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WORKING PAPER

IMPROVING THE FORESTS DATABASE TO SUPPORT SUSTAINABLE FOREST MANAGEMENT

SCOPING STUDY FINAL REPORT

JUNE 2014

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PROFOR
PROGRAM ON FORESTS

RESOURCES
FOR THE FUTURE

WAVES
Wealth Accounting and
the Valuation of Ecosystem Services

Acknowledgments

We thank the World Bank team, Urvashi Narain, Glenn-Marie Lange and Esther Naikal, for their helpful inputs to this report and comments and suggestions during the scoping study. We also thank the participants at the workshop held at the World Bank on January 9, 2014, including Juan-Pablo Castaneda, Tuukka Castren, Peter A. Dewees, Julian Lee, Robert De L'Escaille, Alexander Lotsch, Carole Megevand, Daniel Charles Miller, Ulf Gerrit Narloch, Nga Nguyen, Christian Albert Peter, Klas Sander, Stefanie Sieber, and Robert Shannon Stearma, for their comments and suggestions. Finally, we met with David Morales Hidalgo, Arvydas Lebedys, Yanshu Li, Robert W. Mayo, Kenneth McDicken, Ewald Rametsteiner, and Rebecca Tavani at FAO in Rome and with Torsten Bondo, Stephen Coulson, and Benjamin Koetz at the European Space Agency near Rome in November 2013. We thank everybody for their helpful comments and suggestions. This project was funded by the World Bank Group through the Program on Forests (PROFOR) trust fund.

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Published in June 2014

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EXECUTIVE SUMMARY

At the heart of the issue of determining whether growth in a country is sustainable, is the issue of accumulation of wealth. It is wealth—broadly defined to include manufactured capital, natural capital (including forests), human and social capital—that underlies the generation of national income. Gross domestic product (GDP) has conventionally been used to assess economic performance, measuring economic growth from one year to the next. But GDP does not take into account depreciation and depletion of wealth, and therefore does not provide an indication of whether growth is sustainable: an economy could appear to be growing in the near term by running down assets. Assessments of economic performance should therefore be based on both measures of annual growth (such as GDP) and measures of the comprehensive wealth of a country, which indicate whether that growth is sustainable in the long term.

For the past 15 years, one of the core business lines of the Agriculture and Environmental Services Department of the World Bank has been the comprehensive wealth program, which provides indicators to measure the sustainability of a country's growth path. The indicators include Adjusted Net Saving (ANS) and adjusted Net National Income, which have been published annually since 1970, and comprehensive wealth estimates, which have been published for 1995, 2000, and 2005. Underpinning these indicators are data on natural resource rents (from forests, minerals, and energy) that provide policy makers with information on potential revenues from natural capital.

Findings from recent World Bank assessments suggest that while wealth data and ANS data are used by colleagues within the World Bank and researchers and policy analysts outside, the greatest demand is for the data on natural resource rents. Moreover, while minerals and energy rent data have gained a lot of traction, data for forests are not used as frequently. This is despite the importance of forests for the livelihoods of the poor and their role in economic development.

This study focuses on evaluating and improving the assessment of forest wealth. In its broad purpose, the study is intended to help improve the current forest wealth assessment methodology by the World Bank to enable more accurate estimates of forest wealth and other related indicators. The effort has involved three main activities: (1) review of the current methodology and relevant literature to evaluate and update the current approach for the estimation of forest wealth; (2) assessment of potential new data sources to help improve the current approach; and (3) development of implementation plan to revise the current approach.

The scoping study also involved several consultations with experts, including the January 9, 2014, workshop at the World Bank and meetings in November 2013 with forestry experts at the United Nations Food and Agricultural Organization (FAO) in Rome and with remote sensing experts at the European Space Agency.

CURRENT METHODOLOGY

Under the current forest wealth assessment, the value of forests is estimated as the sum of

i. wood wealth: the value of standing stock for commercial wood and woodfuel; and

ii. non-wood forest wealth: the value of forests that results from the provision of non-wood forest products, regulating services, recreation, and so forth.

Each category of wealth is valued as the present value of the stream of expected rents from the ensuing goods and services, as highlighted below.

Wood wealth is calculated as the net present value of rents from the production of different timber products, including industrial roundwood and woodfuel, discounted at 4 percent over the asset valuation time horizon. For each timber product category, total gross revenue is defined as the product of total annual production and unit price. Annual production data (m^3) by country are obtained from FAO-STAT. Unit prices are estimated by export unit values, which are also obtained data from FAO-STAT. Using a five-year average of gross timber revenue in combination with regionally estimated rental rates, average annual net timber revenue and its total net present value is estimated.

The concept of sustainable use of forest resources is incorporated into the choice of the asset valuation time horizon. If timber harvests are smaller than net annual increment, harvests are considered sustainable and the resource life span is capped at 25 years (for one generational assessment). For countries harvesting beyond the estimated annual increment, the resource life span is determined as the estimated time to depletion.

Non-wood forest wealth (NWFW) assessment estimates value associated with (i) watershed protection; (ii) recreation, hunting and fishing, and (iii) non-wood forest products (NWFP). Again, the wealth calculation involves deriving the net present value of annual goods and services over 25 years and using a 4 percent discount rate. Values associated with watershed protection and recreation, fishing, and hunting are based on per hectare value estimates found in the literature review by Lampietti and Dixon (1995). These per hectare values, which are globally uniform or vary only between developed and developing countries, are then multiplied by the relevant forest area to obtain the total value for each service, by country. Data on forest area is obtained from FAO's Global Forest Resource Assessment (FRA). For NWFPs, the annual value of these products is taken directly from FAO FRA. No accounting for the cost of production takes place in the estimation of the value of NWTPs.

On a per hectare basis and globally, the current approach estimates, on average, about $700/ha of wood benefits and about $300/ha of non-wood benefits. The estimated wood and non-wood wealth varies considerably by country and world region. On a country basis, wood wealth constitutes, on average, 52 percent of the estimated total forest wealth. The remaining 48 percent is in non-wood wealth.

EVALUATION OF THE CURRENT METHODOLOGY

The main issues with the current methodology involve the uses of outdated or otherwise potentially inadequate parameters or data to estimate wealth. Most such issues arise due to a lack of better, easily accessible, and comprehensive data to obtain consistent estimates for all countries.

For wood wealth, we identify two key limitations: the use of (i) export unit values (EUVs) to calculate the gross timber revenue and (ii) regional rental rates to derive the net timber revenue.

While export unit values are valid for valuing timber exports, domestic production often accounts for a large share or even the majority of timber production. Moreover, export and domestic prices vary due to differences in product categories and product quality attributes. The main justification for the current use of EUVs is that those data are readily available from the FAO statistics whereas data on domestic unit values are not. Obtaining data on domestic prices is difficult but our assessment identifies information from several countries. The analyses of these data, by and large, confirm that the export and domestic prices of timber products diverge, in some cases substantially. Regarding rental rates, we anticipate that they vary also within each region (rather than are constant as in the current assessment) as a result of local conditions such as species mix. We also note that the current approach makes no adjustments to account for illegal logging.

Moreover, the current approach to determining the life span of the resource (time to forest depletion in countries which overharvest forests) does not accurately consider the nature of forests as a renewable resource. More specifically, when considering the depletion of the forest growth stock, the current approach does not incorporate the lost future growth associated with the depleted stock. We develop and outline a revised approach to avoid this limitation.

For the woodfuel, we note that a general issue is the lack of suitable data for comprehensively assessing woodfuel production and its value. Data from FAO-STAT on woodfuel removals and their value is missing for most countries. Moreover, the value is often derived from export or import data, which may be poor proxies for the value of domestic woodfuel. On the other hand, the coverage of FAO data on woodfuel has improved in the recent years. Also, despite the above problems with the current approach, identifying improved yet consistent and comprehensive sources of data on woodfuel production and its value is challenging.

For the estimation of non-wood wealth, the key limitation involves the use of outdated and mostly uniform economic value estimates. For example, the current estimate of benefits associated with watershed protection is uniformly $10/ha, globally. The estimate is derived from the results of four studies conducted in the 1980s. The geographic coverage and methodological sophistication of ecosystem service valuation has improved considerably, so the value estimates used by the current assessment require updating. Additionally, values associated with ecosystem services are inherently spatial, so we recommend developing corresponding value estimates at regional or country-level (instead of using globally uniform or nearly uniform estimates). Similar considerations apply to the assessment of wealth associated with recreation, hunting, and fishing. Additionally, we note that the assumption that 10 percent of the forest area is available for recreation and 100 percent of forest area is available for watershed protection is not supported by any study and could easily vary by country. Finally, the current assessment excludes potentially relevant regulating services provided by forests such as forest carbon storage.

For NWFPs, the main limitation is that they are country reported with missing data for many countries. This pushes the assessment towards underestimating the value of NWFPs. The degree of underestimation likely varies by country and could be substantial especially for countries where NWFPs contribute most to livelihoods. Additionally, the cost of production is not considered in the valuation of NWFPs. This pushes the assessment towards overestimating the value of the NWFPs included in the current estimate.

RECOMMENDATIONS FOR IMPROVED METHODOLOGY

We identify several key areas where improvements to the current methodology are necessary and feasible. We prioritize areas for improvements based on their potential effect on the total wealth estimates. We consider data and parameters, which have (a) large potential current discrepancies and (b) substantial impacts on the final wealth estimates, priority candidates for revision.

Following the above logic, two key areas for improvement emerge. First, as explained above, we find considerable evidence that the export unit values inadequately reflect the value of timber gross revenues, thus, the value of wood wealth. Moreover, the estimates of wood wealth are highly sensitive to the estimated per unit price of timber. For example, doubling the price of timber per unit nearly doubles the corresponding wood wealth estimate (the value of woodfuel, which comprises a portion of the total wood wealth, remains unchanged, so moderates the impact on total wood wealth estimates). We therefore recommend and outline a concerted effort to revise the timber valuation methodology to better account for the value differential between timber production for domestic and export markets.

Second, we suggest a complete revision of the current outdated approach to the estimation of non-wood benefits associated with watershed services, recreation, hunting, and fishing. Again, the estimates of non-wood wealth are directly proportional to per-hectare estimate of non-wood benefits, so the suggested revision has the potential to substantially revise the wealth estimates. We recommend and outline a rigorous meta-analysis to examine and summarize current literature on ecosystem service values associated with forests. A number of previous meta-analyses are available but their data and methodological approaches limit the usability of the results for this assessment. Moreover, a comprehensive and rigorous meta-analysis of ecosystem service values would likely be beneficial for the World Bank also beyond the needs of this assessment.

There are also a number of other adjustments we recommend as next steps, including the development of country-specific rental rates for the calculation of net timber revenue; developing rental rate estimates for deriving net value estimates for NWFPs; further examining the potential use of remote sensing approaches to the estimation of forest cover and timber volume as well as their changes; examining the use of World Bank surveys to collect data on woodfuel use and valuation as well as examining benefits from non-wood goods and services provided by the forests; and examining the availability and use of information on illegal logging in the literature.

FAO-STAT is the main data source for the current forest wealth assessment. While these data have several widely-acknowledged limitations and gaps, the distinct advantage of using the FAO data involves the availability of consistent, relatively comprehensive, and frequently updated data for different countries around the world. While specific refinements such as supplementing or adjusting the FAO estimates using other data sources may be helpful, we find that, by and large, the continued use of FAO data is warranted and beneficial to the assessment.

Finally, the current assessment of non-wood wealth focuses exclusively on watershed services, recreation, fishing, and hunting. While accounting for all possible ecosystem services associated with forests across the globe is neither feasible nor sensible in the context of the assessment, we recommend augmenting the current assessment by including additional ecosystem services, such as carbon sequestration and storage.

INTRODUCTION

At the heart of the issue of determining whether growth in a country is sustainable, is the issue of accumulation of wealth. It is wealth—broadly defined to include manufactured capital, natural capital (including forests), human and social capital—that underlies the generation of national income. Gross domestic product (GDP) has conventionally been used to assess economic performance, measuring economic growth from one year to the next. But GDP does not take into account depreciation and depletion of wealth, and therefore does not provide an indication of whether growth is sustainable: an economy could appear to be growing in the near term by running down assets. Assessments of economic performance should therefore be based on both measures of annual growth (such as GDP) and measures of the comprehensive wealth of a country, which indicate whether that growth is sustainable in the long term.

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Findings from recent World Bank assessments suggest that while wealth data and ANS data are used by colleagues within the World Bank and researchers and policy analysts outside, the greatest demand is for the data on natural resource rents. Moreover, while minerals and energy rent data have gained a lot of traction, data for forests are not used as frequently. This is despite the importance of forests for the livelihoods of the poor and their role in economic development.

UPDATING FOREST WEALTH DATABASE

The World Bank is in the process of reviewing and improving the current forest wealth assessment methodology to enable more accurate estimates of forest wealth and other related indicators. The activity to review and improve the current forest wealth assessment takes a two-phased approach, where Phase 1 is a scoping out exercise and Phase 2 is the implementation of the updated forest database. The expected outcome of Phase 1 is to increase awareness of more accurate forest data sources, better information on updating the forest wealth database, and increased collaboration with key forestry partners. Phase 1 will be followed by an implementation phase, Phase 2, where the updated forest database will be created.

Ultimately, the entire effort, including Phase 1 and Phase 2, will help increase the use and usefulness of the World Bank forest data (forest rents, net forest depletion, and forest wealth), so that the World Bank staff as well as countries and other data users are better equipped with credible and more accurate information on forest resources and their contribution to societal wellbeing. The medium-term outcome is an increase in policy discussions with governments on forest resource management, forest governance, and rent revenue management, based on the improved forest database.

The rest of this report explains Phase 1: Scoping Study and its findings. The broad purpose of the scoping exercise is to help improve the current forest database and estimation of forest wealth. This requires three main activities: (1) a review of the relevant literature to evaluate and update parameters used in the current methodology; (2) assessment of new data sources to help improve the current approach; and (3) development of implementation plan. Each of these steps is described in more detail below.

The scoping study also involved several consultations with experts, including the January 9, 2014, workshop at the World Bank and meetings in November 2013 with forestry experts at the United Nations Food and Agricultural Organization (FAO) in Rome and remote sensing experts at the European Space Agency near Rome (see the Appendix for the experts consulted).

In the rest of this report, we first explain the current forest wealth assessments methodology, including the wood and non-wood wealth components of the wealth. We then review the current methodology, discuss its limitations, and examine potential for addressing them. Finally, we discuss possible paths forward to revise the forest wealth assessment methodology.

CURRENT METHODOLOGY

Under the current forest wealth assessment, the value of forests is estimated as the sum of

i. wood wealth: the value of standing stock of timber, including wood for fuel,[1] and
ii. non-wood forest wealth: the value of forests that results from provision of non-wood forest products, regulating services, recreation, and so forth.

Each category of wealth is valued as the present value of the stream of expected annual rents from the resultant goods and services.

The Food and Agriculture Organization (FAO)'s statistics division is the main data source for the current forest wealth assessment. FAO's Forest Resources Assessment (FRA) provides a report every five years on global forest resource statistics. FAOSTAT–Forestry provides annual production and trade estimates for numerous forest products, such as roundwood, sawnwood, wood panels, and pulp and paper. Historical data are available from 1961 for many of these. Estimates are provided by countries through an annual survey conducted by FAO's Forestry Department in partnership with the International Tropical Timber Organization (ITTO), the Statistical Office of the European Communities (Eurostat), and the UN Economic Commission for Europe (UNECE).

