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Projecting global forest area towards 2030 ☆

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ABSTRACT

There is strong interest in gaining an informed view of changes likely to occur in forest area and the impacts of these changes on production forestry and forest conservation. Despite the complexity of underlying causes, it is largely accepted that deforestation is mainly focused in the tropics and driven by conversion to agriculture. Similarly, energy demand and GDP are largely determining wood consumption and production. Based on these assumptions, we built a model predicting natural forests and planted forests' evolution in the next 15 years, and compared the results of the modelling with survey results from country expertise. The results suggest that on a global level, forest resources loss is likely to slow down. The forests that are most at risk of conversion were clearly identified within the tropical domain, while the forest under protected areas showed very little risk of being converted to other land uses in the near future.

1. Introduction

The world's population is growing rapidly: the UN predicts a 15% population increase in the next 15 years to a total of 8.4 billion people (UN 2012). Per capita consumption is increasing as well, especially in fast-growing economies, resulting in an unprecedented demand for resources. In response to increased forest loss over the past decades, international decisions have set global targets like the Aichi targets for biodiversity (CBD, 2010) and incentives to reduce emissions from deforestation and forest degradation in developing countries are being negotiated (UNFCCC, 2014). An informed vision on future forest area dynamics may help guide and prioritize international decisions aimed at reducing forest loss; this paper explores projected forest area change and its potential effect on the production and conservation functions of forests towards 2030.

Deforestation is the result of many processes driven by multiple causes. We can distinguish underlying and direct causes of land conversion; underlying causes can include economic development, demographic trends and technology factors, and direct causes can include cropland, pasture land or urban development expanding on, and replacing, forest land (Geist and Lambin, 2001; Smith et al., 2010). The underlying causes determine the degree of direct causes resulting in land-use change.

Despite the complexity of deforestation causes, it is generally accepted that deforestation is primarily occurring in the tropics (FAO and JRC, 2012) and the largest direct cause of deforestation is agricultural expansion as 70–95% of forests lost in the tropics are converted to agriculture (Holmgren, 2006; Hosonouma et al., 2012).

Hosonouma et al. (2012) used information reported in REDD+ Readiness Preparation Proposals from various countries and the Global Forest Resource Assessment (FRA) (FAO, 2010) to suggest that agriculture (cropland and pasture) is by far the largest direct cause of deforestation; according to their estimations between 70% and 80% of forest conversion is to agriculture in Africa, around 70% in subtropical Asia and >90% in Latin America. Other studies equally indicate agricultural expansion as the largest direct cause of deforestation in Africa, Asia and Latin America (Nepstad et al., 2008; Guitierrez-Velez et al., 2011).

Forest gains, on the other hand, are driven by two main factors: natural forest regrowth on abandoned agricultural land (Baumann et al., 2011) and tree planting for consumption, either as timber (Antweiler et al., 2012) or energy wood. Many studies suggest that wood is indeed increasingly used as an energy source at the global level, not only in developing countries (Smeets et al., 2007; IEA, 2011) but also in developed economies (UNECE and FAO, 2009; USEIA, 2014). As a consequence, the regional and global patterns of wood production have changed in the last few decades, with a rapid and significant increase in the area of planted forests and

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the growing importance of these resources for wood supply (Carle and Holmgren, 2008; Whiteman, 2014). However, technological development in wood processing and the use of other bio-energy sources does not imply that the increased energy demand results in an equal increase in wood demand. For instance, Buongiorno and Zhu (2014) looked at changes in technology and found that wastepaper is increasingly used to replace virgin fibre in pulp and paper production, buffering the effect of increased global bio-energy demand on global wood demand.

In order to capture these different patterns of losses and gains of forest in the next 15 years, we built a model based on several hypotheses: the first is that the changes occurring in agricultural land and natural forest land are meaningfully correlated. This is despite the fact that magnitude of changes occurring in agricultural land and natural forest land are not directly and linearly comparable. Our second hypothesis is that we can use wood consumption projections to build a model predicting planted forest projections. To test the hypotheses we looked at the correlation between past natural forest area change and past arable land area change on the one hand, and wood consumption and planted forests area on the other hand.

Further on, forest area change per country was projected based on a historical trend analysis of FAOSTAT (2013) and FRA country reported data on forest and agricultural area, combined with exogenous global cropland projections to 2030 (Alexandratos and Bruinsma, 2012) and global wood demand projections to 2030 (as in Buongiorno et al., 2012, harmonized with FAO data).

To assess the impacts of forest area changes on production and conservation functions, a global forest map with information on forest functions was produced and the forest area loss projected by the first model was spatially allocated based on an analysis of socio-economic and biophysical characteristics of past forest loss.

Finally, we compared the outcomes of the model with regional change estimates based on country expectations on future forest area changes reported in the global forest resources assessment (FRA) 2015 user survey and provided possible explanations for diverging expectations. The results are presented by region and income level and are limited to the countries that reported data in the FRA 2015 survey, answering to the question, "What is forest area likely to be in the future?"

2. Material and methods

In this paper, the definitions of forests, planted forests and other land uses follows the FRA Terms and definitions (FAO, 2012b). In particular, forest land use excludes any agricultural use (i.e. oil palm plantations are not considered forests), natural forests are comprised of both primary forest and naturally regenerated forest and planted forests are established through planting and/or deliberate seeding.

Three sets of data on forest area change, compliant with the FAO definitions, were used to determine and discuss potential forest projection towards 2030:

– A tabular data country-based model that produces regional and global trends (explained in 2.2–2.5),
– a spatially explicit model using the quantitative projections from the first model and spatially allocating these losses on a global forest map based on a historical trend analysis of locations of past forest loss (2.6),
– a set of country-specific predictions provided as expert judgment for the 2015 Global Forest Resource Assessment (FRA 2015) user survey (2.7).

