WORLD RESOURCES INSTITUTE

Global Assessment of Opportunities for Restoration of Forests and Landscapes

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Contents

Global Assessment of Opportunities for Restoration of Forests and Landscapes i
Global Assessment of Opportunities for Restoration of Forests and Landscapes 1
Objective 1
Forest and landscape restoration 1
Definitions... 2
Area opportunity assessment 2
    Method 2
        Point of departure.. 2
        Overview 3
        Potential forest extent 3
        Current forest extent 4
        Deforestation and degradation 4
        Opportunities for restoration... 5
    Results... 6
    How to interpret the results... 9
    Conclusions... 10
Carbon opportunity assessment 10
References.. 13
Annex: Technical description 14
    1. Spatial analysis framework 14
    2. Land mask... 14
    3. Potential forest extent 14
    4. Current forest extent 18
    5. Comparison between potential and current forest extent maps 19
    6. Current land use intensity 21
    7. Aggregated areas with forest restoration potential 23
    8. Carbon assessment.. 24
    9. References.. 26

Global Assessment of Opportunities for Restoration of Forests and Landscapes

Method Description

Objective

The objective of this assessment is to determine, in a coarse but globally consistent way, the extent and location of opportunities for restoration of forests and landscapes as well as the associated potential for carbon sequestration.

The results will stimulate interest in restoration among international and national policy-makers, help set the global agenda on restoration, and serve as a point of departure for more detailed assessment at the national and regional levels.

Many international processes reference restoration, including the Convention on Biological Diversity (Strategic Plan Target 15), the UN Framework Convention on Climate Change (the REDD+ goal and the Cancun COP 16 decision on reversing forest and carbon loss and enhancing forest carbon stocks), the UN Forum on Forests, and the International Tropical Timber Organization.

Forest and landscape restoration

Forest and landscape restoration is about more than just trees. It goes beyond afforestation, reforestation, and ecological restoration to improve both human livelihoods and ecological integrity. Key characteristics include the following:

- Local stakeholders are actively engaged in decision making, collaboration, and implementation.
- Whole landscapes are restored, not just individual sites, so that trade-offs among conflicting interests can be made and minimized within a wider context.
- Landscapes are restored and managed to provide for an agreed, balanced combination of ecosystem services and goods, not only for increased forest cover.
- A wide range of restoration strategies are considered, from managed natural regeneration to tree planting.
- Continuous monitoring, learning, and adaptation are central.

A restored landscape can accommodate a mosaic of land uses such as agriculture, protected reserves, ecological corridors, regenerating forests, well-managed plantations, agroforestry systems, and riparian plantings to protect waterways.

Restoration must complement and enhance food production and not cause natural forests to be converted into plantations.

Definitions

For the purposes of this assessment, the following terms and definitions were used.

Forest – Ecosystem dominated by trees. Forests vary enormously in characteristics across the world. Three types of forests were considered in this study:

- closed forests (canopy cover greater than 45 percent),
- open forests (canopy cover between 25 and 45 percent), and
- woodlands (canopy cover between 10 and 25 percent).

Lands with less tree cover were considered to be either naturally nonforested or converted to some other land use from any of the forest categories above.

Dry areas with a canopy density less than 10 percent, such as the Sahel, were not included in the assessment. Although trees play an important role there and opportunities for restoration exist, it was not technically possible to assess areas of this type in this study.

The forest related definitions used by the Food and Agriculture Organization could not be meaningfully used as they require information of much greater detail than was available to this study.

Landscape – A broad, typically heterogeneous land area. As defined in this study, a forest landscape is any landscape, regardless of its current vegetation or use, which is naturally capable of supporting forests or woodlands.

Degradation – A process that reduces the volume and canopy cover of trees across a landscape. Degradation leads to reduced biomass, reduced biodiversity, and a reduction in the ecosystem services provided by forests.

Forest and landscape restoration – An active process that brings people together to identify, negotiate, and implement practices that restore an agreed balance of the ecological, social, and economic benefits of forests and trees within a broader pattern of land-uses.

Area opportunity assessment

Method

A more detailed description of the method is contained in the Annex to this report.

Point of departure

Forests have in the past occupied a much greater area than they do today. The gradual process of forest decline which was set off by the Neolithic revolution is a recent event if measured on a forest time scale. Absent human pressure, forests can and will return. This is shown by formerly deforested areas in Europe and North America, which are again carrying forests.

The *potential* extent of forests and woodlands is therefore used as the point of departure, rather than their current extent. The search for restoration opportunities extends to the entire area where forests would grow if the only constraints were climate and soils, although there is no presupposition that forests ought to be returned to all potential forest landscapes.

Apart from the obvious reason that forests can grow in these areas, the potential extent of forests is also a useful benchmark for assessing the consequences of human civilization in terms of loss of carbon, water, soils, habitats, etc.

Overview

The assessment was carried out by posing a sequence of questions and then answering them in terms of maps, using globally consistent datasets. This sequence goes as follows:

A. Set the stage

1. **What is the area of analysis?** Delineate the lands to be examined.

B. What has been lost or degraded?

2. **Where can forests potentially grow?** Map the potential extent of forests and woodlands if the only constraints were climate and soils.
3. **Where are forests growing today?** Map the current extent of forests and woodlands.
4. **Where have forests been lost or degraded?** Contrast the potential with the current extent of forests in light of current land use.

C. What can be restored?

5. **Where are the constraints on restoration?** Map human pressure.
6. **Where are the opportunities for restoration?** Map the areas where human pressure is low enough to provide opportunities for restoration of different types.

D. What are the carbon benefits of restoration?

7. **What are the opportunities for carbon sequestration through restoration?** Assign carbon values to the restoration opportunities.