We next explain the methodology in more detail by wealth assessment category.

WOOD WEALTH

Wood wealth is calculated as the present value of rents from the production of different timber products, discounted at 4 percent over the estimated lifetime of the forests. More specifically, wealth for country *c* in year *t* is estimated using the following formula:

$$W_{ct} = \sum_{t}^{T} \frac{(TR_{ct} * RR_{c})}{(1+r)^{t}}$$

where, W = wood wealth ($),
TR is total timber gross revenue ($),
RR is the regional rental rate (% of gross revenue),
r is the discount rate, set at 4%, and
T is the length of the discounting time horizon (25 years or the number of years to resource exhaustion).

1 Conceptually, the value of forests comprises the sum of the value of bare land, standing timber stocks and the non-timber forest goods and services; land is separate from the value of individual component stocks. In practice it is often impossible to separate land and timber value, so the timber value is often considered to include the land on which timber is growing.

Total timber revenue (TR) for country *c* in year *t* is estimated using the following formula, calculated as a lagged five-year average:[2]

$$TR_{ct} = \sum_i \left(\left(1/5 \right) \sum_{t-4}^{t} \left(H_{cti} * P_{cti} \right) \right)$$

where, H is timber harvested (production) (m^3),
P is price, calculated as the export unit value (constant$/$m^3$), and
i is the timber product

The purpose of the wood wealth accounts is to cover both formal (industrial) and informal (e.g., own-account wood for cooking) products, and encompass all timber products reported by FAO with the exception of wood residues. For both coniferous (largely softwoods) and non-coniferous (largely broadleaves or hardwoods) tree species, timber products are grouped into three categories: Industrial Roundwood, Chips and Particles, and Woodfuel. The products included are listed in Table 1 below.

TABLE 1. DEFINITION OF TIMBER PRODUCTS

TIMBER PRODUCT SERIES (CONIFEROUS, NON-CONIFEROUS)		DEFINITION
Industrial Roundwood	Pulpwood, Round and Split	Roundwood that will be used for the production of pulp, particleboard or fiberboard. It includes roundwood that will be used for these purposes in its round form or as splitwood or wood chips made directly from roundwood. It is reported in cubic meters solid volume excluding bark.
	Sawlogs and Veneer Logs	Roundwood that will be sawn (or chipped) lengthways for the manufacture of sawnwood or railway sleepers (ties) or used for the production of veneer (mainly by peeling or slicing). It includes roundwood that will be used for these purposes; shingle bolts and stave bolts; match billets and other special types of roundwood (e.g., burls and roots, etc.) used for veneer production. It is reported in cubic meters solid volume excluding bark.
	Other Industrial Roundwood	Industrial roundwood (wood in the rough) other than sawlogs, veneer logs and/or pulpwood. It includes roundwood that will be used for poles, piling, posts, fencing, pitprops, tanning, distillation and match blocks, etc. It is reported in cubic meters solid volume excluding bark.
Chips and Particles		Wood that has been reduced to small pieces and is suitable for pulping, for particle board and/or fiberboard production, for use as fuel, or for other purposes. It excludes wood chips made directly in the forest from roundwood (already counted as pulpwood, round and split). It is reported in cubic meters solid volume excluding bark.
Woodfuel		Roundwood that will be used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees and wood that will be used for charcoal production (e.g., in pit kilns and portable ovens). The volume of roundwood used in charcoal production is estimated by using a factor of 6.0 to convert from the weight (mt) of charcoal produced to the solid volume (m3) of roundwood used in production. It also includes wood chips to be used for fuel that are made directly from roundwood. It excludes wood charcoal. It is reported in cubic meters solid volume excluding bark.

Source: FAOSTAT-Forestry, Joint Forest Sector Questionnaire. http://faostat.fao.org/Portals/_Faostat/documents/pdf/FAOSTAT-Forestry-def-e.pdf>

2 Using a lagged average makes the wealth estimates less sensitive to annual variation in the underlying data.

Total Gross Revenue

Total revenue (TR) is defined as the product of total production and unit price. For each of three timber product categories listed in Table 1, annual production data (in cubic meters, m^3) by country are obtained from FAOSTAT-Forestry.[3] Unit prices are estimated as export unit values (EUV), using a five year lagged average.[4] Country specific export unit values are calculated using data from FAOSTAT-Forestry.

For each product *i*, the export unit value is determined as the ratio of export value ($1000) to export quantity (m^3) for each year available:

$$P_{cti} = \left(\frac{\text{Export Value}_{cti}}{\text{Export Quantity}_{cti}} \right)$$

Country specific EUVs are bounded: if the value exceeds the sum of the third quartile plus 1.5 times the interquartile range (i.e., third quartile minus first quartile), then value in that year is considered an outlier[5] and the country's EUV is replaced with the world median value.

Rental Rates

FAO statistics provide data for calculating total revenues (gross revenues) in forestry but the World Bank forest wealth assessment requires information on the forestry net revenues. By definition, net revenue is determined by the difference between total gross revenues and costs. In the absence of direct estimates of net revenue, the current forest wealth assessment uses an estimated rental rate to determine net revenues as the percentage of gross revenues. Rental rate (RR) is determined as the ratio of the difference in total revenue and total cost to total revenue:

$$RR = \left(\frac{\text{Total Revenue} - \text{Total Cost}}{\text{Total Revenue}} \right)$$

Limited availability of data prevents the estimation of rental rate by country or product group. Instead, rental rates are determined by world region from country case studies in consultation with World Bank forestry experts. The following studies are used as a basis for estimating rental rates: Fortech, 1997; Whiteman, 1996; Tay and others, 2001; Lopina and others, 2003; Haripriya Gundimeda, 1998; Global Witness, 2001; Eurostat, 2002. Table 2 below lists the rental rates used for the different regions.

3 FAOSTAT-Forestry at http://faostat3.fao.org/home/index.html.

4 EUVs were converted to 1995, 2000 and 2005 prices using GDP deflator (i.e., 1991-1994 converted to 1995 value, 1996-1999 converted to 2000 value, and 2001-2004 converted to 2005 value). GDP deflator was obtained from http://measuringworth.com/calculators/uscompare/. Lagged five-year-average of export unit values of Industrial Roundwood and Woodfuel were used to estimate prices for 1995, 2000 and 2005.

5 This approach was applied in the 2008 update for consistency with the methodology for calculating crop EUVs in the *Changing Wealth of Nations*. The wood product EUVs were not bounded in the previous wealth accounts.

TABLE 2. REGIONAL RENTAL RATES FOR TIMBER PRODUCTION

REGION	RENTAL RATE (share of gross revenue)
Sub-Saharan Africa	0.41
East Asia and Pacific	0.39
Eastern Europe and Central Asia	0.40
Western Europe	0.50
Latin America and the Caribbean	0.58
Middle East and North Africa	0.55
North America	0.42
South Asia	0.50

Life Span of the Resource

Forests are renewable resources so their future productive potential is in part determined by the current rate of harvests. Forests can be harvested at a rate which maintains or increases their future productive potential or they can be unsustainably exploited and depleted over time. In the wealth assessment, the concept of sustainable use of forest resources[6] is incorporated into the choice of the time horizon (T) over which the stream of timber rents is capitalized:

- If timber harvests (the total production of roundwood and woodfuel) are smaller than the net annual increment, then the forests of a country are harvested at sustainable or lower rates and the resource life span is capped at 25 years for asset valuation. The 25-year time horizon is similar to the treatment of other natural assets in the World Bank assessments.
- If timber harvests are greater than the net annual increment, then the time (years) to forest depletion in a country is calculated by dividing the current productive volume of forest stock by annual net depletion. The equations 1–4 below explain this approach more precisely.
    1. Time to Depletion = Productive Volume/Net Depletion
    2. Productive Volume = Productive Area * Volume Converter
    3. Net Depletion = Total Production – Net Annual Increment
    4. Net Annual Increment = Annual Commercial Increment * Productive Area

Net annual increment is defined as the natural growth of timber volume minus natural losses from mortality. Table 3 below lists the data sources.

6 UN System of Environmental-Economic Accounting framework specifies that "… the sustainable yield of timber resources is the quantity of timber that can be harvested at the same rate into the future while ensuring that the productive potential is maintained. The sustainable yield will be a function of the structure of the growing stock and needs to take into account both the expected natural growth and the natural losses of trees"(European Commission 2012).

TABLE 3: DATA COMPONENTS FOR CALCULATION OF DEPLETION TIME

DEFINITION	UNIT	SOURCE
Productive Area: Forest area designated for productive purposes. Forests inside protected areas or above an altitude threshold are not available for wood supply. The availability of the remaining forest area determined based on distance to infrastructure (roads and railroads).	1000 ha	*Table 7*: Designated functions of forest – total area with function 2005 (FRA 2005) *Table 15*: Forest in protected areas, available for wood supply (FRA 2000). The 1995 data is imputed using estimates from the 2000 FRA.
Volume Converter: Growing stock of forest, per hectare.	m^3/ha	*Table 11*: Growing stock in forest and other wooded land 2005 (FRA 2005).
Annual Commercial Increment: Total change in volume over the measurement period including growth and recruitment and deducting losses from mortality, averaged as an annual value.	m^3/ha/yr	*Source:* "Potential Productivity" map (Figure 2.3, A. Mather, Global Forest Resources, 1990) and other country specific studies and data sources; under the guidance of a WB forestry expert.[7]

NON-WOOD WEALTH

Overview

Wood production is not the only source of wealth provided by forests. Forests also provide a number of additional products and ecosystem services that contribute to wealth, such as non-wood forest products, recreation, hunting and fishing, watershed protection, species habitat provision, and carbon sequestration. Accounting for the non-wood benefits is challenging, because these benefits often occur outside established markets. However, not accounting for the non-wood wealth leads to the undervaluation of forest resources.

The current World Bank methodology for estimating non-wood forest wealth (NWFW) values the following products and services:

1. watershed protection
2. recreation, hunting and fishing, and
3. non-wood forest products.

NWFW is calculated as the sum of the present value of these annual goods and services over 25 years, using a 4 percent discount rate. Benefits are based on per hectare values of the good or service derived from the literature. The per-hectare benefit estimates are then multiplied by the relevant forest area to obtain the total value for each service, by country. Data on forest area and change rate is obtained from FAO's Global Forest Resource Assessment (FRA), and are consistent with the data used for timber valuation.

7 According to the available documentation, these data were created by calibrating "Potential Productivity" map with known data points and using a Delphi technique and other expert assessments. The first round of increment estimates calculated roundwood production as a percent of increment for a sample year (1994). These results were revised by (1) adjusting the increment in East Africa to reflect non-forest roundwood production, (2) correcting roundwood production for Malaysia, and (3) directly revising some increment estimates.

The following formula estimates the value of non-wood benefit category *i* for country *c* in year *t*:

$$TNFW_{ct} = \sum_i \sum_t^T \frac{NWFW_{cti}}{(1+r)^t}$$

where, *TNFW* = total non-wood forest wealth ($),
NWFW is the annual value of non-wood good or service ($)
r is the discount rate (4%), and
T is the time horizon of asset valuation (25 years).

Value estimates for watershed protection and recreation, hunting and fishing come from a literature by Lampietti and Dixon (1995). Lampietti and Dixon review the relevant valuation literature available at the time and provide median per hectare values for various non-timber categories, including watershed services (categorized as 'ecological functions') and recreation, hunting and fishing. We explain the estimates in more detail below.

Watershed Services

The value of watershed protection provided by forests for country *c* in year *t* is estimated using the following formula:

$$NWFW_{ct,i=watershed} = A_{ct} * V_{ct,i=watershed}$$

where, *NWFW* is the total benefits ($),
A is total forest area (ha), and
V is the annual benefit per hectare from watershed protection ($10/ha; see below).

The assessment uses a constant annual benefit per hectare from watershed protection (*V*). It is estimated at $10/ha (1995 USD) and taken directly taken from Lampietti and Dixon (1995). The $10/ha value is adjusted to other years using a GDP deflator. This estimate also takes into account annual deforestation rate (2005-2010) by taking into account the current forest area change rate and assuming it remains constant over time.

The $10/ha value adopted by the current assessment is the median value of the four studies—ranging from $1 to $30/ha—which are reviewed in Lampietti and Dixon (1995) and contain sufficient information to calculate value on a per hectare basis. These studies (and their year of publication and study location) include Magrath and Arens (1989, Java), Cruz et al. (1988, Philippines), Ruitenbeek (1989, Cameroon) and Johnson and Kolavalli (1984, Thailand).

Each of the four studies above examines watershed protection through erosion and sedimentation control. Magrath and Arens (1989) estimate the damage cost associated with soil erosion in a study area in Java, including damages associated with the siltation of irrigation systems and harbor dredging. The total cost is derived as the total damage cost divided by the total land area considered. Cruz et al. (1998) examine the annual opportunity cost associated with soil erosion in a study area in Philippines. Ruitenbeek (1989) calculates the value of watershed protection for flood control and supporting in-shore fisheries in a coastal area of Cameroon. Johnson and Kolavalli (1994) examine the economic returns in fisheries in a bay in Thailand and model the reductions in fisheries returns as a result of the conversion of forest to agricultural lands and the consequent soil erosion and water quality deterioration.

Recreation, Hunting and Fishing

Value estimates for benefits from recreation, hunting and fishing for country *c* in year *t* are derived using the following formula:

$$NWFW_{ct,i=recfishhunt} = (0.10 * A_{ct}) * V_{ct,i=recfishhunt}$$

where, *NWFW* is total value of services ($)
A is total forest area (ha)
V is the annual benefit per hectare from recreation, hunting, and fishing ($/ha).

As with watershed protection, the assessment uses a constant value per hectare, also based on Lampietti and Dixon (1995). However, values are different for developed and developing countries ($119/ha and $17/ha, respectively, in 1995 USD, see below).

Lampietti and Dixon use six studies (one in Venezuela, three in Africa and two in Malaysia) to estimate the value of hunting in developing countries. Their median value estimate is $5/ha/year. Three studies (in Mexico, Kenya and Costa Rica) were used to estimate the recreational benefits in developing countries, with a median value of $12/ha/year. Summing up the median values, estimated benefits from recreation and hunting total $17/ha/year for developing countries.

For developed countries, only one study (from the US) was used for hunting value (Johnson and Linder 1986) since it was the only one that contained information on a per hectare basis. This study calculated the value of hunting at $64/ha/year. Recreational benefits value estimates for developed countries were taken from Walsh et al. (1989) (US) and amounted to $55/ha/year, bringing the total benefits from recreation and hunting in developed countries to $119/ha/year. Both these values (in 1995 USD) are adjusted using a GDP deflator.

Finally, one-tenth of the total forest area is assumed to be available for recreation in each country, so the formula multiplies total forest area by 0.10.

Non-Timber Forest Products

Non-wood forest products (NWFPs) "consist of goods of biological origin other than wood, as well as services, derived from forests and allied land uses" (FRA 2010). They include forest plant products harvested for food, which consist mostly of oil seeds, nuts and bamboo shoots, tanning extract and raw lacquer; and raw materials for medicinal and aromatic uses.