2.1. Forest projection model: GFRM

The Global Forest Resources Model (GFRM), developed in this study, is based on tabular data per country and projects forest area change using exogenous projections of arable land and wood demand. Because of the strong prevalence of agricultural expansion as the main determinant of past deforestation, we built our modelling choices on the assumption that future forest loss is likely to be strongly determined by future agricultural expansion. Agricultural expansion is approximated with arable land projections up to 2030 by Alexandratos and Bruinsma (2012), which are mainly driven by projections of Gross Domestic Product (GDP) and population expansion, the main exogenous drivers for most global land-use change models (Fischer et al., 2005; Van Vuuren et al., 2007; Schmitz et al., 2014). The arable land projections also include projected changes in agricultural intensification which include policy assumptions that potentially provide an enabling environment and some major assumptions on future commodity trade (Conforti, 2011; Alexandratos and Bruinsma, 2012). The model assumes forest gain to be determined by forest regrowth on a share of abandoned agricultural land and an increase in forest planting driven by wood demand (timber and fuelwood).

The GFRM consists of projections of natural and planted forest as described in Fig. 1.

2.2. Arable land and natural forests

The GFRM projection for natural forest change is a linear relationship between arable land change projection and forest change projection:

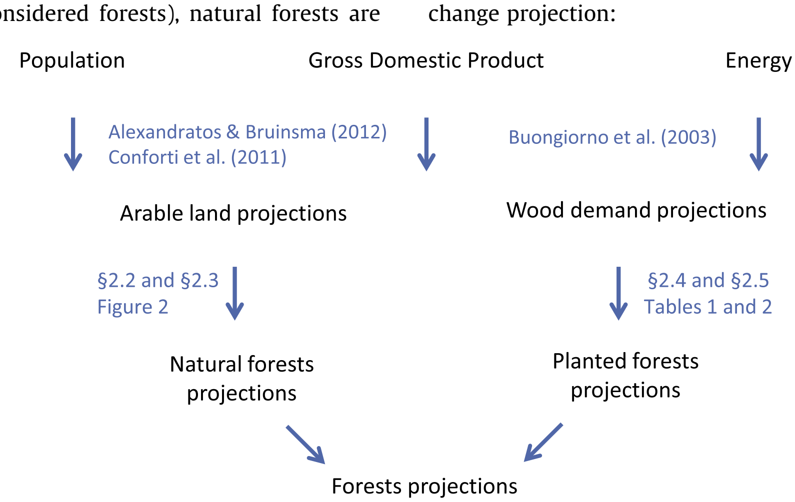

Fig. 1. Schematic representation of the modelling approach used in the study: the Global Forest Resources Model (GFRM).

$$[\textit{Natural forest change projection}] = \alpha * [\textit{Arable land change projection}] \quad (1)$$

In Eq. (1), α is a parameter that depends on the correlation, at the country or sub-regional level, between recent arable land change (ALC) available in FAOSTAT (2013) and recent natural forest area change (NFAC) available in FAO (2010). The α parameter is determined by the following circumstances:

– Where there is a correlation, the natural forest change projection is simulated proportionally to the ratio between the variables ($\alpha = \frac{NFAC\_0}{ALC\_0}$). If the correlation is country specific, the country ratio is taken, if the correlation is only sub-regional, the sub-region ratio is taken.
– Where there is no correlation between ALC and NFAC and the arable land decreases, the GFRM simulates that half of the abandoned arable land will grow back to forest evaluating the country's potential area for forest ($\alpha = \frac{Forest\_Pot}{2}$). The potential is calculated from the global ecological zone map from FAO (2012a) as the proportion of zones where the biophysical conditions are such that the estimated vegetation would be forest in the absence of human induced or natural disturbances.
– Where there is no correlation and the arable land increases, the model assumes the full arable land expansion to occur on forest ($\alpha = 1$).

Fig. 2 summarizes the modelling process of arable land and natural forest change projections as a decision tree, with the number of countries concerned at each node and the share of the global forests they represent.

2.3. Projections of arable land

FAO's arable land projections are driven by exogenous assumptions on population and GDP, in simplified terms described as more people will consume more agricultural products, and richer people will consume more agricultural products up to a certain extent and will have different diets, i.e. eat more meat. Increased production demand in the model is met by arable land expansion and intensification, either through increased cropping intensity or increased yield intensity. A more detailed description of FAO's agricultural production, yield and arable land projections is derived from Alexandratos and Bruinsma (2012) and Conforti (2011).

