155.9	NA	100	NA
Egypt	59	70	1.724	1631	74.6	32.4	25	28.2
Martinique	49	49	0	NA	NA	NA	NA	NA
Saint Lucia	47	47	0	5514	270.1	NA	91.7	NA
Dominica	47	45	–0.434	5680	91.7	NA	100	NA
Lesotho	42	44	0.466	616	68.1	61.6	75	87.3
Seychelles	41	41	0	9531	182.7	NA	66.7	80
Palau	40	40	0	7234	43.2	NA	100	NA
Mauritius	39	35	–1.076	5459	610.6	79.2	100	100
Turks and Caicos Islands	34	34	0	NA	31.2	NA	NA	NA
Northern Mariana Islands	32	30	–0.643	NA	143.7	NA	NA	NA
Sao Tome and Principe	27	27	0	876	159.2	NA	83.3	NA
Saint Vincent and the Grenadines	26	27	0.378	5202	278.7	NA	91.7	NA
Guam	26	26	0	NA	311.1	NA	NA	NA
United States Virgin Islands	22	20	–0.949	NA	312.6	NA	NA	NA
Niue	20	19	–0.512	NA	NA	NA	NA	NA
Iceland	18	30	5.241	43896	3	98.1	100	NA
American Samoa	18	18	0	NA	314.9	NA	NA	NA
Grenada	17	17	0	6412	302.5	NA	91.7	NA
Andorra	16	16	0	29767	162.1	NA	100	NA
Cook Islands	16	16	0	NA	NA	NA	NA	NA
Mayotte	16	14	–1.326	NA	474.1	NA	NA	NA
Cayman Islands	13	13	0	NA	209.8	NA	NA	NA
Marshall Islands	13	13	0	2610	291.6	NA	100	NA
Kiribati	12	12	0	1138	113.4	NA	100	NA

APPENDIX 1 *Continued*

Country/Area	Forest area in 2000 (1000 ha)	Forest area in 2010 (1000 ha)	Forest area change per year (%)	GDP per capita (US$)	Population density (inhabitants / km²)	Econ-omist	Free-dom	Polity
Saint Kitts and Nevis	11	11	0	10871	187.8	NA	91.7	NA
Antigua and Barbuda	10	10	0	12517	190.1	NA	83.3	NA
Occupied Palestinian Territory	9	9	0	NA	NA	56.3	NA	NA
Tonga	9	9	0	2581	140.2	NA	50	NA
Barbados	8	8	0	11403	629	NA	100	NA
Comoros	8	3	–9.343	582	346.9	32.4	50	79.1
Liechtenstein	7	7	0	104418	216.1	NA	100	NA
Anguilla	6	6	0	NA	NA	NA	NA	NA
Djibouti	6	6	0	908	34.9	15.1	33.3	60
Wallis and Futuna Islands	6	6	0	NA	NA	NA	NA	NA
Kuwait	5	6	1.84	33192	129.2	23.3	41.7	15
British Virgin Islands	4	4	0	NA	NA	NA	NA	NA
Pitcairn	4	4	0	NA	NA	NA	NA	NA
Isle of Man	3	3	0	32325	140.3	NA	NA	NA
Montserrat	3	3	0	NA	NA	NA	NA	NA
Saint Pierre and Miquelon	3	3	0	NA	NA	NA	NA	NA
Oman	2	2	0	13055	8	19.7	25	9.1
Saint Helena (shortened from FAO)	2	2	0	NA	NA	NA	NA	NA
Singapore	2	2	0	30010	6472.1	54.9	41.7	40
Bermuda	1	1	0	74831	1269.6	NA	NA	NA
Jersey	1	1	0	NA	NA	NA	NA	NA
Maldives	1	1	0	4037	983.2	NA	25	NA
Netherlands Antilles	1	1	0	NA	NA	NA	NA	NA
Saint Martin (French part)	1	1	0	NA	523.3	NA	NA	NA
Tuvalu	1	1	0	2309	322	NA	100	NA