In the current assessment, the annual value for NWFPs is taken directly from the FAO FRA, published every 5 years. Because these data are country reported, their adequacy is determined in part by the priority given to the NWFPs in each country, as well as the human and financial resources in the national statistics institutions in charge of collecting and analyzing the data (FRA 2010).

The value of the NWFPs is defined as their market value at the site or collection or forest border. Importantly, the value estimates does not account for any cost of firewood collection.

SUMMARY OF DATA SOURCES

Table 4 summarizes the key variables currently required for producing the wood and non-wood wealth estimates.

TABLE 4. SUMMARY OF CURRENT KEY VARIABLES AND DATA SOURCES

WOOD WEALTH	FREQUENCY	COVERAGE	SOURCE
Annual Production (commercial timber, woodfuel; m^3)	Updated Annually	All countries	FAOSTAT
Unit Value (export unit value; $/$m^3$)	Updated Annually	All countries	FAOSTAT
Rental Rate (% of gross revenue)	Based on a literature review; not updated	Regional estimates based on country case studies	Fortech, 1997; Whiteman, 1996; Tay et al., 2001; Lopina et al., 2003; Haripriya, 1998; Global Witness, 2001; Eurostat, 2002.
TIMBER LIFE SPAN (time to depletion)	**FREQUENCY**	**COVERAGE**	**SOURCE**
Forest Productive Area	Updated every five years	All countries	FAO FRA 2005 (Table 7: Designated functions of forest – total area with function).
Volume Converter (m^3/ha)	Updated every five years	All countries	FAO FRA 2005 (Table 11: Growing stock in forest and other wooded land 2005).
Annual Commercial Increment (m^3/ha/yr)	Based on a literature review; not updated	All countries	A. Mather, Global Forest Resources, Belhaven Press, London, 1990); "Potential Productivity" map (Figure 2.3, other country specific studies; expert guidance.
NON-WOOD WEALTH	**FREQUENCY**	**COVERAGE**	**SOURCE**
Total Forest Area (ha)	Updated every five years	All countries	FAO FRA
Value of non-wood forest products (e.g., oil seeds, nuts, raw materials; $)	Updated every five years	All countries	FAO FRA
Estimated benefits from recreation, hunting, fishing ($/ha/yr)	Based on a literature review; not updated	Developed country average; developing country average	Lampietti and Dixon (1995)
Estimated watershed protection benefits ($/ha/yr)	Based on a literature review; not updated	Globally uniform	Lampietti and Dixon (1995)

SUMMARY OF ESTIMATED WOOD AND NON-WOOD WEALTH

Table 5 summarizes, on a per-hectare basis, the current estimates of wood and non-wood wealth (World Bank 2011; data from 2008, in 2008 $) by world region. The table clearly shows that the magnitude of wood and non-wood forest wealth varies by both country and world region. For example, in the OECD countries, wood wealth is estimated at, on average, $1,321 per hectare. But within the group of OECD countries, the wood wealth varies from $0/ha to $3,859/ha. Non-wood wealth is estimated at, on average, $831/ha, for the OECD countries, with the range of estimates varying between $254/ha and $5,958/ha.

TABLE 5. CURRENT ESTIMATES OF TIMBER AND NON-TIMBER FOREST WEALTH, BY REGION (WORLD BANK 2011 ESTIMATES)

REGION	WOOD WEALTH (PER HA)				NON-WOOD WEALTH (PER HA)			
	Min	Max	Median	Mean	Min	Max	Median	Mean
High income: non-OECD	0	953	0	208	0	21,017	436	2,294
High income: OECD	0	3,859	1,094	1,321	254	5,958	487	831
East Asia & Pacific	0	3,992	587	1,152	106	639	227	247
Europe & Central Asia	0	1,758	103	334	0	2,505	241	377
Latin America & Caribbean	0	35,978	414	2,687	56	321	228	212
Middle East & North Africa	0	14,249	481	3,022	204	2,406	270	596
South Asia	0	6,351	2,616	2,447	211	2,334	266	577
Sub-Saharan Africa	0	43,935	307	2,029	0	12,218	229	545

The lowest value for wood wealth is $0/ha in each region. Note that the estimates of zero wood wealth may be due to missing observations for timber production. Non-wood forest wealth is projected using forest area and the estimated benefit per hectare so those estimates are generally non-zero (not missing).

Table 6 shows the portion of the total forest wealth comprised by timber and non-timber sources of wealth in the current assessment (World Bank 2011; data from 2008, in 2008 $). The table also shows that the relative magnitude of timber and non-wood forest wealth varies by both country and world region. For example, in the OECD countries, wood wealth constitutes, on average, 59 percent of the total forest wealth. But within the group of OECD countries, the proportion of the total forest wealth comprised by wood wealth varies from 0 percent to 90 percent. Similar variation is observed in all other world regions included in the table.

TABLE 6. PROPORTION OF THE TOTAL FOREST WEALTH IN TIMBER AND NON-WOOD FOREST WEALTH, BY REGION AND GLOBALLY

REGION	WOOD WEALTH			NON-WOOD WEALTH (%)		
	Min	Max	Mean	Min	Max	Mean
High income: non-OECD	0%	75%	24%	25%	100%	76%
High income: OECD	0%	90%	59%	10%	100%	41%
East Asia & Pacific	2%	95%	61%	5%	98%	39%
Europe & Central Asia	0%	88%	37%	12%	100%	63%
Latin America & Caribbean	0%	99%	56%	1%	100%	44%
Middle East & North Africa	0%	98%	55%	2%	100%	45%
South Asia	0%	93%	70%	7%	100%	30%
Sub-Saharan Africa	0%	100%	54%	0%	100%	46%
GLOBAL TOTAL						
Share of the total forest wealth (%), by country, on average			52%			48%
Share of the global total forest wealth (%)			70%			30%
Total forest wealth, $billions			2,721			1,159

When averaging by country, the proportion of the total forest wealth comprised by wood wealth is 52 percent (Table 6, third row from the bottom). In other words, at the country level, timber and non-wood sources of wealth generate roughly equal portions of the total forest wealth.

Globally, the timber and non-wood wealth is predicted at $2,771 billion and $1,159 billion (Table 6, last row), respectively. This yields a total global forest wealth estimate of $3,880 billion. At the global level, the wood wealth therefore constitutes 70 percent of the total forest wealth. The remaining 30 percent is associated with non-wood forest wealth.

Estimates in Table 6 are instructive in considering how sensitive the estimated overall total forest wealth is relative to the different parameters and data underlying the valuation results. Note again that, for example, the estimates of wood wealth are directly proportional to the estimated unit price of the timber product. Similarly, the estimates of non-wood wealth are directly proportional to the estimated non-wood wealth per hectare of forest.

Accordingly, if the per-unit value of wood or non-wood benefits doubles (or halves), the corresponding wood or non-wood wealth estimate also doubles (or halves). For example, keeping everything else constant, the doubling of the timber value per unit (per m^3) globally increases the estimated global total forest wealth by about 70 percent.[8] It also increases the proportion of the total forest wealth comprised by wood wealth from the current 70 percent to about 82 percent. On the other hand, a 50 percent reduction in the timber unit value reduces the total global forest wealth by 35 percent and the share of wood benefits to about 54 percent of the total forest wealth. Similar examples can be formulated for the non-wood benefits.

8 To see this by way of example, consider that the current estimate of the total forest wealth (TFW) is about 70% timber (TW) and 30% non-timber (NTW) wealth. For illustration, consider that in the baseline TW=$0.70 and TW=$0.30, so that TFW_1=$1.00. Doubling TW to $1.40 results in TWF_2=$1.40 + $0.30 = $1.70, which is 70% greater than TFW_1.

EVALUATION OF THE CURRENT METHODOLOGY

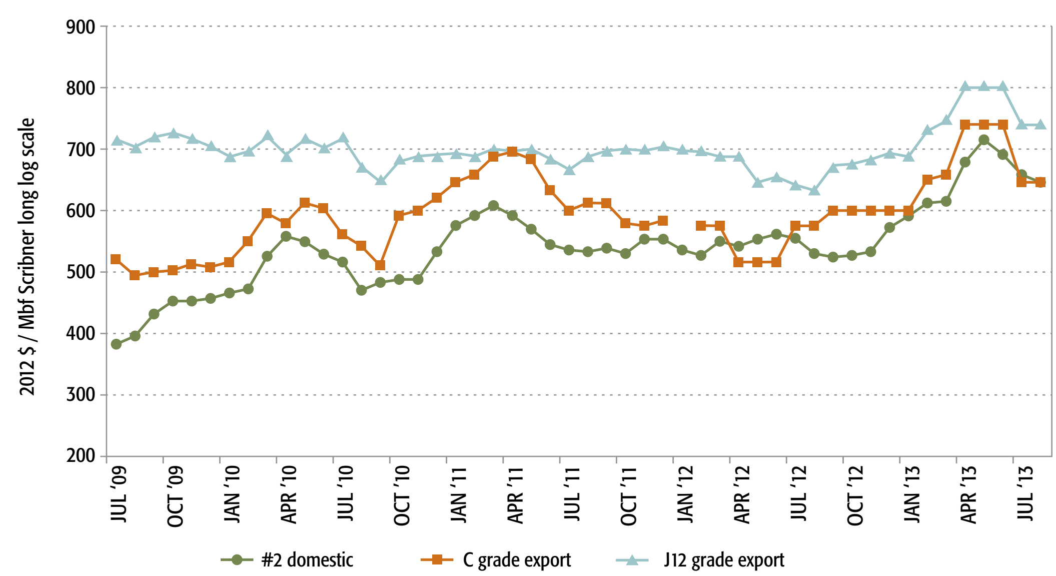
This section discusses the current wood wealth parameters and methodology with emphasis on identifying potential limitations. They mainly involve the uses of currently outdated or otherwise inadequate parameters to calculate revenue as well as the life span of the resources. Most of these issues arise due to a lack of better, easily accessible data to obtain estimates values for each particular country. There are also, however, some methodological inconsistencies, such as in the conceptual formulation of the estimation of the life span of the resource.

WOOD WEALTH

Export Unit Values

The timber assessment uses export unit values (EUVs) to calculate total revenue. While export unit values are valid for valuing timber exports, in many countries domestic production covers a large share or the majority of timber production. Moreover, it is common that export and domestic prices vary and address different product and product quality categories. The main justification for the current use of EUVs is that those data are readily available from the FAO statistics whereas data on domestic unit values are not.

FIGURE 1. DOMESTIC AND EXPORT PRICES FOR DOUGLAS-FIR IN THE US' PACIFIC NORTHWEST (CAMPBELL GROUP)[9]



Source: Loglines.

9 Taken from: https://www.campbellgroup.com/research/timber-trends.aspx

We searched for available data on export and domestic prices for timber. These data, although scarcely available, in general suggest that the use of EUVs likely overestimates the value of the timber production.

Figure 1 shows domestic and export prices for Douglas-fir in the US Pacific Northwest between July 2009 and July 2013. Although both series are moving together, export prices tend to be considerably higher than domestic prices.

The Baltic region is a location with perhaps the best availability of data on domestic and export timber prices. The region is an important timber market and is composed of Finland, Sweden, Estonia, Lithuania and Norway. The Finnish Forest Research Institute METLA offers annual data on roundwood prices and production in the Baltic Sea Region.

Using these data, Figure 2 summarizes the ratio of domestic and export prices over a five year period 2007–2012. The figure shows, for example, that the domestic price of roundwood in Finland was, on average, 39.4 percent of the export prices. The corresponding ratio is 22.6 percent in Sweden, 37.0 percent for Estonia, 42.5 percent for Lithuania, and 42.9 percent for Norway.

FIGURE 2. RATIO OF DOMESTIC AND EXPORT ROUNDWOOD PRICES IN THE BALTIC SEA REGION, USING A FIVE YEAR AVERAGE

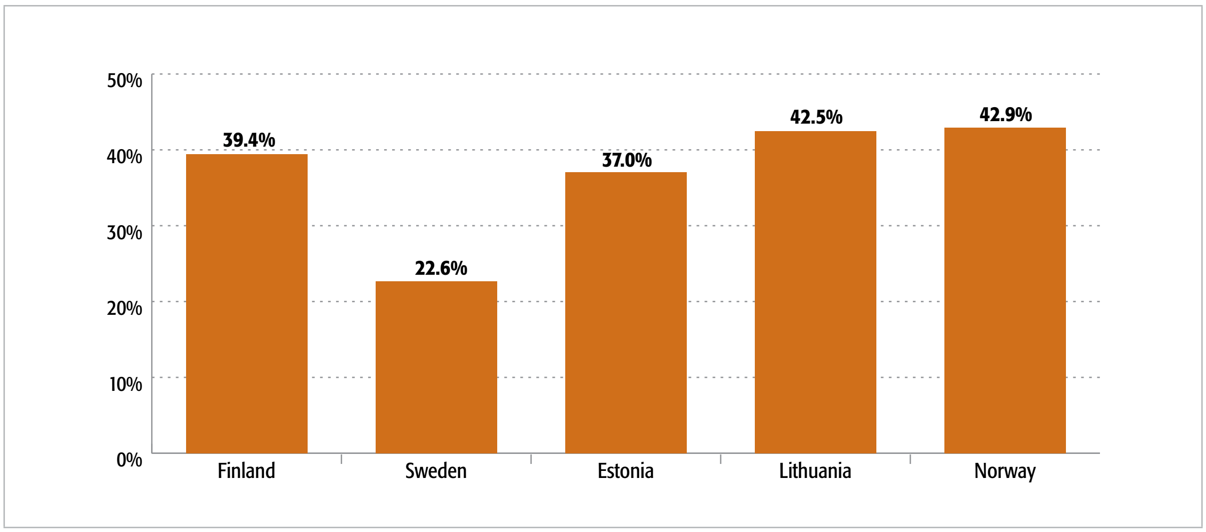
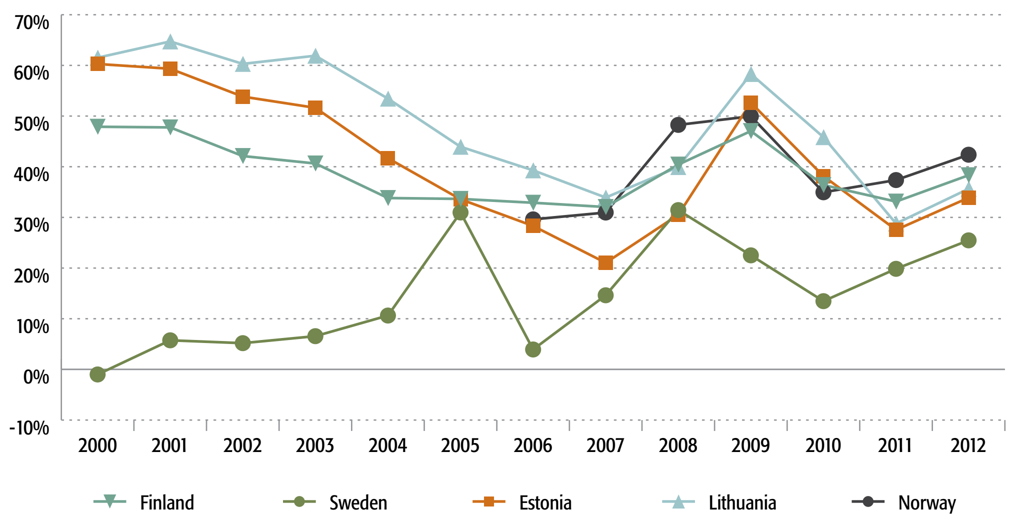


Figure 3 displays the same data annually. The figure shows that although the price ratio is not consistent over time, domestic roundwood prices are consistently below the export prices. Excluding Sweden, domestic prices generally range from around 30 percent to 60 percent of export prices.