Potential forest extent

Mapping potential the potential distribution of forests of different density is a difficult task. First, no reliable map exists that shows the potential forest extent differentiated by tree canopy cover. Second, even if we could make an accurate map at the level of ecological zone or ecoregion, based on information on current climate and vegetation cover, this map might still be inaccurate at the local level as there are likely to be patches of unsuitable soil or moisture, periodic flooding, high elevation, and other local constraints on tree growth.

As no map of potential forest extent exists that would satisfy our needs we had to create our own, based on commonly agreed existing ecoregion/ecozone classifications (FAO, 1999, Olson et al., 2001), climate data (Hijmans et al., 2005), and current forest distribution. It is important to note, however, that this map of potential forest extent is valid at the macro-regional level only and might be inaccurate at the local level.

When the map of potential forest distribution is compared with the map of current forest distribution, disagreements show up. These may have two reasons:

- Forest loss/degradation has occurred; or
- The map of potential forest extent is inaccurate (the potential tree cover has been overestimated, e.g. because local constraints have been overlooked).

There is no simple way to attribute the "disagreement areas" to either of these two reasons. Using a global MODIS image composite dataset and guided by a set of ecoregion and ecozone maps, we used manual expert interpretation to do so:

- Anthropogenic landscapes and burnt areas were classified as degraded.
- Areas where natural causes seem to explain why the tree cover is sparse or missing (high elevation, unsuitable soils, periodically flooded areas, swamps, etc) were classified as non-degraded. The potential forest map was considered to have overestimated forest cover in these areas and was therefore adjusted accordingly.

Current forest extent

To map the current tree cover distribution we used a combination of two MODIS-derived products:

- A global forest map (SDSU, 2011), and
- A tree canopy density layer from the VCF product (Hansen et al., 2003).

The global forest map was used to map the extent of forests in general regard less of canopy density (e.g., closed and open forests), while the tree canopy density map was used to separate open and closed forests within their common extent. It was also used to add woodlands areas.

Deforestation and degradation

Forest degradation was defined as a substantial reduction in tree cover density in relation to the potential tree cover density.

Several classes of forest degradation were mapped. Some of them are derived from the disagreement between potential and current forest map, including "*deforestation*" (where potential forest cover of different density has been converted into non-forest), and "*partial deforestation*" (where potential forest has been converted into woodland with low tree canopy density) and "*degradation*" (where potential closed forest has been converted into open forest). The "degradation" class includes vast areas of agroforestry, palm plantations, and secondary forests in the tropical regions, where secondary forests were mapped by Hansen et al. (2003) as having lower tree canopy density than intact forests.

Not all of the secondary forests or forest plantations were classified as degraded. Areas not considered degraded include timber plantations (mature timber plantations in the tropics and most of the softwood timber plantations in boreal and temperate forests), mature secondary forests (for the boreal zone secondary forests in which coniferous trees dominate), and forests affected by selective logging or surface fires.

Two additional classes were defined within the area of non-degraded forests: intact forest landscapes and the rest of the forest. We used the World IFL Dataset to select the intact portion of the non-degraded forests. The non-intact portion ("the rest") was assumed to consist of forest that is fragmented, managed as plantations or having experienced some level of timber extraction (e.g. selective logging).

It is possible to argue that at least some of the non-intact portion of the forest is ecologically degraded by fragmentation and simplification of forest structure that is a consequence of forest management. To map ecological degradation of this kind was beyond the conceptual scope and technical possibilities of this study, however.

Opportunities for restoration

Having created a map of degraded forest areas we used information on current land-use to assess the opportunities for restoration. The land-use data include maps of population density, urbanized or industrial areas, and cropland distribution. Areas with high population density, or occupied by intensively managed croplands, were considered as having no or low forest restoration potential, while areas with scattered cropland areas, pastures, agroforestry and all types of forest plantations were considered as providing promising opportunities for restoration.

Deforested and degraded forest lands were divided into four categories, resulting in a map of restoration opportunity areas and other former forest lands (with resolution of one square kilometer):

- **Wide-scale restoration** – Less than 10 people per square kilometer and potential to support closed forest.
- **Mosaic restoration** – Moderate human pressure (between 10 and 100 people per square kilometer).
- **Remote restoration** – Very low human pressure (density of less than one person per square kilometer within a 500km radius).
- **Croplands** – Intensive human pressure (over 100 people per square kilometer).

A restored landscape can accommodate a mosaic of land uses such as agriculture, protected reserves, ecological corridors, regenerating forests, well-managed plantations, agroforestry systems, and riparian plantings to protect waterways.

Restoration must complement and enhance food production and not cause natural forests to be converted into plantations. Croplands were considered as providing no restoration opportunities in the sense that the map of restoration opportunity areas includes no croplands. This does not mean, however, that some croplands would not benefit from protective restoration to secure hillsides and streamside zones, reduce wind erosion, etc.

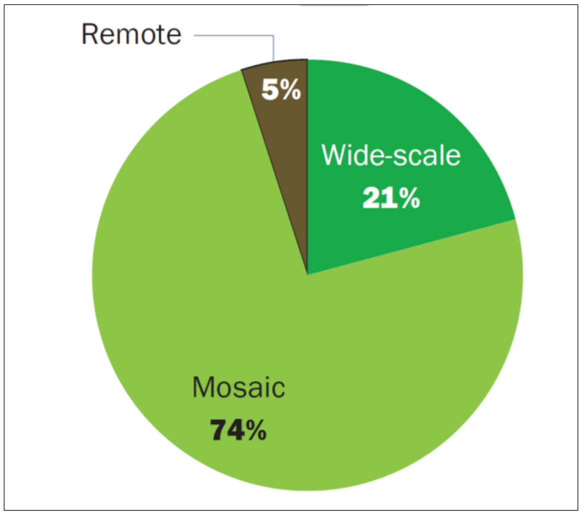
Results

More than two billion hectares worldwide offer opportunities for restoration — an area larger than South America. Most of these lands are in tropical and temperate areas.