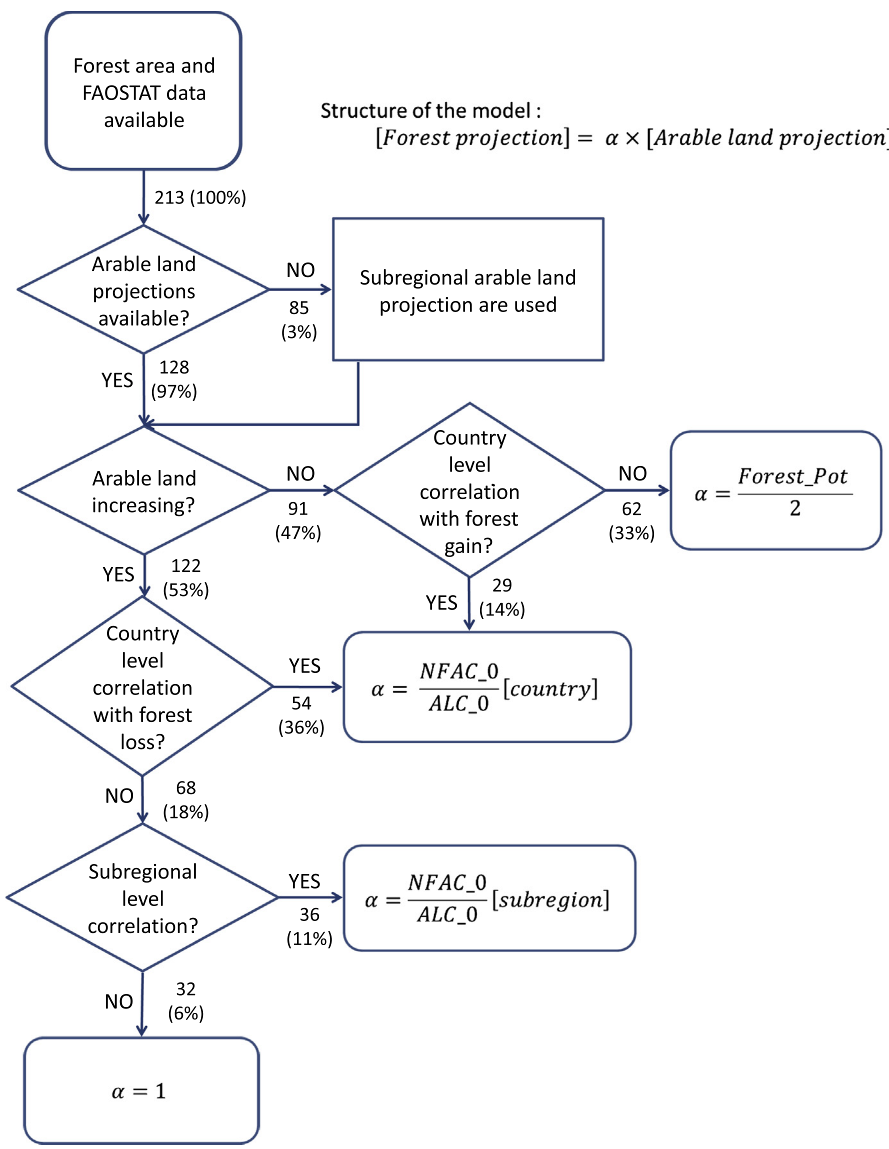

Fig. 2. Flowchart representing the decision tree of the Arable Land/Natural Forest module of GFRM. Explanations of the main equation and parameters are found in the text. At each node, number of countries concerned and the share of the global forests they represent are given.

2.4. Wood demand and planted forests

The GFRM projection for planted forest area is a function of (i) global wood demand, (ii) the changing supply of regional wood production from planted forests and (iii) the productivity change foreseen in planted forests. The projections include assumptions regarding changes in the production intensity of planted forests and in the share of supply coming from planted forest as estimated by national FRA correspondents. These assumptions were translated into sub-regional weighted average predictors of change (Tables 1 and 2).

The general structure of that module can be written as:

$$[\mathit{Planted\,forest\,change\,projection}] = [\mathit{Wood\,demand\,projection}] * [\mathit{Supply\,change}] * [\mathit{Productivity\,change}] \quad (2)$$

2.5. Projections of wood demand

Exogenous projections of wood demand were derived from Buongiorno et al. (2012), IPCC emission scenario B2, using intermediate assumptions on globalization, updated to ensure full harmonization with the forest loss projections discussed in 2.2. The Global Forest Products Model (GFPM), by Buongiorno et al. (2003), is a dynamic economic model of the forest sector where the equilibrium in a particular year is a function of the equilibrium in the previous year. Following Buongiorno et al. (2003), we calculated equilibrium by maximizing the global "net social payoff" under the assumption that markets work optimally in the short-run (one year) to maximize consumer and producer surplus for all products in all countries (Samuelson, 1952). Yearly changes in equilibrium are then simulated by recursive programming, showing the recursive dependency of the current equilibrium on the past and assuming that imperfect foresight prevails over longer time periods (Day, 1973). The details of the GFPM parameters used in this study are the same that have been used in Buongiorno and Zhu (2014). The wood demand projections take into account historical elasticity between GDP and wood demand and assumptions on future technological changes in wood production based on trend extrapolation. The model simulates the evolution of competitive world markets for forest products and recognizes country interaction through world economic trade (Buongiorno et al., 2012).

Table 1
Change in share of total wood production originating from planted forests by sub-region, region and globally as estimated by FRA correspondents, including the number of countries the estimate is based on and the share of total production they represent. The sub-regional, regional and global estimates are obtained by weighing each county estimate by its relative production share in the sub-region/region/world.

	Wood production from planted forest		Number of countries	Share of total production (%)
	in 2013 (%)	in 2050 (%)		
Africa (E&S)	14	36	6	21
Africa (N)	29	52	4	78
Africa (W&C)	11	45	11	70
Asia (E)	48	71	3	96
Asia (S)	83	97	3	83
Asia (E&S)	39	62	4	61
Asia (W&C)	6	23	4	77
Europe	33	59	3	12
Caribbean	20	20	3	10
Central America	34	63	2	51
North America	37	58	2	73
Oceania	80	95	3	48
South America	77	86	5	86
Total	49	69	52	60

Table 2
Expected increase by 2030 in the production of wood in planted forest as estimated by FRA correspondents (including the number of countries the estimate is based on and the share of total production they represent). The sub-regional, regional and global estimates are obtained by weighing each county estimate by its relative production share in the sub-region/region/world.