FIGURE 3. PRODUCTION-WEIGHTED PRICE DIFFERENCE BETWEEN DOMESTIC AND EXPORT ROUNDWOOD PRICES IN THE BALTIC SEA REGION, BASED ON EXPORT PRICES



Source: METLA

These findings above confirm that a gap generally exists between domestic and export timber prices. Consequently, timber production that remains in the domestic market should be valued differently than the production targeting export markets.

Rental Rates

The current assessment uses regional rental rate constants (Table 2). However, rental rates may vary considerably between countries within regions due to differences in production costs. Using a fixed rental rate over time also implicitly assumes that the cost of production is perfectly correlated with the timber price, though export prices vary considerably by year.

Another issue with the rental rate estimates is that the studies which underlie the estimates are not consistently in the inclusion of production costs; thus, do not produce consistent and comparable estimates. Moreover, the documentation of the current methodology is somewhat vague regarding the calculations and number of studies used to estimate these values.

Life Span of the Resource

The current approach to wood wealth assumes that the annual production of timber continues fixed at its current level either (i) until the end of asset valuation time period (harvests do not exceed annual growth) or (ii) until the entire forest stock is depleted (harvests exceed annual growth). Then, for countries for which harvests exceed current growth, the number of years to the depletion of the forest stock is estimated by dividing the total growing stock (m^3) by the estimated net annual depletion (m^3) in year $t = 0$.

This approach is intuitive for non-renewable resources, such as minerals, as their total resource stock is fixed over time. But the forest resource stock is renewable, so grows over time, as predicted by the annual commercial increment in the current assessment. When the resource stock grows over time, depleting the current stock not only leads to an instant decline of the stock but also prevents any future stock growth (compound growth) associated with the depleted portion of the stock.

The current wealth assessment ignores the compound growth associated with the depleted portion of the stock. Instead, the growth of the stock (annual commercial increment) is assumed to continue fixed at its current volume (m^3), either indefinitely or until the entire forest growing stock is exhausted. This is a highly unrealistic approach especially for countries on a path to forest depletion.

A more realistic approach would directly consider the reduction of the compound growth associated with the depleted forest stock. Accordingly, net depletion diminishes the growing stock which in turn results in declined annual growth volume. But how does one determine the level of growth over time? A reasonable approximation is to first consider that the current annual commercial increment reflects any growth associated with the current stock (minus harvests). Then, the ratio between the current annual commercial increment and commercial growing stock indicates the growth rate of the resource. For example, if the commercial growing stock volume is 1,000 m^3 and the annual commercial increment is 30 m^3, then the current stock grows at the rate of 3 percent. In the absence of harvests, the next year's commercial growing stock is 1,030 m^3, with an estimated second year annual commercial increment at 30.9 m^3 (0.03*1,030 m^3). On the other hand, if annual harvests and commercial increment exactly match, with both at 30 m^3, then the current annual harvests and annual commercial increment can continue indefinitely.

Similarly, we can consider a case in which annual harvests exceed current growth. For example, assume again that the commercial growing stock in year one equals 1,000 m^3. Next, assume that annual harvests equal 100 m^3 and remain constant over time. Then, the annual net depletion in the first year amounts to 70 m^3 (harvests of 100 m^3 minus the annual commercial increment of 30 m^3). With a 70 m^3 net depletion, the next year's growing stock declines to 930 m^3. Continuing the growth at the 3 percent rate, the annual commercial increment becomes 27.9 m^3. Then, maintaining harvests at 100 m^3, the annual net depletion grows to 72.1 m^3. Continuing harvests at 100 m^3, forest growing stock declines at an increasing rate until the stock is completely depleted. With a declining volume of growth and increasing volume of net depletion, the overall depletion of the forest stock is quicker than predicted by the current approach.

We next develop a formal approach to the estimation of time to net depletion under a growing resource stock. The terms below are defined as follows:

- S_t denotes the volume of the forest growing stock (m^3) in period t
- r denotes the annual growth rate (%) of the forest stock
- H denotes the constant annual volume of harvests (m^3)
- T denotes the asset valuation time horizon (years)

Starting with the initial (t = 0) commercial growing stock of S_0, the commercial growing stock in the consequent years (t = 1,2,3,…, T) is determined as follows:

$$
\begin{aligned}
S_1 &= S_0 + rS_0 - H = S_0 (1 + r) - H \\
S_2 &= S_1 (1 + r) - H = S_0 (1 + r)^2 - H (1 + r) - H \\
S_3 &= S_2 (1 + r) - H = S_0 (1 + r)^3 - H (1 + r)^2 - H (1 + r) - H \qquad (1) \\
&\vdots \\
S_T &= S_0 (1 + r)^T - H \left[(1 + r)^{T-1} - \ \dots\ - (1 + r)^2 - (1 + r) - 1 \right]
\end{aligned}
$$

The expression in the square brackets, $(1 + r)^{T-1} - \dots - (1 + r)^2 - (1 + r) - 1$, is a geometric series for which the sum is determined as

$$\sum_{k=0}^{T-1} x^k = \frac{1 - x^T}{1 - x} \quad (2)$$

Substituting expression (2) above into the stock volume equation results in

$$S_t = S_0 (1 + r)^t - H \frac{1 - (1 + r)^t}{1 - (1 + r)} = S_0 (1 + r)^t - H \frac{(1 + r)^t - 1}{r} \quad (3)$$

which can be expressed as

$$S_t = \left(S_0 - \frac{H}{r}\right) (1 + r)^t + \frac{H}{r} \quad (4)$$

The expression (4) determines the volume of the growing stock at time *t*. Consider next that harvests remain constant and the task is to determine the number of years for the growing stock to deplete from S_0 to zero. It can be determined by setting $S_T = 0$ in (4) and solving for T:

$$T = \frac{-1}{\ln (1 + r)} \ln \left(1 - \frac{rS_0}{H}\right) \quad (5)$$

The expression (5) determines the time to depletion under constant annual harvest and a resource stock growing at a constant rate.[10]

Table 7 illustrates the revised approach, denoted here a *compound method*, by listing the annual forest stock, biological growth, and net depletion over a resource lifetime. For comparison, the table also lists the corresponding estimates using the current wealth assessment methodology. The calculations in the table assume that the initial stock (S_0) equals 1,000 m^3, harvests equal H = 100 m^3/year, and the growth rate is constant at r = 0.03.

The table illustrates how the compound method realistically predicts that the net depletion increases over time as the growing stock is depleted. On the other hand, the current assessment approach assumes constant annual growth volume (not a constant growth rate) so the net depletion also remains constant until the stock is completely depleted. Using the compound method, the estimated time to depletion is 12.1 years. The current approach predicts that the depletion of the forest stock takes 14.3 years; an estimate almost 20 percent greater than that under a compound method.

10 Note that similar problems regularly arise in financial transactions, such as when determining the amount of fixed monthly payments required to pay off a loan with a certain interest rate and lifetime. A comparable financial problem involves determining the number of periods required to pay off a loan with the current value of S_0 when the loan payment is fixed at H in each period. In Excel, the number of periods can be readily obtained using the NPER function.

TABLE 7. FOREST STOCK DEPLETION UNDER CONSTANT ANNUAL HARVESTS EXCEEDING ANNUAL GROWTH, RESULTS USING A COMPOUND METHOD AND THE CURRENT APPROACH. THE CALCULATIONS ASSUMED S_0=1,000, H=100, AND R=0.03.

	COMPOUND METHOD					CURRENT APPROACH				
Year	Initial stock	Harvest	Growth	End stock	Depletion	Initial stock	Harvest	Growth	End stock	Depletion
0		100	30	1000	-70		100	30	1000	-70
1	1030	100	28	930	-72	1030	100	30	930	-70
2	958	100	26	858	-74	960	100	30	860	-70
3	884	100	24	784	-76	890	100	30	790	-70
4	807	100	21	707	-79	820	100	30	720	-70
5	728	100	19	628	-81	750	100	30	650	-70
6	647	100	16	547	-84	680	100	30	580	-70
7	564	100	14	464	-86	610	100	30	510	-70
8	478	100	11	378	-89	540	100	30	440	-70
9	389	100	9	289	-91	470	100	30	370	-70
10	298	100	6	198	-94	400	100	30	300	-70
11	203	100	3	103	-97	330	100	30	230	-70
12	107	100	0	7	-100	260	100	30	160	-70
13	7	100	0	0	0	190	100	30	90	-70
14	0	100	0	0	0	120	100	30	20	-70
15	0	100	0	0	0	50	100	30	-50	-70
16	0	100	0	0	0	0	0	0	0	0
17	0	100	0	0	0	0	0	0	0	0
18	0	100	0	0	0	0	0	0	0	0
19	0	100	0	0	0	0	0	0	0	0
20	0	100	0	0	0	0	0	0	0	0
21	0	100	0	0	0	0	0	0	0	0
22	0	100	0	0	0	0	0	0	0	0
23	0	100	0	0	0	0	0	0	0	0
24	0	100	0	0	0	0	0	0	0	0

The implementation of the compound method to predicting time to net depletion is relatively straightforward. The data requirements include information on the current forest stock S_0 and annual harvests, both of which the current wealth assessment already uses and draws directly from FAO statistics.

The third required parameter is *r*, the underlying growth rate of the forest stock. It could be derived, for example, using the current estimates of annual commercial increment. Specifically, dividing the current estimate of annual commercial increment (m^3/ha) by average stock per hectare (total forest stock over total hectares of forests) predicts growth rate. Another possibility is to use the expression (2) together with FAO data on forest stock and annual harvests during a specified time period (say, 2005–10). Then, under known T, H, S_0, and S_T, one can solve for *r*.

Another methodological issue with the estimation of time to depletion is that the current approach automatically imputes the maximum life span of the resource (25 years) if the 'Time to Depletion' parameter is missing (which could happen if there is no data for either Productive Area or Annual Commercial Increment). This results in a considerable number of countries (74) with a depletion time of 25 years when there is essentially no data to support this.

Finally, the documentation of the current determination of the total life span is somewhat partial. For example, for the estimation of Annual Commercial Increment, the current methodology offers one reference for the parameter used: *Figure 2.3, A. Mather, Global Forest Resources, Belhaven Press, London, 1990* but also indicates that additional sources included supplementary data, a Delphi study, and various other inputs by World Bank staff. In the absence of detailed methodology or calculations, it would be difficult to update the current approach. This further supports the need to revise the approach.

Illegal logging

Illegal logging denotes any unauthorized (i.e., in violation of established laws and regulations) removal of wood (FAO 2002).[11] Examples of illegal logging involve harvests in places where logging is prohibited, harvest by unauthorized parties, or harvests in excess of set limits.

Documenting the overall extent of illegal logging is difficult, but it is a substantial problem especially in the developing countries. For example, some estimates suggest that nearly half of all tropical wood products, including logs, sawn timber, and plywood, traded in the world market were illegally sourced (Seneca Creek/Wood Resources, 'Illegal' Logging and Global Wood Markets, S. Lawson, Illegal Logging and Related Trade: Measuring the Global Response, Chatham House, 2007). The same assessments estimate that illegal logging account for as much as 5–10 percent of all industrial roundwood production (Seneca Creek/Wood Resources 2004).

Illegal logging is a particularly pressing problem in developing countries, so its proportion of roundwood production is greater there. A number of country-specific studies suggest that in several important roundwood source areas, such as Amazon, parts of Indonesia, Benin, Cameroon, Myanmar, Bulgaria, and many other countries, the majority of roundwood production may be illegally sourced (Chatman House 2012, OECD 2007). The World Bank has estimated that the losses to public assets from illegal logging in public lands exceed US$10 billion per year in developing countries (World Bank 2006).

Lack of information on the extent of illegal logging prevents its inclusion in the international forestry statistics. For example, FAO's FRA in 2010 states that "Several disturbance factors such as illegal logging, encroachment, overharvesting and other unsustainable management practices were not included in the reporting for FRA 2010 because of a lack of quantitative information in most countries." The same assessment also notes that "The analysis is clearly sensitive to the selection of variables. The variables that could be selected were limited by the set of FRA 2010 reporting tables and further reduced by the limited information availability for several of these. It was particularly difficult to obtain information on negative aspects, such as forest degradation and illegal logging, due to a lack of common definitions and assessment methodologies" (FAO FRA 2012).

The lack of data on illegal logging limits the forest wealth assessment in several ways. First, when the volume of illegally sourced wood is substantial, as it likely is in some countries, then the assessment underestimates the volume of wood extraction. Moreover, if the extent of illegal logging is also associated with the net depletion of forest stock, then the assessment will overestimate time to the depletion of forests. Because the extent of illegal logging varies considerably by world region, country, and even within country, it is difficult to pinpoint how its omission affects the wealth estimates, let alone suggest robust approaches to adjusting the assessment for illegal logging. Therefore, addressing the issue meaningfully requires substantial additional research.

11 Illegal logging is an ill-defined concept and has many different definitions, which depend on the source. We use the FAO definition.

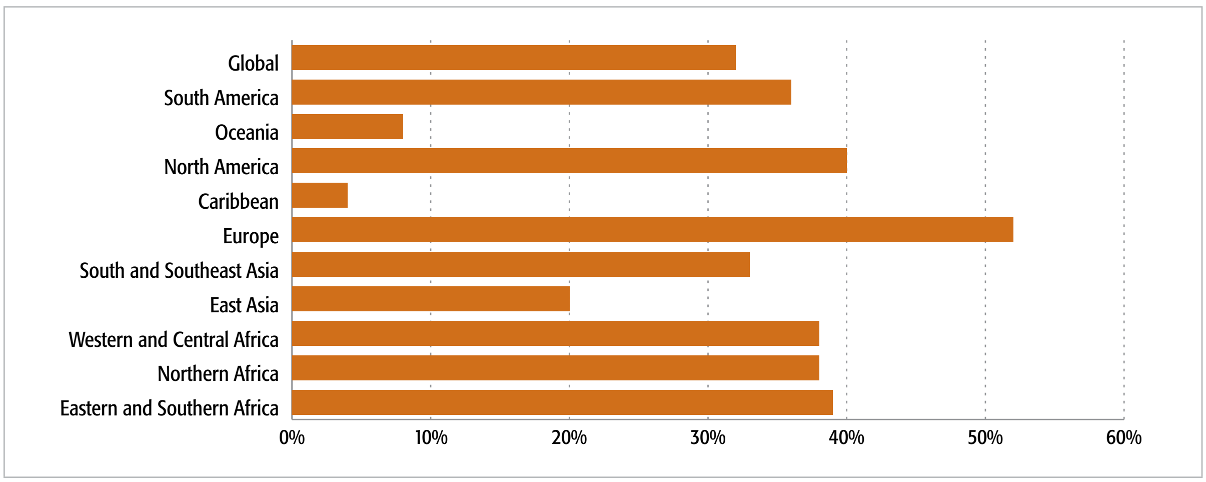
Woodfuel

As with the other timber accounts, information on woodfuel production and its value are taken from FAO-STAT. These data are limited in many ways. For example, data on woodfuel removals is missing for most countries (see below). Moreover, the value of woodfuel is missing for most countries and in cases where value data are available, they are derived from export or import data, which may be poor proxies for the value of domestic woodfuel.