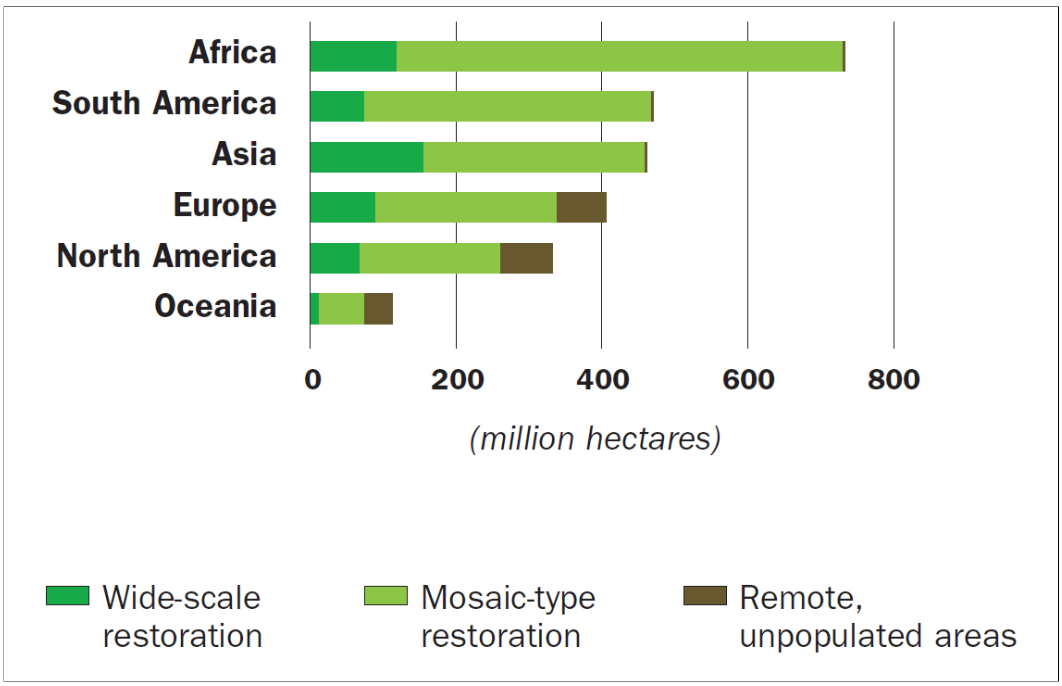
- One and a half billion hectares would be best-suited for mosaic restoration, in which forests and trees are combined with other land uses, including agroforestry, smallholder agriculture, and settlements.
- Up to about half a billion hectares would be suitable for wide-scale restoration of closed forests.
- In addition to these two billion hectares, there are 200 million hectares of unpopulated lands, mainly in the far northern boreal forests, that have been degraded by fire. These areas would likely be difficult to restore due to their remoteness.

Croplands and densely populated rural areas on former forest lands amount to a further one billion hectares. They do not offer extensive restoration opportunities in terms of area, but some of these lands would benefit from having trees planted in strategic places to protect and enhance agricultural productivity and other ecosystem functions.

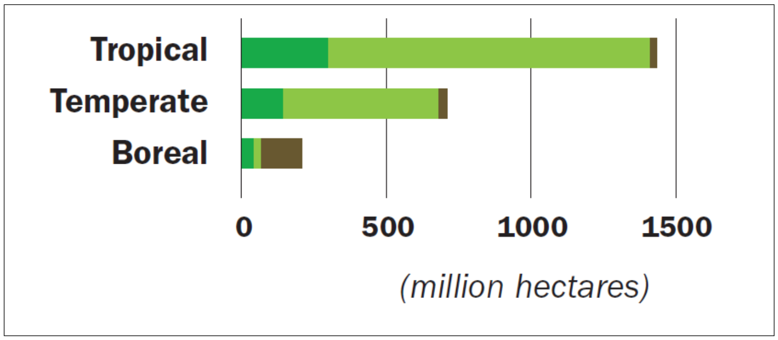
Most of the opportunities for restoration are found in tropical and temperate areas, and most of these opportunities are for mosaic restoration.



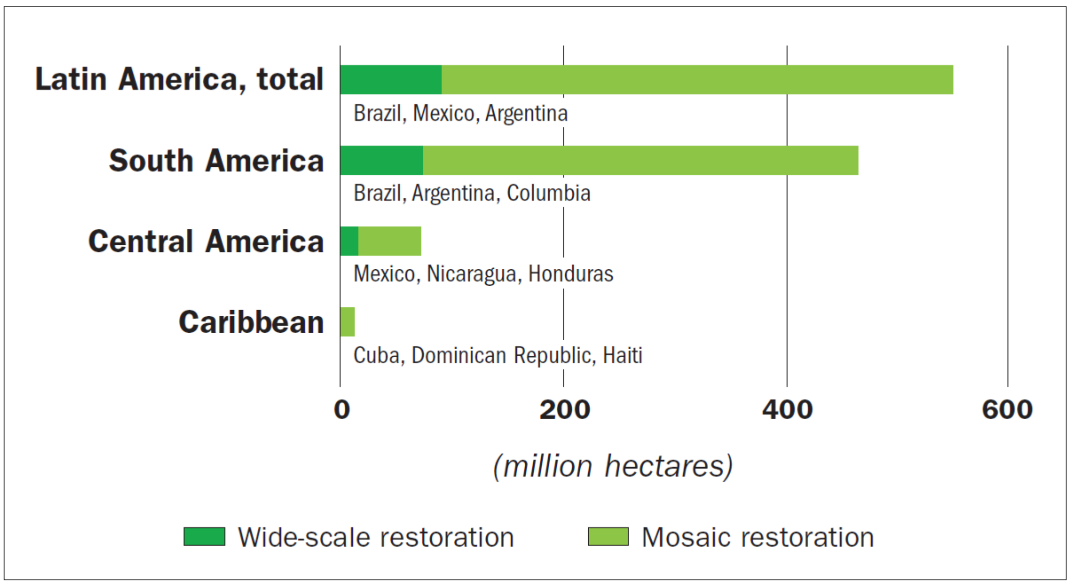
Restoration opportunity area by type of opportunity.