	Expected increase in production of planted forests (%)	Number of countries	Share of total production (%)
Africa (E&S)	24	3	11
Africa (N)	186	4	78
Africa (W&C)	13	9	49
Asia (E)	27	2	96
Asia (S)	98	3	83
Asia (E&S)	20	4	61
Asia (W&C)	44	4	72
Europe	12	4	16
Caribbean	3	2	0
Central America	34	3	65
North America	48	2	73
Oceania	10	2	48
South America	18	4	86
Total	43	46	58

2.6. Spatial analysis of forests being at risk of loss

The second step of the modelling exercise aims to assess the risk of future forest loss by management type, i.e. forest used primarily for protection and conservation and forest used primarily for production. The quantitative data from the GFRM determines the amount of forest loss per country and is fed into the spatial model, which determines the location of forest at risk of being lost. The spatial model used, GEOMOD, identifies areas likely to be lost based on a trend analysis between historical forest loss and a set of driver variables (Pontius et al., 2001). Variables that revealed a correlation with historical forest loss were used as driver variables and include: rural population density (FAO, 2013), slope (EROS, 1996), crop suitability (Fisher et al., 2010), and accessibility (World Bank, 2009). To determine the function of forests at risk of being lost, spatial data for production forest and protected areas were compared to the spatial allocation of the GFRM loss projection.

Globally compiled spatial data for production forests do not currently exist; therefore a spatial approximation for production forest was created. In order to approximate the area of production forests by sub-region, the data reported to FRA for forests primarily designated as production forests, plus a third of forests designated as multiple use were summed up by sub-region. Many countries indeed report areas which contain production forest under the multiple use primary designation, due to its all-encompassing nature. The location of production forests were determined by excluding (i) forests which are in protected areas, (ii) forests with slopes greater than 17°, and (iii) forests in countries which did not report production forest area for FRA 2010. The remaining areas were considered exploitable forests and served as a rough proxy for production forests.

The location of forests with the primary function of conservation was determined using the World Database on Protected Areas (WDPA, 2012). WDPA gives spatial location and attribute information on over 190,000 nationally and internationally protected sites at a global scale. Protected areas with a designated status and classified as IUCN category I–IV (Dudley, 2008) are included in the spatial analysis of protected areas. The coarse resolution of the analysis caused some protected areas to be excluded: the resulting total area of forests in protected areas is 409 million hectares while FRA 2010 reported a higher 460 million hectares of forests within protected areas.

The Intact Forest Landscapes (IFLs) dataset (Potapov et al., 2008) defines intact forest as unbroken expanses of natural ecosystems within the zone of current forest extent, with an area of at least 500 km^2 and minimal signs of human activity in the year 2000. In 2010, intact forest covered over 1 billion hectares of the global forest area and the IFL map is used as a proxy for 2010 primary forest area.

2.7. Country-specific predictions to FRA2015 survey

The question asked in the survey was "What is forest area likely to be in the year 2030?" and was answered by 91 countries, containing 65% of the world's forests. The answers were estimated by FRA national correspondents, based on varying level of data quality and they represent the official positions of the countries. They essentially reflect country-specific expectations and helped take national circumstances into account in the discussion of the model's results.

3. Results and discussion

3.1. Validation of the model assumptions

The first assumption of the model involved trends in agricultural land change and forest land change that were correlated in the past. Table 3 shows the comparison between forest area change and arable land change. In all sub-regions where forest area was decreasing between 1990 and 2010, there was a negative correlation with arable land change. In two sub-regions where the area of natural forest was increasing, again a negative correlation with arable land dynamics appears, while in a third (the Caribbean) this trend is absent. Therefore, we assume the first assumption to be valid.

The second assumption in the model was also corroborated by the systematic expected correlation, for all sub-regions, between wood demand and planted forests (Tables 1 and 2).

The accessibility data was used to determine the locations of production forest and was also used as a driver of future forest change determining the locations of projected loss. The coincident use of accessibility data to determine the spatial distribution of both location of production forest and location of projected forest loss may have led to overestimation of production forest at risk of being lost, and this must be considered while analyzing the results.

Table 3
Correlation between natural forest area change as estimated in FRA 2010 and Arable land change in FAOSTAT (2013).

Subregion[a]	Natural forest area change (1990–2010)	Negative correlation [b] with arable land?
Central America	Decreasing	Yes
Eastern and Southern Africa	Decreasing	Yes
Northern Africa	Decreasing	Yes
South America	Decreasing	Yes
South-east Asia	Decreasing	Yes
Western and Central Africa	Decreasing	Yes
East Asia	Increasing	Yes
Europe	Increasing	Yes
Caribbean	Increasing	No
North America	Stable[c]	No
Oceania	Stable	No
South Asia	Stable	No
Western and Central Asia	Stable	No

[a] Only countries for which FAOSTAT data from 1990 was available are included, e.g. Europe does not include the Russian Federal Republic.
[b] Given the small amount of dates compared here (4) we say a negative correlation exists when the correlation factor <−0.7. The average correlation for the subregions where natural forest area is decreasing is −0.93 (a perfect negative correlation would be −1).
[c] Stable is defined as a <5% change in natural forest area between 1990 and 2010.

3.2. Global and regional forest projections

As observed in Fig. 3, global forest area is projected to continue to decrease over the next 15 years. However, the rate of overall loss is projected to slow down, going from 0.13% per year at the beginning of the century to 0.06% per year by 2030. This is the result of the decrease in the rate of natural forest loss (0.26% per year to 0.19% projected per year by 2030) combined with the decrease of the rate of the planted forest gains (2.36% per year to 2.0% projected per year by 2030).

Our projections fall within global forest area projections found in the literature (MEA, 2005, UNEP, 2007, and OECD, 2012) that show a range of outcomes from recovered forest area numbers resulting in no net change in global forest area or slight area increase, to a substantial loss (>15%) up to 2030 compared to the year 2010.