Using data from the FAO 2010 FRA, Figure 4 summarizes the availability of country-level data on woodfuel globally and by world region. Globally, we find that 65 countries (32%) out of the 201 countries included in the assessment provided data on woodfuel removals. The availability of woodfuel data is the highest for Europe (52%) and lowest for the Caribbean (4%). In Africa, the availability varies between 38 percent and 39 percent. In East Asia, data are available for 20 percent of the countries, whereas the coverage in South and Southeast Asia is about 33 percent. In South America, data are available for 36 percent of the countries.

Nonetheless, FAO's statistical yearbooks on forestry indicate that the coverage of FAO data on woodfuel has improved in the recent years. National reports in some cases have improved data on fuel use, so addressing these data gaps may be feasible through FAO assistance.

FIGURE 4. CURRENT AVAILABILITY OF COUNTRY-LEVEL DATA ON WOODFUEL REMOVALS, GLOBALLY AND BY WORLD REGION. THE BAR REPRESENTS THE PERCENTAGE OF COUNTRIES IN THE REGION FOR WHICH DATA ARE AVAILABLE.



The valuation of woodfuel uses the same rental rate as the valuation of timber production. However, only one of the studies used in the derivation of regional rental rates considers the costs of woodfuel harvests; others are for timber production.

NON-WOOD WEALTH

Watershed Services

The current wealth assessment uses a globally uniform value of $10/ha for watershed protection benefits, based on Lampietti and Dixon (1995). As explained above, this estimate is the median value of four studies from the 1980s. The value estimate is outdated. There are numerous, more recent, valuation studies that could be used to project improved estimates. Moreover, advances in non-market valuation theory as well as in econometric methods to conduct meta-analyses could provide a better approximation of the value of such benefits.

In addition, the use of a globally uniform watershed value estimate is inadequate. The approach fails to consider any of the broad range of geographic differences in the value of watershed services. Value differences potentially arise from many sources, such as geography and hydrology. Moreover, differences in the water usage and other benefits associated with water quantity and water quality necessarily results in differences in the value of watershed services. For example, the spatial distribution of forests in relation to the location of agricultural production and populations likely would impact the value of forests in watershed services.

Using a globally uniform value per hectare to derive the value of watershed services ignores all potentially substantial geographic variation in the value. In reality, the value of one hectare of forest for watershed protection differs substantially by country and also within each country. Addressing fine-scale geographic differences in the values would be hard and of limited information value relative to the costs, but improving the current approach to consider at least some spatial heterogeneity in the values is feasible and warranted.

Recreation, Hunting and Fishing

The current value estimate for recreation, hunting and fishing suffers from similar problem as the value for watershed services. The estimate is based on nine studies in developing countries (six for hunting value and three for recreation value) and only two studies (one for recreation and hunting each, both from the US) in developed countries. There are numerous more recent valuation studies for these types of services that could be used, together with more advanced econometric methods, to provide better value estimates for these services.

In addition, the assumption of the amount of forest area available for recreation (currently 10% of the forest area) is not supported by any study and could easily vary by country.

Forest Area

The current assessment uses estimates of forest area by country primarily to predict the value of non-wood benefits (watershed services, recreation, fishing, and hunting). Data on the forest area come directly from the country-reported estimates of FAO. With the rapidly advancing technologies to develop remotely sensed estimates of forest cover from satellite and radar images, it is natural to ask whether remote sensed estimates of forest area may be easily available and potentially more robust than FAO data.

In a recent study, Hansen et al. (2013) mapped global tree cover extent, loss, and gain for the time 2000–2012 period at a 30m spatial resolution (Hansen et al. 2013). The analysis was based on Landsat data and besides improving current knowledge on forest cover and change by (1) being spatially explicit and (2) providing annual information on forest loss and quantifying forest loss trends, it also has the advantage of (3) "being derived through an internally consistent approach that is exempt from the vagaries of different definitions, methods and data inputs" (Hansen et al. 2013). The analysis illustrates the potential for using remote sensing to construct estimates of forest area.

For the Hansen et al. (2013) study, forest loss is defined as "a stand-replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale;" whereas forest gain was defined as the opposite (establishment of canopy). In an important difference, FAO defines "forest area" based on land use instead of land cover (as it is defined in the Hansen study). Accordingly, the FAO definition is not directly linked to the actual presence of tree cover. Hence, there may be forest change (from a biophysical perspective), but no change in land use, which is FAO's main criterion. On the other hand, changes in forest cover through forest management are essential to systematic forest management, so a reduction or loss of forest cover does not necessarily mean that the forest is permanently lost; it could simply be managed for regeneration.

This difference in the definition of forest results in inconsistencies between forest gains and losses reported by countries and earth observation-derived forest area change data. Essentially, for the FAO, deforestation consists of converting natural forests to non-forest land uses. However, using that approach, "the clearing of the same natural forests followed by natural recovery or managed forestry is not deforestation and often goes undocumented…" (Hansen et al. 2013).

Despite some limitations, FAO data on forest area offer several substantial strengths. First, it is publicly and readily available. Second, the methodology is consistent, commonly known and agreed upon. Third, the forest area estimates are regularly updated. Fourth, the FAO data are also beginning to incorporate remote sensing data. For example, in future FRAs, countries will have the option to draw from FAO-supplied estimates of forest area , and those estimates will in part be constructed using remote-sensed and field-validated data on land use and forest cover.

Finally, although remote sensing based approaches to the measurement of forest area could be useful to validating and possibly adjusting the FAO data, it is not likely that the discrepancies in the different data sources would result in wholesale changes in the forest area. The forest area calculations are used primarily in the assessment of non-wood benefits (hunting, fishing, recreation, watershed services), and those assessments are likely much more sensitive to the revisions required to update underlying value estimates (per hectare benefits) than any reasonable adjustment to the estimation of forest area.

Non-Wood Forest Products

The main limitation with the value estimates for NWFP is that they are country reported, and most countries do not report on NWFP removals. For example, in the FRA 2010, "141 countries, representing 21 percent of the global forest area, did not report any data at all, even though it is known that NWFPs play a significant role…". The FRA also mentions that "[w]here national statistics do exist, data on removals are often limited to those NWFPs that are (inter)nationally traded." However, noncommercial uses of NWFPs can be common especially in low-income and forest-adjacent communities.

Overall, these limitations likely result an underestimate of the value of NWFPs. The degree of underestimation likely varies by country and could be substantial especially for countries where NWFPs contribute most to wellbeing.

Another, related, issue is the fact that there is no standard methodology for estimating the value of NWFPs. The FRA (2010) mentions that countries employ different methodologies to come up with their NWFP value estimates.

Finally, the valuation of NWFPs does not consider the cost of production, although it is required for a conceptually and empirically accurate valuation approach.

ECOSYSTEM SERVICES EXCLUDED FROM THE CURRENT ASSESSMENT

Forests contribute to the provision of wide range of ecosystem services. The current assessment considers some of the key but not all services known as potentially important. In particular, the current assessment excludes any benefits from forests that are associated with carbon sequestration and storage, which is a key area of current focus in the international climate and forest policy. Another area of important global importance is the biodiversity loss, much of which is associated with the loss of habitat such as forests.

CARBON STORAGE

Deforestation is known as the second most important anthropogenic source, after the fossil fuel combustion, of global greenhouse gas (GHG) emissions (IPCC 2007). According to recent estimates, annual emissions of carbon dioxide, on average, from deforestation and forest degradation are roughly 1.2 Gt of carbon, or about 4.4 Gt of carbon dioxide. This represents around 12 percent of total anthropogenic carbon emissions (van der Werf et al. 2009). To help put these figures in context, the estimated current annual emissions from deforestation are over 4½ times the annual emissions from all sources in Germany and roughly equal to the emissions from all sources in the entire European Union in 2009 (Siikamäki and Newbold 2012).[12] In some areas, including several tropical countries, deforestation is the main source of carbon emissions. For example, Brazil and Indonesia are globally among the largest emitters of GHGs almost entirely due to their emissions from deforestation (Parker and Blodgett 2010).

To encourage forest conservation for GHG reasons, programs are developed to reduce emissions from deforestation and degradation (REDD programs). Their purpose is to incentivize developing countries to decrease forest-based emissions of CO_2 and as such, generate carbon offsets. Carbon offsets can then be sold to buyers, typically in developed countries, who are voluntarily or under a regulatory requirement seeking to offset their CO_2 emissions. REDD programs are particularly attractive for their potential to provide low-cost options to mitigate global GHG emissions in the near term (Kindermann et al. 2008). REDD has become prominent in international climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC).

Assessments of carbon storage in forests require information on forest cover, forest biomass, and the carbon content of the biomass. To evaluate changes in forest carbon, one needs to monitor changes in the determinants of forest carbon, most typically forest cover. Although such assessments are subject to substantial uncertainties, the state of knowledge about forest carbon has considerably improved over the last decade or so. Currently, the accuracy and precision of such assessments is well within the bounds of other assessments included in the forest wealth assessment. For example, in just over the last few years, researchers have published global datasets of high quality and fine spatial resolution to estimate forest cover (Hansen et al. 2013), forest biomass (Saatchi et al. 2011), and emissions due to deforestation (Harris

12 Deforestation has the potential to be even more detrimental to climate change if concerted efforts to reduce forest losses are not undertaken or turn out to be less effective than anticipated (Siikamäki and Newbold 2012). The carbon pool currently stored in the world's forests and possibly subject to release due to deforestation is massive: more carbon is estimated to be stored in standing forest biomass and forest soils combined than currently resides in the atmosphere (IPCC 2007; Pan et al. 2011). Much of these current and potential emissions are not covered by existing reduction targets or management frameworks.

et al. 2012). Inventories of current carbon storage, sequestration, and emissions due to habitat losses have also been developed for specific forest ecosystems, such as mangroves (Siikamäki et al. 2012).

For the economic valuation of forest cover, two main options are available: (1) social cost of carbon or (2) market value of carbon offsets. Social cost of carbon, by its definition, denotes the net economic damage caused by the release of additional CO_2 into the atmosphere. In the United States, a recent federal inter-agency working group has developed a consensus estimate of the social cost of carbon. According to its recently revised assessment, the economic damage from emissions is $39 per ton CO_2 (in 2012). Because CO_2 emissions pose a global externality, valuing forest carbon storage at a globally uniform value equal to the social cost of carbon could be justified.

The current market value of carbon offsets does not match the social cost of carbon, but is a relevant reference value to countries or other parties potentially providing carbon storage through forest conservation activities. Although no regulatory markets currently exist for forest carbon offsets, some market-based opportunities exist to sell them through voluntary markets. The value per ton CO_2 in those markets is nowadays considerably below the estimates of social cost of carbon, typically in the range of a few dollars per ton CO_2. Regardless, the voluntary market provides another possible reference point to the valuation of forest carbon storage.

Several factors suggest that forest carbon deserves consideration in the forest wealth assessment. First, forests are of central importance in global climate policy, as explained above. Second, the availability of improved methodological approaches and vastly improved data sources make the assessment of forest carbon increasingly feasible. Third, countries vary in the forest carbon stock and its development over time, often as a result of specific policies, or the lack thereof, to sustainably manage forests. Deforestation is particularly pressing in the tropical regions, but even among tropical countries substantial variation exists in this regard. Moreover, in some areas, such as several temperate and boreal areas the carbon storage in forests is increasing. The exclusion of forest carbon from the wealth assessment omits an economically valuable and globally important service provided by the forests.

BIODIVERSITY

The current assessment excludes any potential values associated with biodiversity conservation, although forests provide an important habitat to many species. Moreover, there is considerable evidence from the economic literature that people value biodiversity (e.g., Loomis 2006) and that many species are under threats due to changes in forest habitat. In fact, habitat change in general is one of the main drivers of current biodiversity loss, and the conversion of forests to agricultural uses is among the most detrimental kinds of land use change in its effects on biodiversity (Pereira et al. 2010).

Overall, biodiversity loss is among the globally central environmental problems, along with especially climate change.[13] To address biodiversity loss, the majority of global nations are signatories to the Convention for Biological Diversity (CBD), signed at the Earth Summit in Rio de Janeiro in 1992. The broad purpose of CBD is to halt the loss of biodiversity.

Although forests undoubtedly provide potentially valuable ecosystem services, their consistent economic valuation throughout the world is challenging at best. While biodiversity valuation studies have estimated benefits from the protection of threatened and endangered species in the developing countries (for the summaries of literature, see, e.g., Loomis 1996 and Siikamäki and Chow 2008), the availability of such studies for developing countries is much more limited. On the other hand, the literature is improving both methodologically and in its geographic scope,

13 Biologists estimate that the rate of species extinctions over the last few hundred years is several orders of magnitude higher than the average rate in the fossil record (May et al. 1995; Pimm et al. 1995). Furthermore, the current rate of species extinctions is comparable to the most rapid extinction episodes paleontologists have identified (Wake and Vrendenburg 2008; Barnosky et al. 2011).

so considering biodiversity-related values a specific sub-category in a systematic meta-analysis of forest-related ecosystem values is warranted.

BIOPROSPECTING

Bioprospecting, an ecosystem benefit closely related to biodiversity, involves collecting wild biological samples to use their genetic and biochemical information as sources of new or improved pharmaceutical and industrial products and applications. Preserving biodiversity for especially possible pharmaceutical purposes was once touted as one of the principal economic rationales for protecting biodiversity. However, economic returns from bioprospecting are likely quite modest even in biodiversity hotspots that are rich in endemic species. Simpson et al. (1996) demonstrate that when researchers must analyze an abundance of biological material to locate a species that yields valuable material, the average incremental value of any one species in an ecosystem is not very high. Even in areas especially high in endemic species richness and under optimistic assumptions, this study finds that benefits from bioprospecting range from around $0.20 per hectare in the California Floristic Province to $20.63 in Western Ecuador. Although, Rausser and Small (2000) suggest that prior information (e.g., indigenous knowledge) on which species possess valuable traits can in some circumstances improve the economic returns from bioprospecting, Costello and Ward (2006) show that under a consistent set of assumptions, the marginal value of an average species or hectare of land for bioprospecting is low.

Moreover, despite efforts to formulate benefits-sharing agreements, bioprospecting has very rarely resulted in benefit-sharing arrangements by which the source areas of biological material receive income from bioprospecting. Therefore, the potential for actual income from bioprospecting to the owners of the forest is low if non-existent.

Finally, we note that bioprospecting is a form of NWFP extraction, so its value should already be included in the FAO statistics used for the valuation of NWFPs. Therefore, an additional assessment to separately value benefits from bioprospecting would involve potential double-counting. We therefore recommend against the separate inclusion of bioprospecting in the assessment.