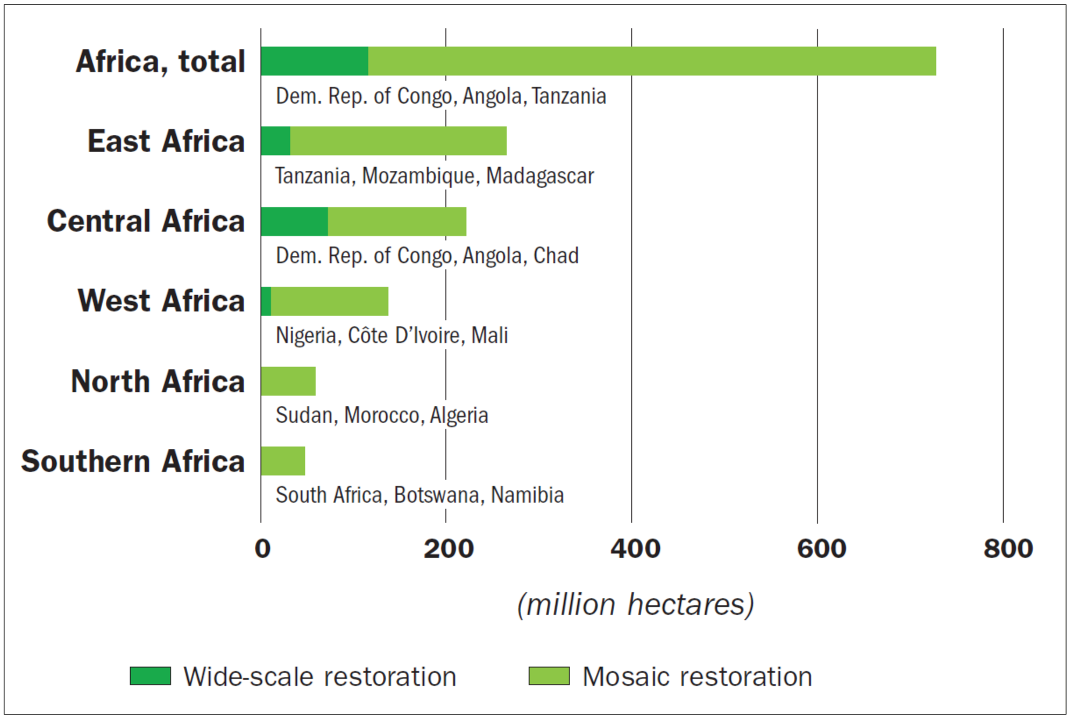
Restoration opportunity area by continent.



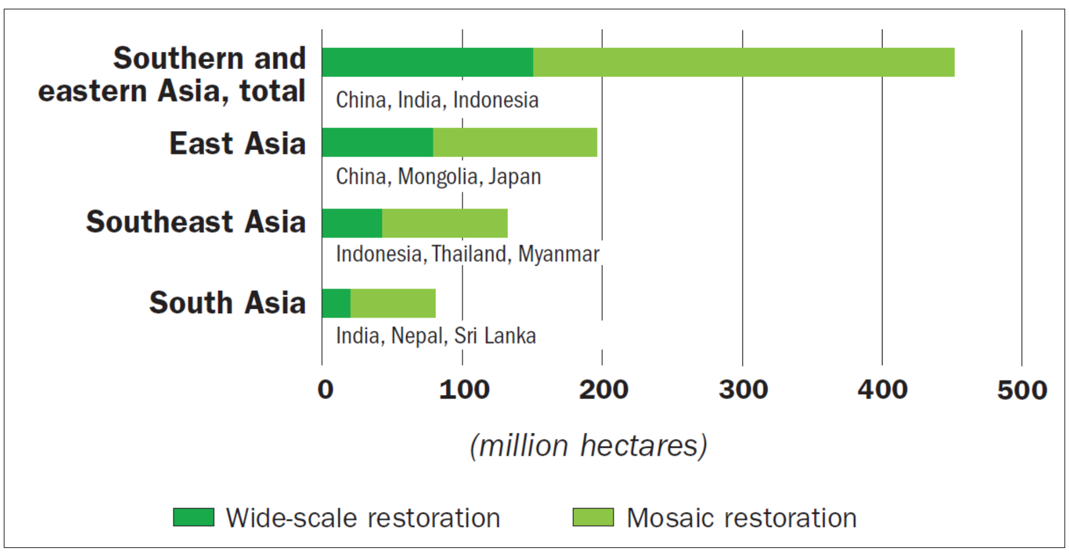
Restoration opportunity area by biome.



Latin America: Restoration opportunity area by region with leading countries listed.



Africa: Restoration opportunity area by region with leading countries listed.



Asia: Restoration opportunity area by region with leading countries listed.

How to interpret the results

The results must be interpreted with caution. The map is based on significant simplifications due to limited data. Only pre-existing information was used. Good information was available on land cover, land use, population density, and other factors. Yet many important factors could not be considered for lack of data, such as resource tenure and landuse dynamics.

The map shows wider landscapes where restoration opportunities are more likely to be found, not the location of potential individual restoration sites. Many features of the landscape are not visible at this map's spatial resolution, and local context could not be considered. No ground validation was conducted.

The map does not prescribe any particular type of restoration intervention. It only shows lands with characteristics that indicate restoration opportunities of a certain type.

The results are globally consistent, but pertain only to lands deemed capable of supporting forests or woodlands. Some areas of dry and very sparse forest, such as can be found in the Sahel, fall outside of these lands but still provide significant needs and opportunities for restoration. It is important to note that the results should not be compared with UN Food and Agriculture Organization global assessments as assumptions, methods, data sources, and definitions are different.