Global loss of forest area is projected to be the net result of forest area increase in some regions and forest area decrease in others (Table 4). The regional forest area changes are also the result of increases in some sub-regions and decreases in other sub-regions. For instance, Asia shows increases in East Asia compensated by losses in Southeast Asia, resulting in a net forest increase for the region. Following the model, South America is projected to continue undergoing the largest net forest area loss over the next 15 years.

As explained under Section 2.1, the projections of arable land dynamics include some assumptions on policies and national circumstances, especially concerning assumptions on agricultural intensification in Africa (Alexandratos and Bruinsma, 2012). No assumptions have been made on future forest policies though, whose inclusion could be considered highly speculative. Provided the limited consideration of future forest policies, the results should be handled with caution and understood as a business as usual scenario, as only global considerations on prices have been incorporated in the model. Policy measures such as future climate change mitigation or future land use planning are not integrated in the model considerations, and can possess an influential effect on the forestry trajectories. For instance, Arima et al. (2014) showed that the decline in rate of deforestation in the Brazilian Amazon forest is the result of two simultaneous processes, stagnation of global demand on agricultural prices and enforcement of policy regime to cut down deforestation while Dalla-Nora et al. (2014) discussed the limitations of models as they often fail to capture the real trajectories of land use change that are strongly influenced by policies.

This could indeed change the picture of global forest evolution: at the global level, non-legally binding political declarations are regularly made to strive to end deforestation by 2030 (UN climate summit, 2014). If these measures are realized by countries, the modelling approach we use would no longer be valid.

Forest policies have only been passively considered if they had an effect on forest area change before 2010. Therefore, climate change policies such as the mechanism for reducing emissions from deforestation and forest degradation (REDD+) are only incorporated based on early actions. Most country-driven actions under REDD+ are expected after 2010, since the Warsaw Framework for REDD+ (UNFCCC, 2014) was adopted in 2013, setting out the guidelines for developing country parties to receive results-based payments for emissions reductions in the forest sector. An example

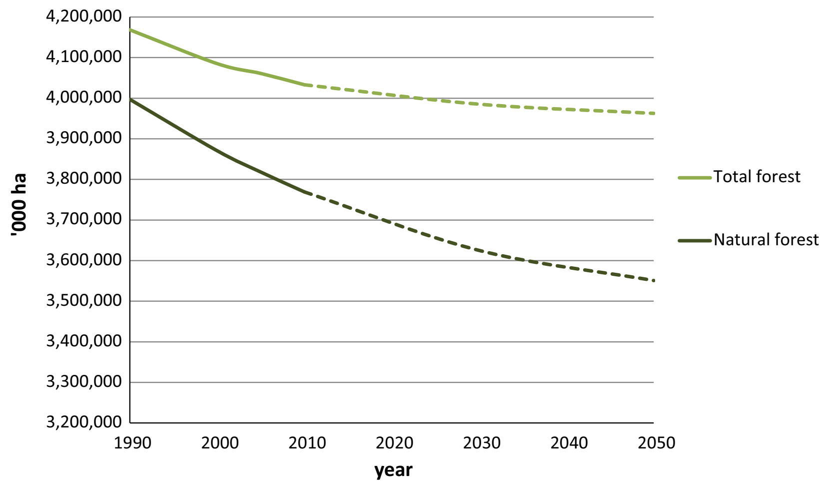

Fig. 3. Total forest area and natural forest area as projected by the GFRM (full line: data reported to FRA 2010, dotted line: data projected with the model).

Table 4
Regional forest areas in 2010 and their projections towards 2030.

Regions	Forest area (1000 ha) 2010	2030
Africa	674,000	646,000
Asia	593,000	604,000
Europe	1,005,000	1,039,000
N&C America	705,000	717,000
Oceania	191,000	190,000
South America	864,000	788,000

The results in this table come from the GFRM modelling exercise.

of early REDD+ action reflected in the model is Brazil where the deforestation rate started to drop as early as 2005 (Brazil, 2014). This trend is therefore considered in the modelling results, though regionally compensated by increasing deforestation trends in other countries.

Furthermore, the model functions on the assumption that the global conditions will remain the same during the period of interest. Yet, we acknowledge that the occurring climate change will have effects up to at least the end of the 21st century (IPCC, 2013).The effect of climate change on forest projection has been quantified in various studies and ranges from limited impact component (Thompson et al., 2011) to game-changer scenario: Kreileman and Alcamo (1998) for instance, project forests towards 2100 under various modalities and show that a scenario including only land-use change would lead to global forest loss, whereas the inclusion of climate change in their model switches the results to substantial forest gains. Depending on how climate changes in the next decades, the effect of climate change could become more significant than presented here. Given the relatively short span of time addressed by this study, we believe the assumption is still acceptable.

The overall pattern of our model shows that global loss will keep on by 2030, while slowing down, and we further explored the projections stratified by regions, to examine what type of forest was at risk of being lost.

3.3. Functions of forests at risk of being lost

The results of the projection of productive and protective areas of forests with GEOMOD are summarized in Table 5. The area comparison showed that 32 countries presented a risk of seeing their protection/conservation forest area be threatened by deforestation, while 36 countries presented a similar risk for their production forests (which mainly concerns natural forest with a production function).

However, according to the spatial modelling at the global scale, most primary forests are not at high risk of loss with less than 1% projected loss. Over 95% of this primary forest loss is projected to occur in the tropical climatic domain only.

The results can also be used to reveal trends in projected loss in production forest areas and protected forest areas, for all regions and climatic domains.

South America has the largest proportion of projected gross loss of production forest, losing 26% of production forest area by 2030, though this does not take into account neither law enforcement nor the increased production function of planted forest. Similarly Africa has very high rates of production forest loss with 15% of its production forest area lost by 2030. Europe (including the Russian Federation) is the region with the largest area of production forest and least projected production forest loss.