ALTERNATIVES FOR IMPROVED ESTIMATES

WOOD WEALTH

Total Revenue

One of the main issues with the estimation of timber revenue is the use of export prices, through EUVs, to calculate total timber revenue. The use of EUVs is necessary due to the lack of data on domestic timber prices, although in most countries a major share of timber production goes to domestic markets. Moreover, we found considerable evidence that EUVs can be poor indicators of domestic prices.

However, we have found very limited publicly accessible data on domestic timber prices by country. Our conversations with the FAO forestry experts confirmed that the availability of domestic prices is inadequate. Some past data are available for some countries but the efforts to collect country level data on domestic prices were discontinued around the early 1970s.

Nevertheless, data from private firms, such as Wood Resources International LLC (WRI), are potentially helpful in addressing this data gap. WRI is a consulting firm which issues quarterly reports (*Wood Resource Quarterly, WRQ*) with domestic prices by country and type of wood (coniferous, non-coniferous). The data are not globally comprehensive but include estimated quarterly domestic roundwood prices for the roughly 20 largest markets in the world. WRQ does not publish export prices but export unit values are directly available from FAO.

There are two key limitations to using privately available data on domestic unit values. First, subscription fees for these resources can be substantial and range in the thousands of US dollars. For example, the annual subscription for the *Wood Resource Quarterly* (WRQ) varies from $2,400 (single use) to $5,400 (multiple users and offices). Separate consulting assignments to more closely examine the data can be substantially more expensive. Second, comprehensive documentation of the methodology which underlies the price estimates is hard to come by, which limits possibilities to evaluate the robustness of the data.

Regardless, the value of roundwood is a centrally important input to the current assessment. It constitutes in many cases a large share or even the vast majority of the total forest wealth estimate (Table 5). And as discussed earlier in this report, the estimated wood wealth is directly proportional to the estimated roundwood value. Therefore, for example, the doubling of roundwood unit prices in a country also doubles the estimated wood wealth of that country. Moreover, wood wealth comprises a substantial share of the total forest wealth (globally, about 70% and about 50% by country, on average). Therefore, any changes in the roundwood unit prices will considerably impact the estimated total forest wealth.

To help further highlight the sensitivity of the wealth estimates to timber prices, we note that a 50% reduction in roundwood prices has an effect similar in magnitude on the total estimated forest wealth by shortening the resource use time horizon from the current 25 years to 13 years (about 35% reduction in the total wood wealth). Note that a 50% overestimation of timber prices when using EUVs is not a completely unrealistic scenario, based on the comparisons we have developed and discussed earlier in this report of domestic and export unit values.

There are two main avenues for potentially improving the data on timber prices. One simple approach is to discount the value of timber production using available data on the relationship between domestic and export unit values. Our analyses suggest that the ratio is consistently below one (domestic prices are below export prices). Our results for the Baltic region suggest that in that region the domestic unit values are, on average, about 40 percent of the export unit values. This ratio is relevant in the Baltic region, but may considerably vary between world regions and, for example, between temperate and tropical and sub-tropical regions.

The second option involves an in-depth assessment of domestic and export prices around the world to more accurately estimate their relationship. The analyses could obtain and analyze proprietary data generated by commercial vendors, such as Wood Resources International LLC (WRI). Those data would help further evaluate the ratio between domestic and export unit values. Moreover, similar third party data can be used to re-evaluate the timber price assessment in the future.

Rental Rates

The current regionally uniform approach to estimating rental rates is limited, because rental rates likely vary within region. The current literature provides limited guidance to improving the current regional estimates, but we identify an alternative approach.

As an alternative approach, we consider data developed for computable equilibrium models to examine land use and forestry. A primary example of such models is the generable equilibrium model for forest use and timber markets developed by Brent Sohngen and Roger Sedjo (as well as Ken Lyon in the early models). A recent extension to the model involves the development of country level data (*Country Specific Global Forest Data Set V.1*, by Sohngen & Tennity 2004). These data are part of the Global Trade in Agriculture Project at Purdue University (GTAP).

The GTAP dataset by Sohngen and Tennity contains inventory and economic information on global forests, by country. The data are tailored for different age classes and also provides economic data on timber types (e.g., merchantable timber production functions, prices, rental values, biomass expansion factors, among others) at the country level, which would prove more useful and insightful than using regional rental rates. The methods used in the development of this dataset also ensure that the total land area in forests by country is consistent with FAO estimates. The data do not include estimates of rental rates, but an implicit country-level rental rate, on average, can be derived using information on timber prices, production costs, and the total area and type of timber grown.

We examined the GTAP data for some countries and derived estimates of the country-level rental rates implicit in the modeling framework. We derive the rental rate as the ratio between the gross log price and net stumpage price, where the net stumpage price is determined as the gross stumpage price minus marginal access, harvesting and hauling costs. This approach accounts only for the revenues and costs associated with timber production, as needed for the rental rate calculation. Price data are determined by species so we derive a country level estimate by using the area of each species grown in the country as weights.

The rental rate estimates vary by country but seem generally quite close to the regional estimates used in the current assessment. For example, the implicit country-level rental rate, which we derived from GTAP data for Finland, is about 0.54. The current regionally derived estimate for Finland is 0.50, so these two approaches are quite close in their results. However, the differences could easily be greater for other countries.

The level of effort required to derive similar estimates for all other countries is feasible but not negligible, involving several weeks of data manipulations, calculations, and imputations required to develop estimates for missing countries.

Woodfuel

Possibilities to improve the estimates for the value of woodfuel are twofold. First, the FAO-STAT data on woodfuel usage and values are continuously improving in the coverage. For example, the most recent annual yearbook of forest products (FAO 2012) has substantially greater coverage of countries for woodfuel values than the year books a few years ago. However, many countries continue to not report unit values for woodfuel, and those which do derive the value estimates from export or import values. Therefore, the applicability of the available statistics to predict the value of domestically used woodfuel continues as limited.

The second alternative to improve data on woodfuel usage could involve the Living Standards Measurement Study (LSMS) and the surveys conducted to support it. Wood wealth assessment could be assisted by data from questions about, for example, woodfuel usage, trade, and values.

Yet another alternative may be to conduct a literature review of existing LSMS or other national household surveys (such as the National Sample Survey in India) to estimate the magnitude of woodfuel usage.

Life Span of the Resource

Our review of the methodology to estimate the life span of the resource calls for and outlines a revision of the current methodology to consider the renewable nature of the forest resources. We propose adopting the new methodology so that the life span of the resource is more accurately determined for countries where timber extraction exceeds annual growth.

The revised approach can also help address the lack of information on key estimates in the current assessment, such as the Annual Commercial Increment. As we outline, the stock increment may be estimable directly from the FAO data.

Finally, we recommend revising the current approach to imputing 25 years to countries with missing data. Again, our proposed revised approach could reduce the number of countries with missing data. Moreover, for countries with missing data regardless, data on land cover could be used to evaluate the sustainability of forest management. For example, if a country experiences substantial loss of forest cover, one could use the estimated forest loss rate to proxy time to resource exhaustion.

NON-WOOD FOREST WEALTH

Several alternatives exist to improve value estimates for NWFW, including a review of the existing literature on ecosystem service values. One possibility would be to update the approach by summarizing the existing literature on forest ecosystem service values by forest type, location, and relevant ecosystem services. The depth and technical rigor of the summary can range from a descriptive analysis to a statistically rigorous meta-analysis. We next discuss information sources to support the revision.

Non-Market Valuation Databases

Over the last decade or so, the valuation of ecosystem services has substantially expanded, resulting in a proliferation of studies about various types of environmental services, such as watershed protection, recreation, hunting and fishing, among many others. Moreover, some of the primary valuation studies are summarized in meta-analyses and valuation databases developed to assist researchers in predicting ecosystem service value in places where primary valuation studies are lacking.

We identified two key databases (TEEB and EVRI) focused on collecting non-market valuation studies, as well as several meta-analyses of certain services. Information from the databases and meta-analyses serves as a useful starring point to improved valuation estimates for the forest wealth assessment. We next explain the TEEB and EVRI databases.

The Economics of Ecosystems and Biodiversity Database (TEEB)

One of the most comprehensive databases of non-market valuation studies is constructed by *The Economics of Ecosystems and Biodiversity* (TEEB) initiative. According to its webpage, TEEB is "a global initiative focused on drawing attention to the economic benefits of biodiversity including the growing cost of biodiversity loss and ecosystem degradation"[14] through helping decision-makers capture, analyze and take into account these values in public-policy decisions.

TEEB database is a searchable collection of valuation study summaries with value estimates for a number of ecosystem services. The database consists of 267 publications from 290 study locations, providing 1,310 estimates.[15] The user of the database can screen value estimates by service, biome and world region, as well as several other study and site characteristics.

Importantly, many of the value estimates in the TEEB database are transformed to per hectare values, which improve the potential suitability of the database to support the forest wealth assessment. However, not all value estimates identified by TEEB were able to undergo the conversion to per-hectare values, and these value estimates are not included in the TEEB publications and value estimates. According to Van der Ploeg et al. (2010), the following criteria were used for the selection of studies and value estimates for the TEEB database:

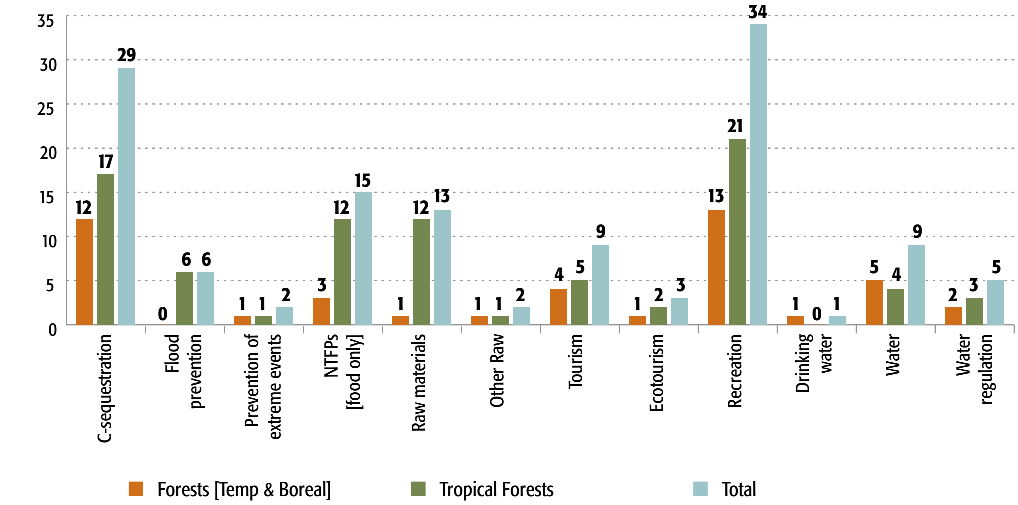
1. Refers to original case studies and global estimates.
2. Provides a monetary value of a given ecosystem service or ecosystem subservice which can be attached to a specific biome/ecosystem and a specific time period.
3. Provides information on the surface area to which the ecosystem service value applies in order to make it possible to convert the monetary value to US$/ha/yr.
4. Provides information about the ecosystem service valuation methodology used.
5. Provides the location of the case study, the service area and the scale of research (local, country, region, continent and global).
6. Is a peer-reviewed, official report, working paper or theses coming from reliable sources such as World Bank, WWF, IUCN, WRI, universities and other research institutes.

Note that TEEB contains value estimates for many ecosystems, not only forests. For forests, TEEB identified 336 value estimates, including temperate and boreal, and tropical forest biomes. Out of these studies, altogether 187 were selected for TEEB publication. The forest valuation studies are further broken down by sub-services.

Figure 5 shows a breakdown of forest value estimates in TEEB by forest subservices. Recreation and carbon sequestration are the two subservice categories with the highest number of value estimates with 34 and 29, respectively. However, most recognized ecosystem services are represented in the database.

14 *TEEB*, 2013. (http://www.teebweb.org/)
15 Van der Ploeg et al. (2010).

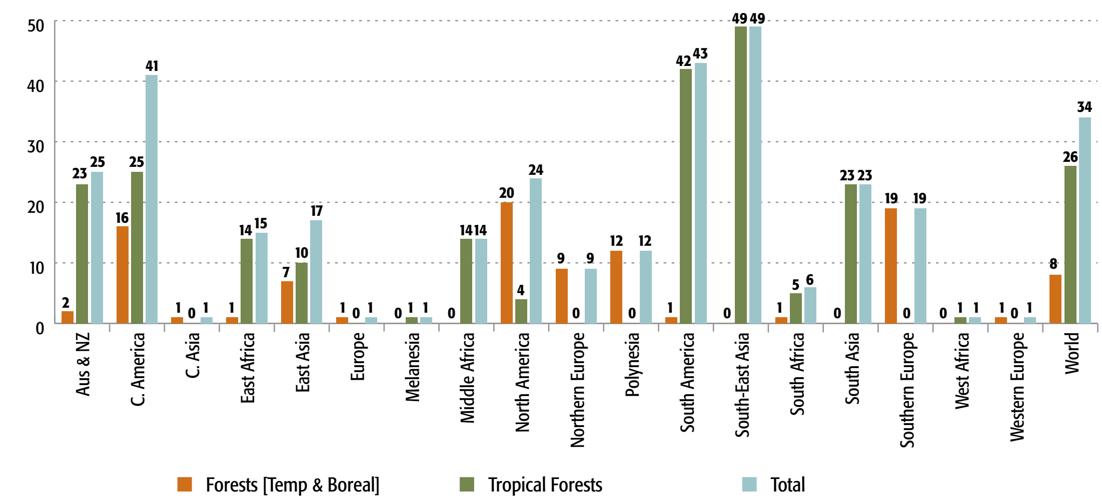
FIGURE 5. TEEB VALUES OF FOREST SUBSERVICES



Source: TEEB Database, RFF

The TEEB database also identifies the work region for each study (Figure 6). All world regions are represented in forest valuation studies found in the database, with South-East Asia (49 values), South America (43) and Central America (41) as the most frequent study regions.

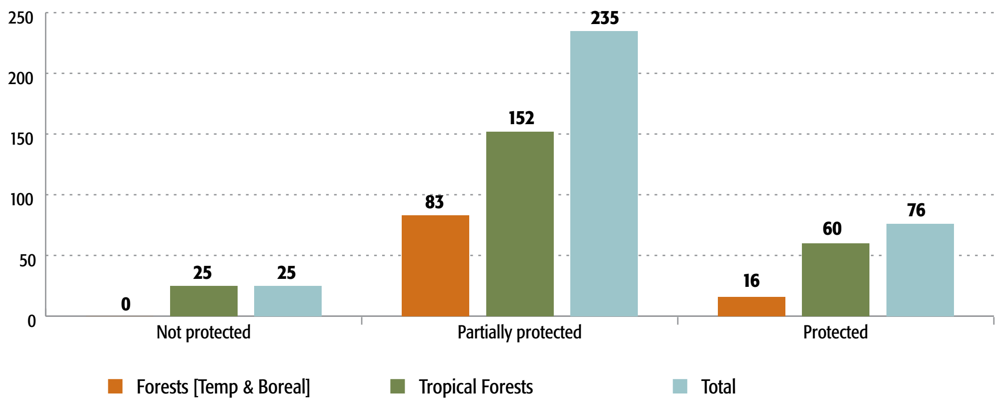
FIGURE 6. TEEB VALUES OF FOREST SUBSERVICES, BY WORLD REGION



Source: TEEB Database, RFF

However, it is worth noting that most of the forest-related values come from either partially (235 values) or completely (76) protected areas. See Figure 7 for a breakdown of TEEB valuation studies by the protected area status of the target area.