The assessment is intended to inform the policy making process at the global level. It should be complemented by further investigation at regional and national scales, where more detailed information is needed and available.

Conclusions

Many countries have suffered forest loss or degradation in the past. Opportunities for restoration exist on all continents and are huge in terms of area.

Many more countries can mitigate climate change through restoration than by avoiding additional deforestation and degradation.

Restoration and avoided deforestation are complementary and mutually supportive measures. Restoration opportunities tend to be located far away from areas of ongoing deforestation.

One of the most attractive features of forest and landscape restoration is its many benefits. The Convention on Biological Diversity has agreed on a target to restore 15 percent of degraded ecosystems by 2020. The UN Framework Convention on Climate Change has adopted a decision that sets a goal for all countries to slow, halt, and reverse forest cover and carbon loss. Properly designed restoration initiatives can bring benefits for both biodiversity and climate while also improving people's lives.

Carbon opportunity assessment

The purpose of the carbon opportunity assessment is to assess the extent to which restoration of deforested and degraded lands can increase the amount of carbon sequestered in forest vegetation.

In principle, the assessment logic is simple. Areas with restoration opportunities are assigned a carbon gain that represents the increase in sequestered carbon as a result of a presumed restoration, as follows:

$$\boxed{\text{Carbon gain} = \text{Carbon gain per unit of area} \cdot \text{Restoration opportunity area}}$$

In practice, however, there a complicating factors.

The assessment is no prediction. No restoration opportunity areas have yet been restored. It is impossible to know whether they will be subject to restoration and, if so, in what way and with what degree of success. Predicting the extent, intensity, and success of restoration is complex, even speculative, given the very large uncertainties involved.

Another complicating factor is time, i.e. the dynamics of growth and loss over time. It is clear that the carbon gain from an attempted restoration will take time to materialize, as the trees take time to grow, but it is not clear what sort of trees will be used or when the restoration will take place (if ever). Nor is the future destiny of the trees clear; they may fall victim to grazing or fire or the axe.

The assessment will bypass these complexities by estimating the <u>potential</u> for carbon gain rather than making a prediction of <u>actual</u> carbon gain.

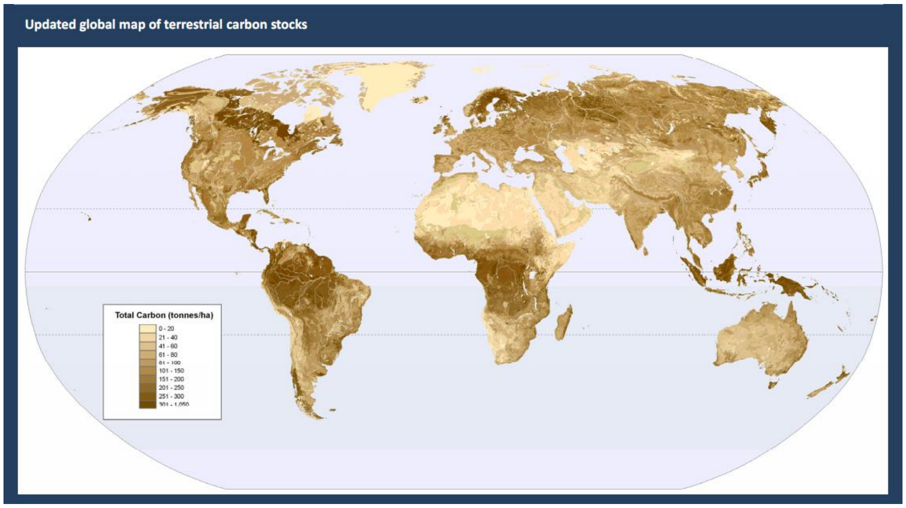
A different type of complexity is presented by the tremendous variability within the lands that provide restoration opportunities. The assessment takes into account some (but not all) of this variability by differentiating the opportunity area as follows:

- Whether the land is currently either deforested or degraded
- Whether the opportunity is for wide-scale or mosaic type restoration
- What ecofloristic zone (or ecozone) the opportunity is located in (FAO, 2001)
- What forest type the opportunity is located in (broadleaved, needle-leaved, or mixed)

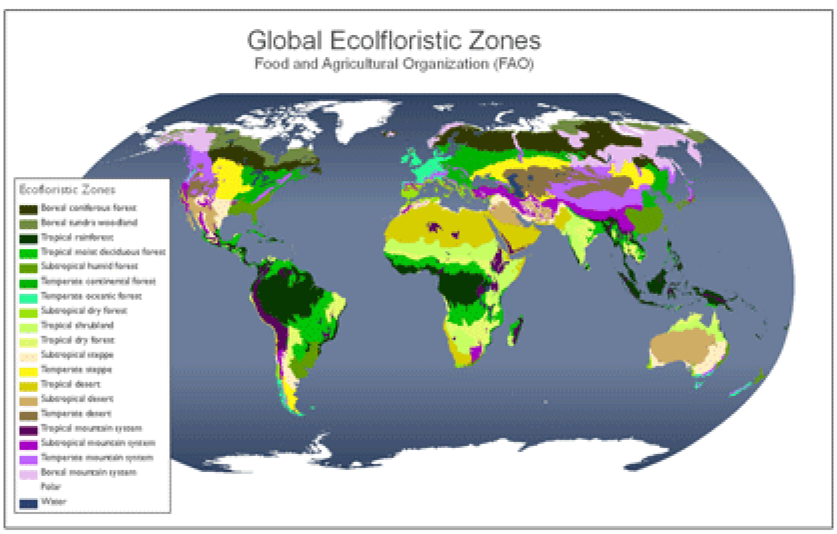
By differentiating the restoration opportunity lands in this way, we are able to differentiate the potential gain in carbon stock.

Mapping the potential carbon gain involves mapping the difference between the current carbon stocking (the floor) and the potential maximum carbon stocking (the ceiling) for restoration opportunity areas. The extent of wide-scale and mosaic restoration areas serves as the study area for the analysis.