When assessing the trends by climatic domain it is apparent that the tropical climatic domain has the highest risk of future forest conversion. Production forest in the tropical domain are projected to have about 15% area loss. Sub-tropical production forest area losses are projected to be 5%. Temperate forests are projected to lose less than 1% of production forest area and boreal forests are projected to experience virtually no loss between 2010 and 2030.

Protected areas make up a smaller proportion of total forest area than production forest. South America, North America and Oceania all have large areas designated for protection and small projected loss within those forests. Africa and Asia are projected to suffer the highest portion of protected areas loss (4%).

Tropical protected forests have the highest risk of conversion to non-forest between 2010 and 2030. The tropical climatic domain is projected to lose 3% of its protected areas between 2010 and 2030. The model projects very little to no change for the subtropical, temperate, and boreal climatic domains.

The results can finally be compared with specific country expectations towards 2030 as a mean to verify the model validity and discuss some of the assumptions.

3.4. Country specific predictions for 2030

Out of the 234 countries that reported data to FRA 2015 only 91 countries (containing 65% of the global forests) reported data to the question "What is forest area likely to be in the future?" This is clearly not sufficient to generate sensible global or regional trends, especially in Africa, North and Central America or Oceania where

Table 5
Projected area of forest at risk of being lost by 2030 within production, protection and primary forests, by climatic domain and FRA region.

Area of forest at risk of being lost (2010–2030)...		Climatic domains				FRA regions					
		Tropical (%)	Subtropical (%)	Temperate (%)	Boreal (%)	Africa (%)	Asia (%)	Europe (%)	N & C America (%)	Oceania (%)	South America (%)
Production forest	Proportion of 2010 production forest	15	5	0.80	0	15	5	0.07	0.30	3	26
	Proportion of 2010 total forest area	4	2	0.50	0	5	2	0.04	0.10	0.50	5
Protected forest	Proportion of 2010 protected forest area	3	1	0.10	0	4	4	0.20	0.20	1	2
	Proportion of 2010 total forest area	0.30	0.10	0.02	0	0.30	0.30	0.01	0.02	0.30	0.20
Primary forest	Proportion of 2010 primary forest area	2	0	0	0	1	1	0	0	0	2
	Proportion of 2010 total forest area	0.10	0	0	0	0.08	0.02	0	0	0	0.20

The results in this table come from the combination of the GFRM modelling exercise and spatial modelling.

reporting countries represent less than half of the actual forests (Table 6).

For that reason, the results of the country specific prediction cannot be extrapolated to regional or global estimate and were not directly compared with the results of the modelling. For instance, the net resulting gain of circa 78 Mha expected for all the reporting countries only concerns 65% of the forests of the world and cannot be compared to the expected global continuing forest loss coming from the model.

However the country-specific predictions aid in understanding the vision and target that the reporting countries intend to meet by the year 2030; these were used to discuss the projections of the model.

There are strong contrasts by region and income level in projected forest area change. For instance, Asia reported to expect the highest gain with 90 million hectares of forest area increase whereas South America reported to expect the highest forest loss with over 35 million hectares of forest area decrease. Little change was reported to be expected in the high and low income categories, while the middle categories comprised both strong gains and losses. This is particularly true when comparing the high income and upper medium income categories: for the same number of reporting countries and a sensibly equal forest area represented, the latter expect 6 times more change to happen in the next 15 years, indicating an economic dynamism in Medium countries (more conversion of forest to agriculture but also more planting) that is not detected in High income countries. The responses for the Low income category countries are not representative enough (only 16% of forests represented) to draw any practical conclusion.

Regarding the magnitude of expected forest area change, 56% of the reporting countries estimated less than 10% of forest area change to occur between 2015 and 2030. However, a small number of countries, listed in Table 7, presumed strong changes towards 2030. These few countries strongly influence upward the entire dataset as it essentially concerns gains, with the exception of Bolivia which suspects increased forest loss in the next 15 years (84% of its current forest area is expected to be lost by 2030).

The figures for China and Russia are in line with the trends observed in the past, and hence would tend to confirm the prediction of the model. China has substantially increased its forest area and forest stock volume since the early 1990s because it made increasingly significant, effective and large-scale programmatic efforts during the past three decades to enhance afforestation and reforestation. These programs have benefited from sustained and substantial allocation of fiscal and other resources by central and local governments (Antweiler et al., 2012).

Table 6
Expected forest area change (losses, gains and resulting net change) for 2015–2030 (1000 ha) summed up by region and income level.

	Expected forest change within reporting countries, 2015–2030 (1000 ha)			Nb countries	Share of total forest area (%)
	Loss	Gain	Net		
Africa	2298	21,686	19,389	22	26
Asia	5615	95,656	90,041	21	80
Europe	557	12,820	12,263	28	92
N&C America	6626		−6626	5	51
Oceania	50	1	−49	2	19
South America	50,145	13,327	−36,819	13	76
High	6122	11,986	5865	29	68
Upper medium	10,193	44,136	33,942	29	73
Lower medium	47,446	78,844	31,398	23	76
Low	1529	8,523	6994	10	16
Total	65,291	143,490	78,199	91	65

The results in this table come from the FRA 2015 user survey analysis. The number of reporting countries and share of the total forest area represented by the reporting countries are given in the last two columns. Because the reporting countries are not enough to adequately represent the regions (e.g. Africa with less than 26% of the forests covered by the survey), results are only summed-up and not extrapolated.

Table 7
Countries expecting strong change in their forest area by 2030.

	Forest change 2015–2030	
	(1000 ha)	(%)
Argentina	12,947	48
Bolivia	−45,764	−84
China	22,079	11
Indonesia	21,330	23
India	37,798	53
Nigeria	13,720	196
Togo	1510	803
Russia	10,070	1

The results in this table come from the FRA 2015 user survey analysis.