FIGURE 7. TEEB VALUES OF FOREST SERVICES, BY PA STATUS



Source: TEEB Database, RFF

Environmental Valuation Reference Inventory (EVRI)

EVRI, the *Environmental Valuation Reference Inventory*, is a searchable database hosted and initially compiled by the Environment Canada. EVRI is now supported and joined by government agencies in several other countries, including environmental and conservation agencies in the US, UK, and Australia. EVRI is one of the earliest and largest databases and it was built with the purpose of helping policy-makers and analysts to make greater use of the existing valuation studies.[16]

EVRI does not modify the valuation estimates from the original estimates. Therefore, the value units included in the database range massively, including value estimates per target area (e.g. country or specific forest or park), per hectare, per household, per individual, per year, total net present value, and so forth. The lack of uniformity in the valuation estimates poses limits to the potential usefulness of the EVRI database to support the forest wealth assessment, but the database serves as a useful, although not comprehensive, collection of potential studies to be included in the assessment.

We searched through EVRI and identified roughly twenty meta-analyses and valuation studies focused on forest ecosystem services. Among these studies are meta-analyses focused on biodiversity, non-timber forest products, recreation, and wetland services. Summaries of the most relevant studies are provided in Appendix.

Watershed Services

Several alternatives exist for updating the watershed protection value of $10/ha provided in Lampietti & Dixon (1995), ranging from updating the median value by using more studies to carrying out a meta-analysis of watershed protection services. The alternatives we have identified for updating the current value estimate are the following:

1. Using the TEEB database, update the median value per hectare for watershed protection.
2. Using existing meta-analyses and a benefit transfer approach, update the value estimates
3. Develop data for and conduct a meta-analysis of watershed protection values.

Alternative 1 is the simplest and quickest approach, but it is also most limited in the improvement provided. It involves deriving a more current value per hectare for watershed protection using the value estimates available

16 *EVRI*, 2013. (https://www.evri.ca/Global/HomeAnonymous.aspx)

from TEEB. We identified from TEEB a total of 23 studies that could be reviewed under this approach; they address valuation endpoints such as flood prevention, prevention of extreme events, drinking water, water and water regulation. Relative to the current approach, these studies comprise a larger, more recent and representative sample of studies from which to derive a new median value.

However, a value estimate calculated in this way would remain uniform across different countries and regions and forest types. More rigorous techniques such as a benefit transfer or meta-analysis can help address the underlying heterogeneity in the value estimates and are the norm in non-market valuation.

Alternative 2 uses the readily available 23 value estimates from TEEB in combination with statistical analyses and external data, including potentially helpful currently available meta-analyses, to conduct a benefit-transfer. This approach also has the advantage of being better able to provide a value by region or a country (potentially taking into account various country characteristics), but is limited by the restricted sample (23 value estimates) offered by the TEEB. It is therefore likely that the assessment would be only marginally, if at all, improved relative to the Alternative 1.

Alternative 3 involves conducting a full-fledged meta-analysis of the currently available valuation literature to develop a benefit-transfer function value associated with watershed protection. This process would entail conducting a comprehensive literature search to build the data for the meta-analysis and carrying out the approach in its entirety. The assessment would help estimate values per hectare by country, instead of using a constant value for all countries. However, the meta-analysis would require a significant amount of time and resources to implement. A full-fledged meta-analysis can easily take a year or more, even with full-time personnel assigned to the task. The adoption of this alternative will depend on the time and resources available for it.

Additionally, we have identified and reviewed several existing meta-analysis (see Appendix for the summaries of the key meta-analyses identified from the literature). While they are informative as such, none of the currently available meta-analyses readily fits the needs of the forest wealth assessment. For example, in several cases the meta-analyses do not enable transferring value estimates using information on the level of economic development of the target country.

Recreation, Hunting and Fishing

Value estimates for recreation, hunting and fishing suffer from the same limitations as the value estimates for watershed services. The alternatives to improve the current value estimates are also similar. Therefore, we refer to the above section for a discussion about the potential approaches to improve the current methodology.

In particular, the TEEB database could be useful for updating the value estimate for these services by means of providing a new median estimate (*Alternative 1*) or as a starting point for a meta-analysis (*Alternative 3*). We identified 34 value estimates for recreation used in the TEEB database, which could prove useful for either or both of those approaches. In our literature search, we also identified a variety of meta-analyses of recreation values (see Appendix) that may be useful for benefit transfer. Finally, as with the previous services, there is also the option of conducting a full-fledged meta-analysis (*Alternative 3*).

Better determining the area of forest accessible for recreation, hunting, and fishing is another issue that requires improvements. The current approach simply assumes that 10 percent of the forest area is accessible in each country. In reality, the accessibility will vary by country so improved information is needed here. One possibility would be to consider data on protected area status as a determinant of accessible forest area. This may be helpful but could also bias the estimates, as protected areas may specifically limit certain recreational activities. Moreover, protected areas may be located far away from the population centers and therefore accessed only in limited terms because of their remote location. Regardless, developing an improved methodology to the estimation of the area of forest accessible for recreation, hunting, and fishing is warranted.

Non-Wood Forest Products

As noted in the review of the methodology, the main issue with the NWFP account is the lack of reliable, standardized country reported data. We identified two chief alternatives to potentially help produce higher quality country data on consistent time intervals:

1. Literature review of existing studies.
2. Evaluate possibilities to use the Living Standards Measurement Study (LSMS) and LSMS-Integrated Surveys on Agriculture (LSMS-ISA) to better inform the valuation of non-timber forest products

Alternative 1 involves a systematic review of studies using the current LSMS data, as well as other potentially available data to evaluate their usefulness for the purposes of this assessment. This option is limited in scope but is also likely to produce mostly modest improvements to the current assessment.

Alternative 2 involves more closely examining the LSMS survey data. In the long run, the World Bank may also consider including specific items in the LSMS survey to address NWFPs. This undertaking will require a significant time investment. However, if successful, the new NWFP accounts would be more complete, plus they could be modified to follow the World Bank classification of NWFPs, providing more accurate estimates of NWFP wealth.

Also, as a minor adjustment, the current methodology uses a GDP deflator to adjust NWFP values over time. However, when a GDP deflator is unavailable, a zero value is substituted for NWFPs. This issue can be addressed by developing baseline GDP deflators for all countries or by region for imputing missing country-specific deflators.

Finally, in the longer term, the World Bank could interact with the FAO's two major programs, the Global Forest Resource Assessment (FRA) and the National Forest Monitoring Assessment (NFMA) to consider options for improving the collection and quality of country-reported data. The FRA is the program in charge of collection of country forest data, while the NFMA works to improve this data collection through capacity-building efforts at the country level. For example, the World Bank could advocate for an increased focus on NWFPs and standardization of the products included as NWFPs. These types of efforts would undoubtedly take a long time. There is also no assurance that FAO or specific countries will implement suggestions to standardize or improve the quality of the NWFP accounts. Our discussions with the FAO forest experts indicated that issues regarding NWFPs are widely recognized and have been discussed at FAO and by the member countries. Currently, the FAO data on NWFPs is focusing exceedingly on commercial activities, mostly due to issues related to data availability and quality. However, that approach necessarily ignores any non-commercial activities to benefit from NWFPs, which in some countries could lead to substantial undervaluation of the forest wealth.

SUMMARY AND RECOMMENDATIONS

EVALUATION OF THE CURRENT METHODOLOGY

The main limitations with the current methodology involve the uses of outdated or otherwise potentially inadequate parameters or data to estimate wealth. Most such issues arise due to a lack of better, easily accessible, and comprehensive data to obtain consistent estimates for all countries.

For the estimation of wood wealth, we identify two key limitations: the use of (i) export unit values (EUVs) to calculate the gross timber revenue and (ii) regional rental rates to derive the net timber revenue.

While export unit values are valid for valuing timber exports, domestic production often accounts for a large share or even the majority of timber production. Moreover, export and domestic prices vary due to differences in product categories and product quality attributes. The main justification for the current use of EUVs is that those data are readily available from the FAO statistics whereas data on domestic unit values are not. Obtaining data on domestic prices is difficult, but our assessment identifies information from several countries. The analyses of these data, by and large, confirm that the export and domestic prices of timber products diverge, in some cases substantially. Regarding rental rates, we anticipate that they vary also within each region (rather than are constant as in the current assessment) as a result of local conditions such as species mix. We also note that the current approach makes no adjustments to account for illegal logging.

Moreover, the current approach to determining the life span of the resource (time to forest depletion in countries which overharvest forests) does not accurately consider the nature of forests as a renewable resource. More specifically, when considering the depletion of the forest growth stock, the current approach does not incorporate the lost future growth associated with the depleted stock. We develop and outline a revised approach to avoid this limitation.

For the woodfuel, we note that a general issue is the lack of suitable data for comprehensively assessing woodfuel production and its value. Data from FAO-STAT on woodfuel removals and their value is missing for most countries. Moreover, the value is often derived from export or import data, which may be poor proxies for the value of domestic woodfuel. On the other hand, the coverage of FAO data on woodfuel has improved in recent years. Also, despite the above problems with the current approach, identifying improved yet consistent and comprehensive sources of data on woodfuel production and its value is challenging.

For the estimation of non-wood wealth, the key limitation involves the use of outdated and mostly uniform economic value estimates. For example, the current estimate of benefits associated with watershed protection is uniformly $10/ha, globally. The estimate is derived from the results of four studies conducted in the 1980s. The geographic coverage and methodological sophistication of ecosystem service valuation has improved considerably, so the value estimates used by the current assessment require updating. Additionally, values associated with ecosystem services are inherently spatial, so we recommend developing corresponding value estimates at regional or country-level (instead of using globally uniform or nearly uniform estimates). Similar considerations apply to the assessment of wealth associated with recreation, hunting, and fishing. Additionally, we note that the assumption that 10 percent of the forest area is available for recreation and 100 percent of forest area is available for watershed protection is not supported by any study and could easily vary by country. Finally, the current assessment excludes potentially relevant regulating services provided by forests such as forest carbon storage.

For NWFPs, the main limitation is that they are country reported with missing data for many countries. This pushes the assessment towards underestimating the value of NWFPs. The degree of underestimation likely varies by country and could be substantial especially for countries where NWFPs contribute most to livelihoods. Additionally, the cost of production is not considered in the valuation of NWFPs. This pushes the assessment towards overestimating the value of the NWFPs included in the current estimate.

RECOMMENDATIONS FOR IMPROVED METHODOLOGY

We identify several key areas where improvements to the current methodology are necessary and feasible. We prioritize areas for improvements based on their potential effect on the total wealth estimates. We consider data and parameters, which have (a) large potential current discrepancies and (b) substantial impacts on the final wealth estimates, priority candidates for revision.

Following the above logic, two key areas for improvement emerge. First, as explained above, we find considerable evidence that the export unit values inadequately reflect the value of timber gross revenues, thus, the value of wood wealth. Moreover, the estimates of wood wealth are highly sensitive to the estimated per unit price of timber. For example, doubling the price of timber per unit nearly doubles the corresponding wood wealth estimate (the value of woodfuel, which comprises a portion of the total wood wealth, remains unchanged, so moderates the impact on total wood wealth estimates). We therefore recommend and outline a concerted effort to revise the timber valuation methodology to better account for the value differential between timber production for domestic and export markets.

Second, we suggest a complete revision of the current outdated approach to the estimation of non-wood benefits associated with watershed services, recreation, hunting, and fishing. Again, the estimates of non-wood wealth are directly proportional to per-hectare estimate of non-wood benefits, so the suggested revision has the potential to substantially revise the wealth estimates. We recommend and outline a rigorous meta-analysis to examine and summarize current literature on ecosystem service values associated with forests. A number of previous meta-analyses are available but their data and methodological approaches limit the usability of the results for this assessment. Moreover, a comprehensive and rigorous meta-analysis of ecosystem service values would likely be beneficial for the World Bank beyond the needs of this assessment.

There are also a number of other adjustments we recommend as next steps, including the development of country-specific rental rates for the calculation of net timber revenue; developing rental rate estimates for deriving net value estimates for NWFPs; further examining the potential use of remote sensing approaches to the estimation of forest cover and timber volume as well as their changes; examining the use of World Bank surveys to collect data on woodfuel use and valuation as well as examining benefits from non-wood goods and services provided by the forests; and examining the availability and use of information on illegal logging in the literature.

FAO-STAT is the main data source for the current forest wealth assessment. While these data have several widely-acknowledged limitations and gaps, the distinct advantage of using the FAO data involves the availability of consistent, relatively comprehensive, and frequently updated data for different countries around the world. While specific refinements such as supplementing or adjusting the FAO estimates using other data sources may be helpful, we find that, by and large, the continued use of FAO data is warranted and beneficial to the assessment.

Finally, the current assessment of non-wood wealth focuses exclusively on watershed services, recreation, fishing, and hunting. While accounting for all possible ecosystem services associated with forests across the globe is neither feasible nor sensible in the context of the assessment, we recommend augmenting the current assessment by including additional ecosystem services, such as carbon sequestration and storage.

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APPENDIX

EXPERTS CONSULTED DURING THE SCOPING STUDY

1) **The World Bank** (January 9, 2014 workshop):

   Participants: Juan-Pablo Castaneda, Tuukka Castren, Peter A. Dewees, Julian Lee, Robert De L'Escaille, Alexander Lotsch, Carole Megevand, Daniel Charles Miller, Ulf Gerrit Narloch, Nga Nguyen, Christian Albert Peter, Klas Sander, Stefanie Sieber, and Robert Shannon Stearman

   Team: Urvashi Narain, Glenn-Marie Lange, Esther Naikal, Juha Siikamäki (RFF), and Francisco Santiago-Avila (RFF).

2) **Food and Agriculture Organization** (study trip November 2013):

   Robert W. Mayo (team leader Environmental Statistics Team), Rebecca Tavani (forestry officer), Ewals Rametsteiner (leader, forest policy team), David Morales Hidalgo (forestry officer), Kenneth McDicken (senior forestry officer, global forest assessment and reporting); Arvydas Lebedys (forestry offers, statistics), Yanshu Li (forestry officer, statistics)

3) **European Space Agency**:

   Stephen Coulson (head of industry section, science, applications, and future technologies department); Benjamin Koetz (application scientist); Torsten Bondo (Earth Observation Exploitation Engineer).

SUMMARY OF BENEFIT TRANSFER AND META-ANALYSES

Current Approach

Lampietti, J. and J. Dixon. 1995. *To See the Forest for the Trees: A Guide to Non-Timber Forest Benefits*. Environment Department Papers, No. 13. World Bank: Washington, D.C.

Current source of values for *Watershed and Recreation* (+ hunting, fishing) benefits in the World Bank assessment.