The current carbon stocking was mapped using the UNEP-WCMC Updated Global Map of Terrestrial Carbon Stocks.



The potential maximum carbon stocking was mapped using the Ruesch and Gibbs Global Biomass Carbon Map for the Year 2000, including any relevant adjustments or additions that have been incorporated in the UNEP-WCMC Carbon and Biodiversity Calculator. Carbon biomass look-up tables developed by Ruesch and Gibbs indicate the potential maximum stocking per forest type by ecofloristic zone in a Tier-1 level (most basic level) assessment (http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html#tables).



The difference between the potential maximum carbon stocking and the current carbon stocking was calculated through geospatial analysis, providing a continuous surface map for restoration opportunity areas that indicates the gap between these two stocking levels.

The carbon opportunity assessment builds on the area opportunity assessment and incorporates its weaknesses (see description above). It also incorporates the weaknesses of the Global Biomass Carbon Map for the Year 2000, and it builds on the assumption that restoration will not change the carbon content of the soil, which is unrealistic in the long term.

It is important to note that the assessment is no prediction. It does not attempt to forecast the amount of carbon that could realistically be sequestered through restoration, nor does it attempt to reflect the dynamics of carbon stocking over time following an attempt at restoration.

What the assessment does do is to give a coarse and highly uncertain, but spatially explicit, estimate of the amount of carbon that could potentially be gained through restoration of opportunity areas up to the level of carbon stocking that is represented by comparable non-degraded areas.

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Hijmans, R. J., Cameron S. E., Parra J. L., Jones P. G. & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology, 25, 1965-1978.

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Annex: Technical description

1. Spatial analysis framework

The following framework was used

- **Projection:** Lat/Long. Ellipsoid: Sphere (radius 6,370,997 m)
- **Spatial resolution:** 30 arc second (0.0083 decimal degree) - approximately 1 km at Equator.
- **Dimensions:** 43200x21600 pixels.

This framework has several advantages:

- The size of the dataset is reasonable in terms of balance between details and overview, and in terms of computation time;
- The distortion within tropical and subtropical forests is relatively low;
- The entire world can be shown; and
- Some of the datasets used have the same projection (e.g. GLS 2000).

A drawback is that the pixel area changes from equator to poles. A special pixel area dataset is needed for area calculations.

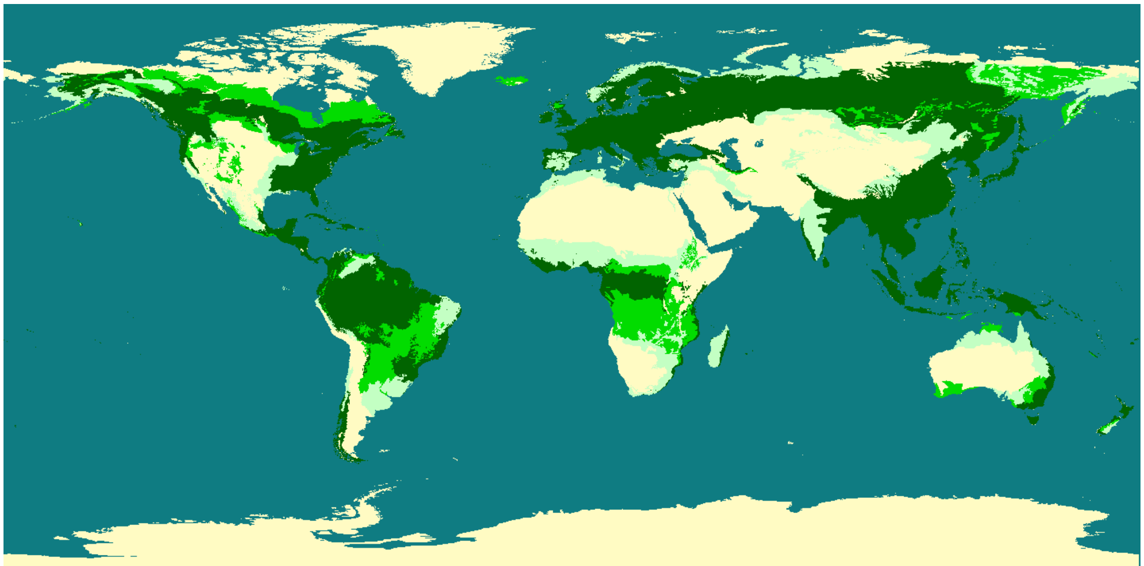
2. Land mask

The global land/water mask derived from MODIS composites at a spatial resolution of 250m (Carroll et al., 2009) was used as the baseline for the land mask. The water mask was re-projected and averaged to the project's pixel grid and the land mask was derived using a threshold for water fraction below 0.5. Some minor problems with the dataset (water omission/commission in coastal areas) were corrected manually using the FAO GAUL country boundaries dataset as reference.

3. Potential forest extent

The potential forest cover map was created through an expert-driven analysis of existing data sources.

The map and database of terrestrial ecoregions of the world (Olson et al., 2001) was used as the main source. Each ecoregion was classified as belonging to one of four categories: dense forests, open forests, woodlands, or non-forest, depending on its description (including current and potential vegetation) and its proportion of different forest types.



Potential forest extent and density before manual correction (closed forests, open forests, woodlands, and non-forest areas).

A classification based only on ecoregions does not provide an acceptable result in terms of potential forest density, however. Historically deforested areas, like the Central African savannas, were classified as non-forest ecoregions, while vast areas of sparse tree cover and treeless swamps in northern Eurasia were classified as dense forests.