In the case of Russia, regrowth of forest on abandoned arable land is a past trend that is expected to continue, as described in the Russian outlook study (FAO, 2012c).

The case of Indonesia illustrates the will of the country to engage in REDD+ (UN-REDD, 2014) process and re-convert a large share of its land to forests. This is another example of political decision-making that tends to counter-effect past trends in the tropics and could, if indeed enforced, invalidate the conclusions of the modelling decisions taken in this study.

To explore that point in more details, we compared trends in forest area over the past 15 years with the expected trend for the next 15 years (Fig. 4). Most countries (58 out of 91) are presuming the trend to remain the same, e.g. continuing loss is presumed in Brazil and Mali and continuing gain in India, China and Russia, though the rate of loss/gain may be expected to change.

The other countries are expecting an inversion in their forest trends: Bhutan, Belarus, Iran and the USA for instance, have seen their forest area increase over the past 15 years but they are assuming a minor forest loss in the next 15 years. Conversely, countries like Argentina, Indonesia, Nepal, Nigeria, Tanzania and

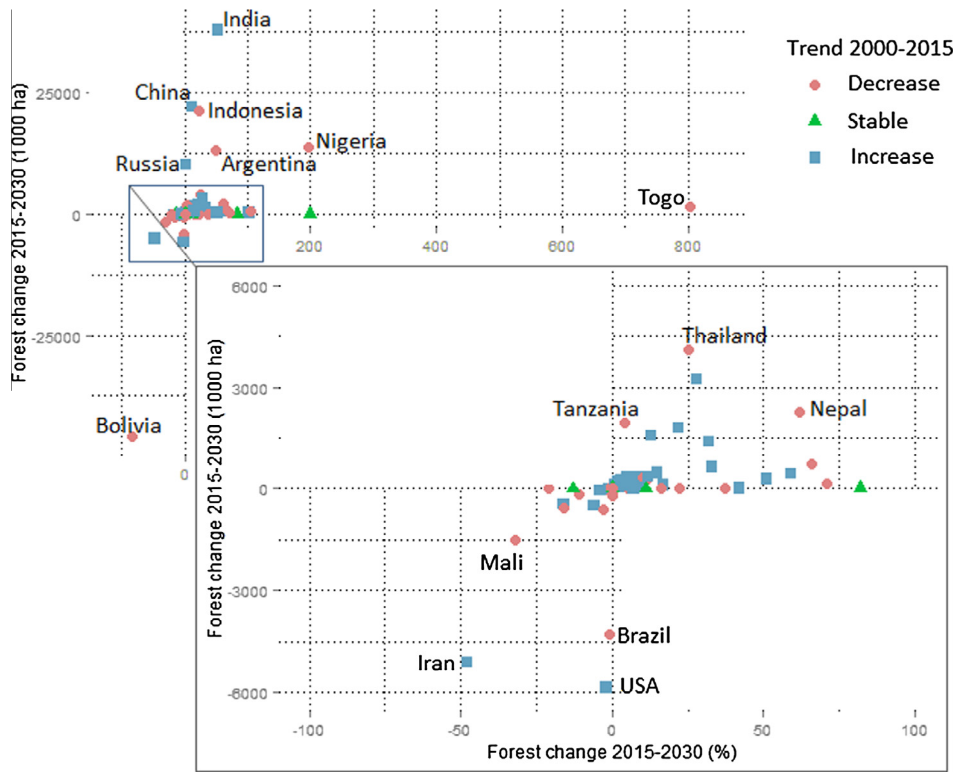

Fig. 4. Plot of forest area change for 2015–2030 as expected by countries, in absolute (1000 ha) against relative values (% of the 2015 forest area). Countries in the upper right quarter are expecting gains in the future, while countries in the lower left are expecting losses. The past trend is showed in colors, with countries that experienced losses during 2000–2015 in red and countries that experienced gains in blue. This helps to underline countries that expect an inversion of their current trend (e.g. USA showing up in blue in the lower left quarter or Nigeria showing up in red in the upper right quarter). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

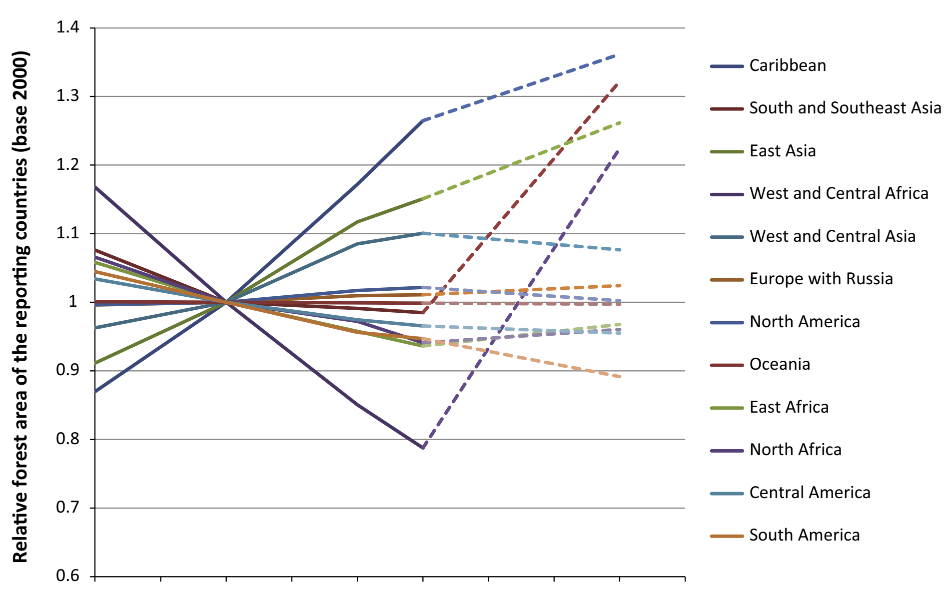

Fig. 5. Relative forest area (year 2000 is taken as the base) as reported in FRA 2015 (for 1990, 2000, 2010 and 2015, full lines) and projected by countries (for 2030, dotted lines). Results are aggregated by sub-region but note that only reporting countries are included (see Table 6) and should hence be handled with caution for underrepresented sub-regions. This graphic is essentially displayed to spot out sub-regions where trends are likely to diverge from the modelling linear solution presented in the GFRM (South and South East Asia and West and Central Africa).