- **Watershed Services: $10 ha/year for all countries**. Selected 4 studies which contained enough information to calculate value on a per hectare basis.
    - Magrath and Arens, 1989 – Java
    - Cruz et al., 1988 – Philippines
    - Ruitenbeek, 1989 – Korup Rain Forest, Cameroon
    - Johnson and Kolavalli, 1984 – Nam Pong Basin, Northeast Thailand
- **Recreation:**
    - Developing countries: **$17 ha/year**
        - Hunting and fishing: $5 ha/year (median from 6 studies, 1987-1994)
        - Recreation: $12 ha/year (median from 4 studies, 1989-1993)
    - Developed countries: **$119 ha/year**
        - Hunting and fishing: $64 ha/year (from Johnson & Linder, 1986)
        - Recreation: $55 ha/year (only 1 study from CO, US)
            - L&D: "this value is high, as would be expected from a study location in Colorado that has two to three times the national average visitation rate."

Other Meta-analyses Identified and Summarized

Barrio, M. and M. L. Loureiro. 2010. A meta-analysis of contingent valuation forest studies. *Ecological Economics* 69: 1023-1030.

This paper presents a meta-analysis of forest studies using the CV method, around the world, to value *non-timber* benefits. The study focuses on the estimation of the marginal value of different forest management programs providing various forest goods/services. Data come from 35 studies from around the world (Scandinavia being the most significant region, with 31% of studies). The methodology consists of a meta-regression equation estimated using three models. The models have R^2s of over .80, with the most extensive model having an R^2=0.89. The results indicate that the type of service provided by the forest, the country GDP and the period of study are generally statistically significant in determining WTP estimates. Amount of forested land has a negative impact on WTP estimates. Distance to urban areas did not turn out to be significant. The study is helpful in considering a benefit transfer function. The study does not estimate transfer error.

Lindhjem, H. 2006. *20 Years of Stated Preference Valuation of Non-Timber Benefits from Fennoscandian Forests: A Meta-Analysis*. MPRA paper No. 11467.

This study examines non-wood benefits in Fennoscandinavia (Sweden, Norway and Finland). The study performs a meta-analysis of approximately 50 studies (30 stated preference surveys) of urban and non-urban forests in this region in the past 20 years. Specifically, they focused on primary studies that value forest protection and/or multiple use forests, spanning various question formats and payment mechanisms. The final meta-dataset consisted of 72 observations. Studies range from 1985 to 2002. Independent variables were classified in various categories: methodological (11 variables; i.e: WTP questions and response formats, survey modes, response rates, etc.); study quality (2 variables: published studies, Master's thesis); good characteristics (14 variables; i.e.: type of protection, forest area, regional/local good, country, use, etc.); other variables (year, continuous). The meta-regression model consisted of 4 models: OLS, Huber-White OLS, Huber-White double-log and a fourth version of consisting of Model 2 including only variables that were significant at 80% of better. The parameters were jointly significant at 0.01 in all models, with R^2s of 0.74-0.82. Overall, WTP was found insensitive to the size of forest. WTP also tends to be higher if people are asked as individuals instead of on behalf of their households. In the context of the forest wealth assessment, the main limitation of this study is its limited geographic scope (Fennoscandinavia). The region has particular social and cultural differences related to forest practices and ownership that complicate generalization to other regions (e.g. right to public access).

Schaafsma, M. et al. 2011. *The Importance of Local Forest Benefits: Valuation of non-timber forest products in the Eastern Arc Mountains in Tanzania*. Centre for Social and Economic Research on the Global Environment, Working Paper. University of East Anglia: Norwich, UK.

This paper estimates a production functions for NWFPs (use value using market prices) for households (over 2000) in the Eastern Arc Mountains in Tanzania. The study estimates "spatially-explicit, micro-economic models of household NWFP collection" and uses the models to predict collection and value of NWFPs across the study area. The study focused on four specific NWFPs: firewood, charcoal, poles and thatch. In the context of the forest wealth assessment, the study is limited by its geographic scope (Eastern Arcs). Results suggest that NWFPs help to reduce inequality and are an important source of income for poor communities near forests. The socio-economic characteristics (i.e.: location, income, economic importance of NWFPs) limit the broader generality of the results.

Shrestha, R. K., and J. B. Loomis. 2001. Testing a meta-analysis model for benefit transfer in international outdoor recreation. *Ecological Economics* 39: 67-83.

This study estimates a meta-regression model tested for benefit transfer using out-of-sample studies from 'rest of world'. The meta-data consisted of 682 value estimates from 131 US studies (1967–1998). The meta-regression model (OLS) was tested with 'Rest of world' (ROW) studies consisting of 28 CVM and TCM studies from 16 developing/developed nations. The meta-regression included method, site, activity and socio-economic variables (optimized model for benefit transfer retained only variables significant at the 20% level). The meta-regression model's explanatory power is low (R^2=0.26). The performance of the benefit transfer function is analyzed using paired t-tests for CS estimates (vs. original study estimates) and correlation analyses. ROW CS values were adjusted for per capita income differentials. The estimated mean CS ranged from $36.79 to $38.70 per person/day (1996 USD) for all countries (slightly lower than original CS values). The estimated values were consistently higher for high-income countries. Average transfer error was 28% across all comparisons (would be deemed acceptable).

Additional considerations:

- Original studies for ROW sample estimated the recreation values of foreign tourists (might overestimate CS).
- Recreation resources valued in ROW countries (mostly in low-income ones) were for unique sites (might overestimate CS).
- Values from original studies "could have been inflated by the small number of studies representing the most popular sites" (might overestimate CS).

Zandersen, M., and R. Tol. 2005. *A Meta-analysis of Forest Recreation Values in Europe*. Working Paper FNU-86: Hamburg, GE.

This study provides a meta-analysis of forest recreation in Europe. The meta-analysis includes 25 studies in 9 European countries between 1979 and 2001 (251 observations) that applied the travel cost method. The authors employed two meta-regression models (linear and semi-log) with three different variable specifications. The variables used in the models included data available from studies (I-III), socio-economic indicators (II-III) and site-specific characteristics (III). CS varied between $0.72 (2000) and $122, with a median of $4.90 per trip. The semi-log model proved to have a much higher explanatory power (R^2 = 0.74-0.87) than the linear model (R^2=0.33-0.41). All studies from Europe.

Zandersen, M., M. Termansen, and F. S. Jensen. 2007. Testing Benefits Transfer of Forest Recreation Values over a Twenty-Year Time Horizon. *Land Economics* 83 (3): 412-440.

This study tests the accuracy of a benefit transfer of recreational values in forests over 20 years, for 52 forests in Denmark. The analysis consists of a multi-site model with a mixed logit specification and GIS analysis to account for heterogeneity of preferences across the population and over space. Data was obtained from two national visitor surveys and two household surveys, and included only visitors from inside the Copenhagen and Frederiksborg regions. Site attributes were also taken into account, including species index, fraction of broadleaf/vegetation/open land, distance to coast, slope, distance to view point, size, fraction of water bodies, etc. The margin of error for the benefit transfer had a mean of 24%.

Additional considerations:

- Limited geographic scope
- Highlights importance of updating transfer models in order to reduce transfer errors.

Chiabai, A., et al. 2009. *Economic Valuation of Forest Ecosystem Services: Methodology and Monetary Estimates*. Fondazione Eni Enrico Mattei: Venice, IT.

This study provides value transfer, per hectare, estimates of the economic value of various sets of ecosystem services for every region and forest biome in the world. The study provides values by world region and forest biome for: provisioning services (forest products), regulating services (carbon sequestration) and cultural services (recreation and passive use, estimated separately), all in annual/per hectare values. Estimates for provisioning services are estimated by using data from the FAO and FAOSTAT, adjusting for total provisioning values (since FAOSTAT provides export values), and including both timber and non-timber products. Estimates for carbon sequestration (regulating services) are made by first identifying the biomass carbon capacity by forest type and world region and then computing annual marginal values of carbon stocked per hectare using market values (and value transfer if the value for the region was not available). Cultural services (recreation and passive use) were estimated separately. The authors conducted a meta-analysis of the literature, highlighting size of forest site and income (both logged) as the primary explanatory variables. The meta-analysis consisted of 59 observations and had an R^2=0.45. For passive uses, the mate-analysis consisted of 23 observations, with an R^2=0.80.

Additional considerations:

- Provides estimates of recreation values per hectare for all world regions
- Provisioning services methodology seems to be in harmony with FAO

Brander, L., R. Florax, and J. Vermaat. 2004. The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature.

This study carries out a meta-regression analysis of wetland values. The authors make use of 191 (1969 – post-2000) wetland valuation studies (215 observations) that include various types of wetlands, study characteristics, valuation methods, wetland functions, physical/geographic characteristics, and a comprehensive geographic coverage (25 countries). The analysis also includes socio-economic variables such as GDP and population density that proved to be significant in estimating wetland values. The average annual wetland value for the dataset was approximately $2,800 US$ (1995) per hectare, with a median of $150 US$ per hectare per year. The meta-regression function had an R^2 of 0.45

The authors made use of a benefit transfer function to estimate values for different wetlands. The average transfer error for the sample was 74% (considered high). However, the transfer error varies with the size of the transfer site. Results indicated that the fit was "acceptable" for medium to high-valued wetlands and poor for low wetland values.

Kuik, Ghermandi, and Brander. 2009. *The Value of Wetland Ecosystem Service in Europe: An Application of GIS and Meta-Analysis for Value Transfer*.

This study carries out a meta-regression analysis of wetland values at a European level. Their objective is to produce a value transfer function through a meta-regression to estimate the values of European wetlands. Data for the meta-analysis was obtained from 84 primary valuation estimates for European wetlands. The spatial variables used in the meta-regression include: wetland location, size, type, abundance, GDP per capita and population density. For the meta-analytic value function, they made use of 264 independent observations of wetland values, mainly from Europe and the US. The median transfer error for the meta-analytic function transfer method was 95% (high), with a long right-hand tail of high errors. The variables used consisted of: characteristics of the valuation study, characteristics of the valued wetland (i.e.: size, type, abundance) and socio-economic and geographical characteristics/context (population, income per capita). The Adjusted R^2=0.43.

Additional considerations:

- Only European wetlands.

Chiabai A., et al. 2010. *Economic Assessment of Ecological Services in Tropical forests: Potential for Conservation Policies in Central America*. Document prepared to the 2010 ISEE Conference: Bremen, GE.

The paper focuses on a thorough economic assessment of "ecosystem goods and services (EGSs)" in tropical forests in Central America, taking into account both market and non-market values. The assessed services include: water regulation, recreation and enjoyment, conservation values, timber products and carbon sequestration. For water, recreation and conservation services, the authors use the same framework, using a combination of market and non-market values in their methodology. For this, they gathered 43 valuation studies (1985-2009), providing 131 value estimates. The studies were mainly case-studies providing site-specific economic values of tropical forests in Central and South America, and include a range of valuation techniques. The authors constructed and applied a meta-regression function (including fixed-effects) in order to relate the value of services to the following explanatory variables: study area, type of service under valuation, valuation method, and country characteristics. The dependent variable was the natural logarithm of the value per hectare for the service valued.

Mean predicted values (2005$/ha) are $254.68 for water provisioning, $0.34 for water regulation, $113.30 for "water various" (consist of an aggregation of water services), $0.72 for conservation, and $7.24 for recreation, for all countries.

Regarding values for carbon sequestration, their review of the literature on voluntary and regulated carbon markets resulted in an estimate of forest carbon of $3, with a likely range of $5-$10 (median value of $7.50). They also used $20 as an upper bound in their assessment. Values per hectare ranged from $381 to $521 at a $3 price; from $953 to $1,304 at a price of $7.50; and from $2,540 to $3,476 at a price of $20.

Additional considerations:

- NWFPs not included.
- Water provisioning services are more highly valued than recreational services.
- Recreational services are more highly valued than water regulating services.
- Population density was not significant (doesn't influence marginal value).
- Lower income per capita is associated with higher marginal values.

Ojea, E., and A. Chiabai. 2010. *Benefits from the Recreation Service of Tropical Central American Forests*. Document prepared to the 2010 ISEE Conference: Bremen, GE.

The paper focuses in the use of market and non-market methodologies for measuring benefits from recreation in tropical forests in Costa Rica. Market benefits are estimated through the construction and analysis of a demand function of visits to natural PAs, using regression. Non-market benefits are estimated through a review of Central American tropical forest studies that value forest recreation services, and using these in a meta-analysis. The period of analysis was 2002-2008.

The authors used estimated market benefits through the use of a multiple regression analysis, applied in order to estimate visitation rates to PAs. The dependent variable was the natural logarithm of number of visits, while the independent variables included: park characteristics, geographic characteristics, and socio-economic characteristics.

For their non-market approach, the authors used a meta-analysis. The database consisted of 11 studies and 29 value estimates (72% of studies come from Costa Rica, plus some from Brazil as well as Mexico), covering the last two decades. The primary studies had a range of recreation values of $11-$1,250 per visitor. For the meta-regression (semi-log model), the dependent variable was forest recreation economic value, measured as the estimated value per visit reported by each study. Explanatory variables included: forest site specific, study specific and context specific characteristics. The model fit was 0.89. The predicted value per visit for Costa Rican PAs was $22.38 per visit.

Additional considerations:

- Only for tropical forests in Costa Rica.
- Most are PAs.
- All values are converted and updated to $2005 using PPP.

Chiabai, A., et al. 2011. Economic Assessment of Forest Ecosystem Services Losses: cost of Policy Inaction. *Environmental and Resource Economics*.

This article analyzes the provision of wood and non-wood forest products, recreation, ecotourism and passive use services and carbon sequestration by forest biomes worldwide (land uses included are: "natural forests" and "managed forests"). The methodology derives estimates of values per hectare for each service, through the application of meta-analysis, value transfer and scaling-up approaches. Through the estimation of flows and stock values, the paper tries to estimate the value of services in baseline year 2000 and in 2050. Provision services (wood and non-wood products) are estimated mainly through the use and analysis of FAO (2005) market data available at the country level (regulating services are also estimated through the use of market data). For cultural and regulating services, the authors rely on a meta-analysis and meta-regression, and then transfer these values to other regions. Meta-analyses for recreation and passive use are carried out separately. For carbon valuation, the authors made use of the WITCH (World Induced Technical Change Hybrid) model developed by FEEM (Fondazione Eni Enrico Mattei, 2008).

For regulating services (carbon), the authors first identified the biomass carbon capacity by forest type and world region and then computed a value of carbon stocked per hectare. For quantities of carbon stocks (above and below-ground biomass), they used Myneni et al. (2001) and Gibbs et al. (2007). For the price of carbon, the WITCH model was employed.

For cultural services (recreation and passive use), the authors made use of a meta value-transfer model. For recreation, the authors used 22 studies providing 59 value observations. For passive use, they used 21 studies providing 27 estimates. These exercises only considered WTP (non-market) values. For the meta-regression, several types of explanatory variables were included, both forest specific (i.e.: size and type of forest…) and context specific (i.e.: income level, population…). The meta-regressions resulted in Adjusted R^2s of 0.42 and 0.78 for recreation and passive use, respectively.

Additional considerations:

- Estimates assume that each hectare of managed forest has the same productivity/profitability, independent of forest type and occupying species.
- WITCH model appears to have several limitations that are discussed in more detail in the article.
- No within-sample value transfer and no transfer error estimate