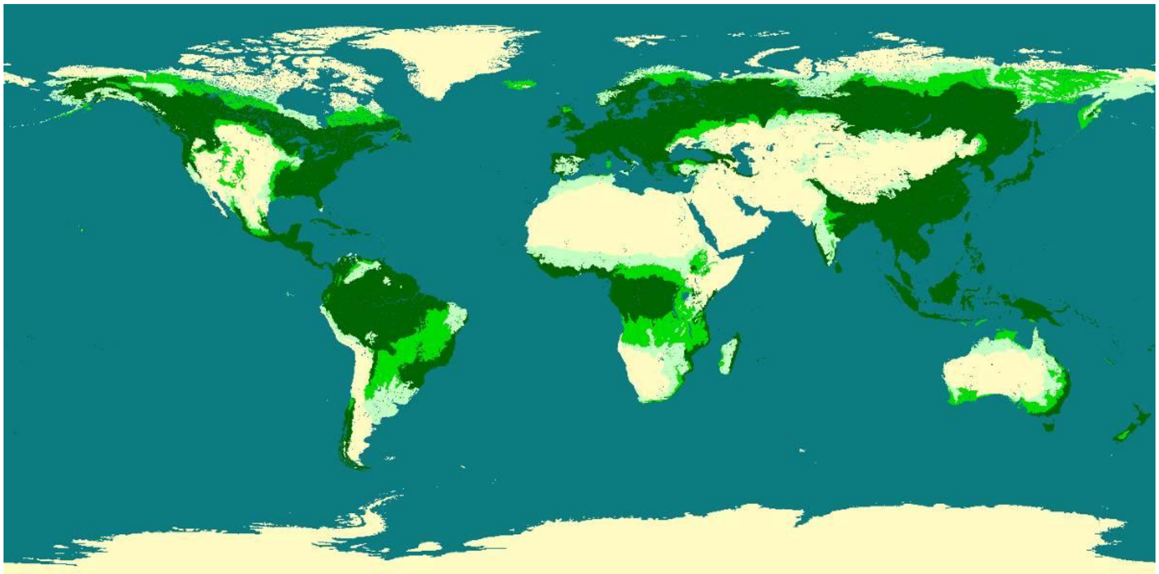
To improve the map of potential forest density, the boundaries of the different forest density classes were corrected manually. This was underpinned by several additional datasets:

- A map of current forest distribution (see below);
- Data on bioclimatic zoning and original forest cover extent (FAO, 1999; Bryant et al., 1997; Zomer et al., 2008); and
- A forest distribution map produced by modeling based on global climate variables and elevation.

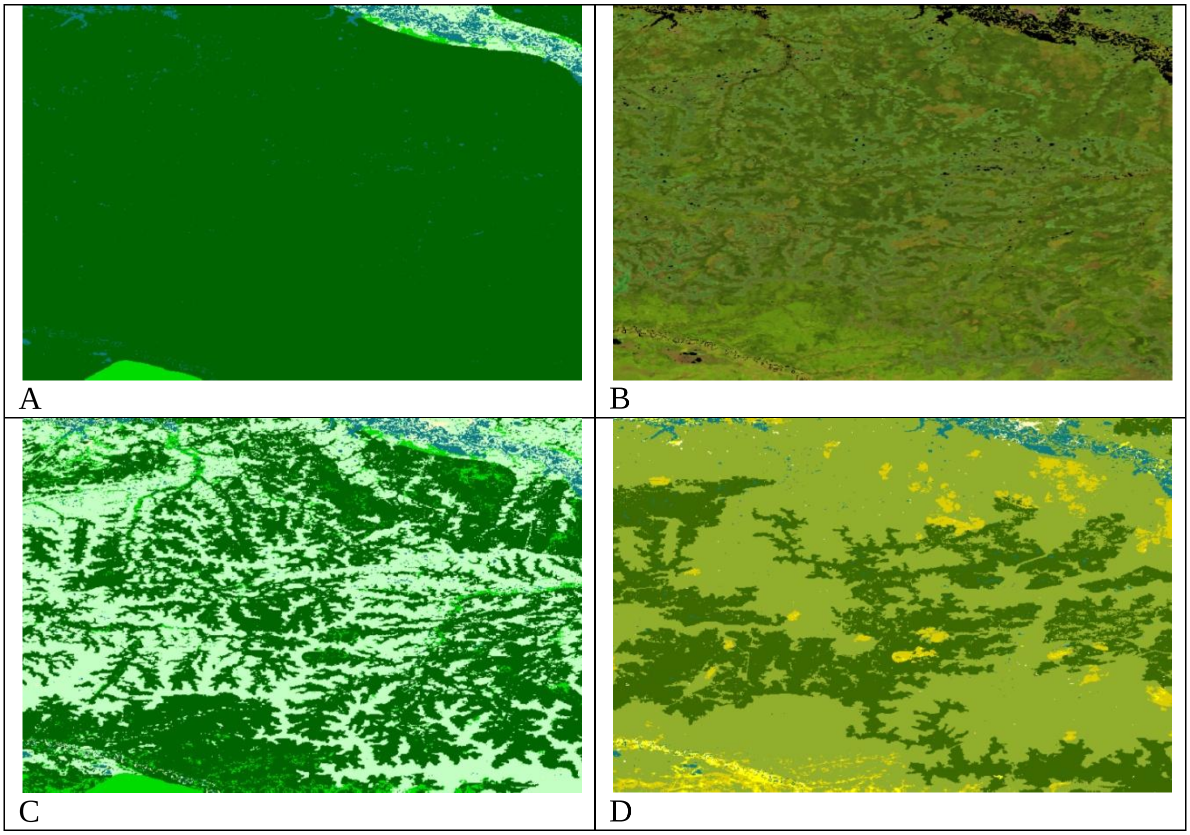
The forest distribution map was created by constructing a simple decision tree model to predict forest distribution based on global climatic variables. Two forest classes from the ecoregional classification were used: dense forests, and a class combining all forests and woodlands. 17 bioclimatic variables from the WorldClim dataset (Hijmans et al., 2005) were aggregated on a 0.0833 decimal degree (approx 20km at Equator) resolution Lat/Long grid. The decision tree model used the global set of climatic metrics as the independent variable and, as the dependent variable, a set of ecoregional labels.