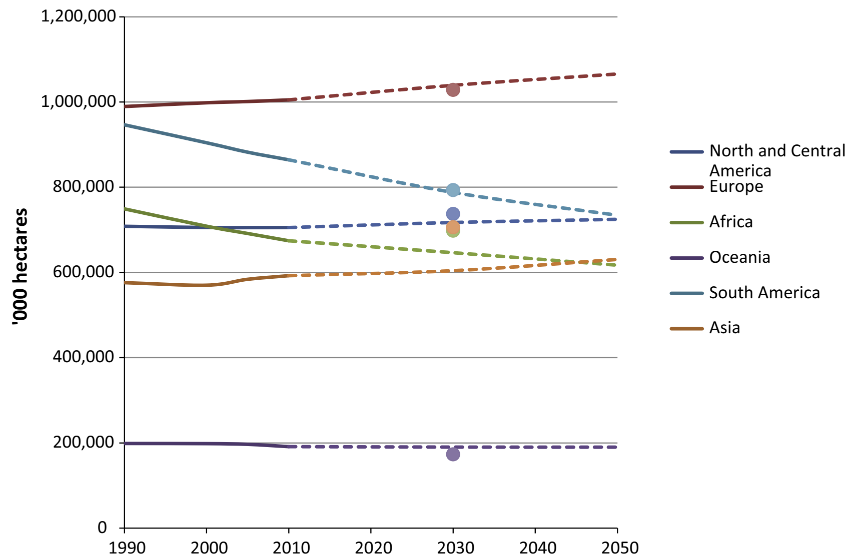

Fig. 6. Forest area by region as (i) estimated in FRA2010 for the period 1990–2010 (full lines), (ii) projected with GFRM towards 2050 (dotted lines) and (iii) extrapolated from the country specific aspiration for 2030 as reported in FRA 2015 (points). Note that the divergence for Asia and Africa is strongly influenced by the low representation of reporting countries and the change of trend expected from countries within these regions.

Thailand are assuming the loss observed in the past will be reverted to gain in forest.

The trends in forest area translate into sub-regional patterns as can be seen in Fig. 5. In most sub-regions, the trend in forest area change observed from 1990 to 2015 is estimated by the reporting countries to remain similar in the future. The trends slow down with lesser gains and lesser losses, which corresponds to the projections we made using the GFRM. However, two sub-regions stand out of that converging picture. In South and Southeast Asia as well as in West and Central Africa, countries are foreseeing a clear inversion of the expanding forest trend. This still holds for North and East Africa, but to a lesser extent.

One should keep in mind that these trends are strongly influenced by outlier countries (e.g. Indonesia and Nigeria), so that the extrapolation for these sub-regions should be used cautiously and only for discussion purposes. We hence used the limited data coming from the expectations of countries and extrapolated them to the regions to compare with the results of the model (Fig. 6).

Overall, the model results and the country expectations are in agreement for North and Central America, Europe, South America and Oceania, but diverge for Africa and Asia. The difference for Asia might be explained by the fact that Asia's planted forest objectives are possibly not entirely driven by a demand for wood but may consider soil restoration, climate change mitigation and other conservation related objectives whereas the model is only driven by wood demand. For Africa, the reporting countries are clearly not representative of the whole region (26% only) and the extrapolation should not be considered valid.

Finally, these discrepancies also show that country specific policies could still influence the pattern of continuing forest loss projected to occur. The diverging results reflect the intentions and expectations of countries regarding their forest policies as relevant items that would need to be incorporated in further global projection exercise.

4. Conclusion

Both the modelling results as well as the country predictions suggest that, at the global level, forest resource loss is likely to continue but slow down by 2030.

However, the relatively smaller global annual net change in forest area in 2030 compared to 2015 masks large regional differences; in some regions, forests are projected to continue to decline at alarming rates. Furthermore, even though global forest loss is projected to slow down, the rate of biodiversity loss may not display a similar levelling trend since loss of natural forest is partially off-set by expansion of planted forests. Additionally, the impacts on biodiversity are not fully captured because forest habitat losses in the tropics cannot be directly compensated for forest gains in other ecological zones (Pereira et al., 2010). The productivity of planted forests is estimated to increase and that may have a trade-off in diminished richness of biodiversity. The forest areas that are the most at risk of conversion were identified as forests under multiple uses, within the tropical domain. The forest under protected areas showed very little risk of being converted to other land uses in the near future.

The conclusions of the modelling effort generally align with the estimations of the FRA2015 user survey, at least for the regions where enough countries have reported their expectations.

This study helped identify countries whose forest policy and/or aspiration for the future might curb the actual trend. If these aspirations prove to be true, the projected loss from the model might be lower than expected. On the other hand, the assumptions of the model that productivity will increase might not prove strong enough to reduce pressure on forests; this, in turn, may lead to more forest loss than projected.

The discrepancies between the modelling exercise and the country estimations reveal relevant aspects that would need to be incorporated in a further global projection exercise, accounting for the global-scale effort to curb deforestation put into place by the international community.

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