Areas above the timberline, and thus not suitable for tree growth, were mapped separately. The timberline position was modeled for each 1 degree Latitude belt from Wieser & Tausz (2007). Elevation data from ETOPO2 were used to run the model. The timberline analysis was performed for the temperate and tropical zones only, due to problems with this approach in the boreal region

The final map of potential forest extent and density distribution was created by manually comparing these datasets for each forest class (closed, open forests, and woodlands) and adjusting the ecoregional boundaries.

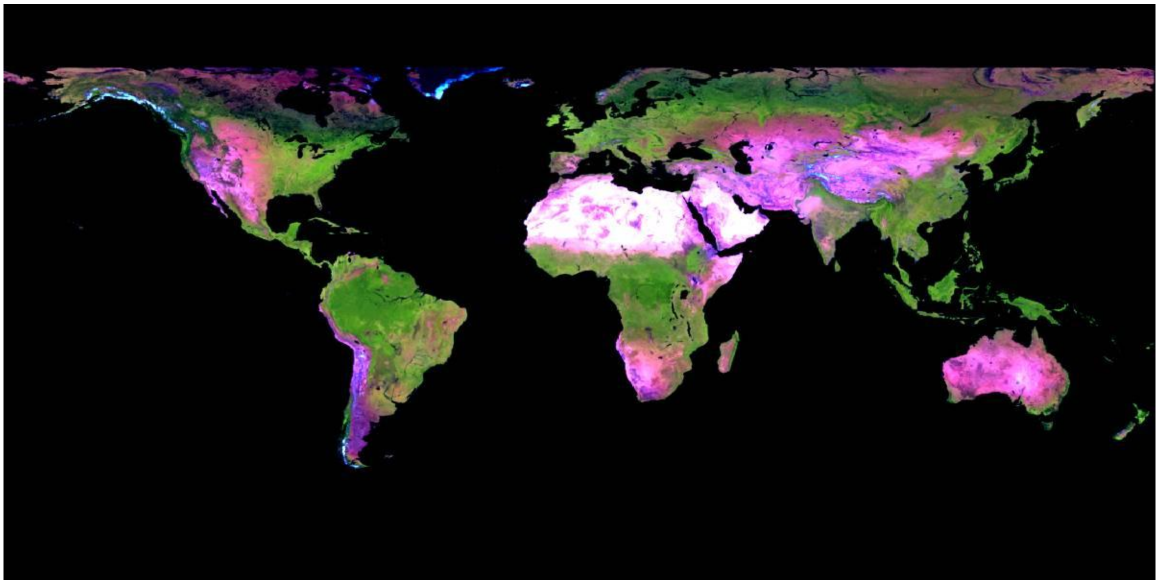


Potential forest extent and density after manual correction (closed forests, open forests, woodlands, and non-forest areas).

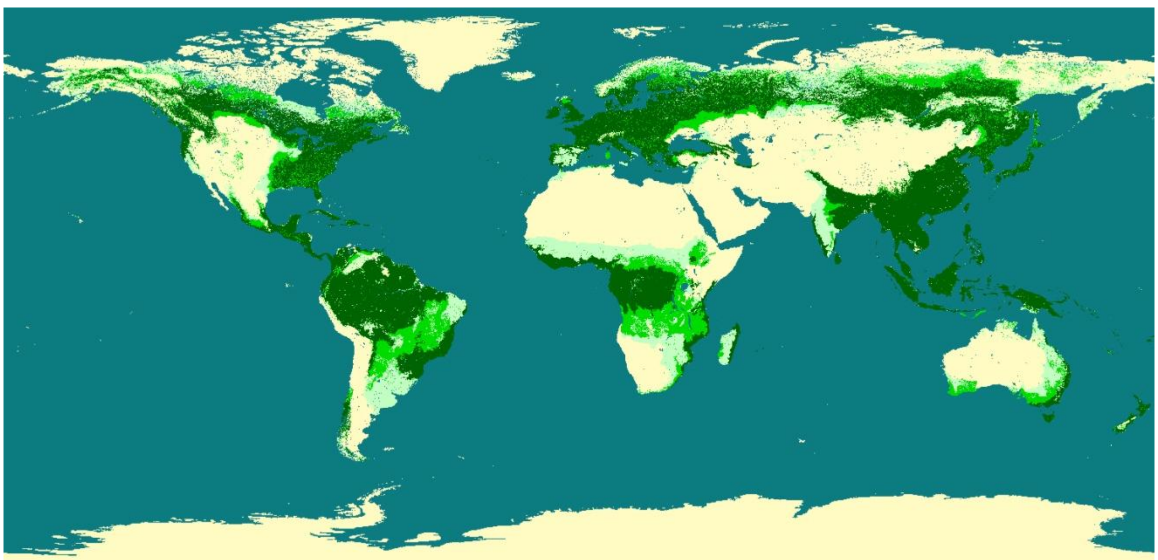


Example showing how the map of potential forest extent was developed.

A. Potential forest map of eastern Siberia based on ecosystem labels and climate data (closed, open forests and woodlands).
B. MODIS spectral composite for the area.
C. Refined map of potential forest extent. Forest distribution has been adjusted using a mask of current forest extent, and forest density has been adjusted using a MODIS composite that shows the occurrence of woodlands over swamp areas.
D. Forest condition map: intact (dark green), fragmented/managed forests and woodlands (green), partly deforested, mostly due to forest fires (orange) and deforested (yellow).



MODIS composite image used for visual assessment of disagreement classes



Final map of potential forest extent (closed and open forests, woodlands and non-forest areas)

4. Current forest extent

Two datasets were aggregated to show current forest extent:

- A global forest map (SDSU, 2011), showing percent tree cover per pixel. In this dataset, forest was defined as an area of at least 1 ha with more than 25 percent tree canopy cover from trees taller than 5 m.

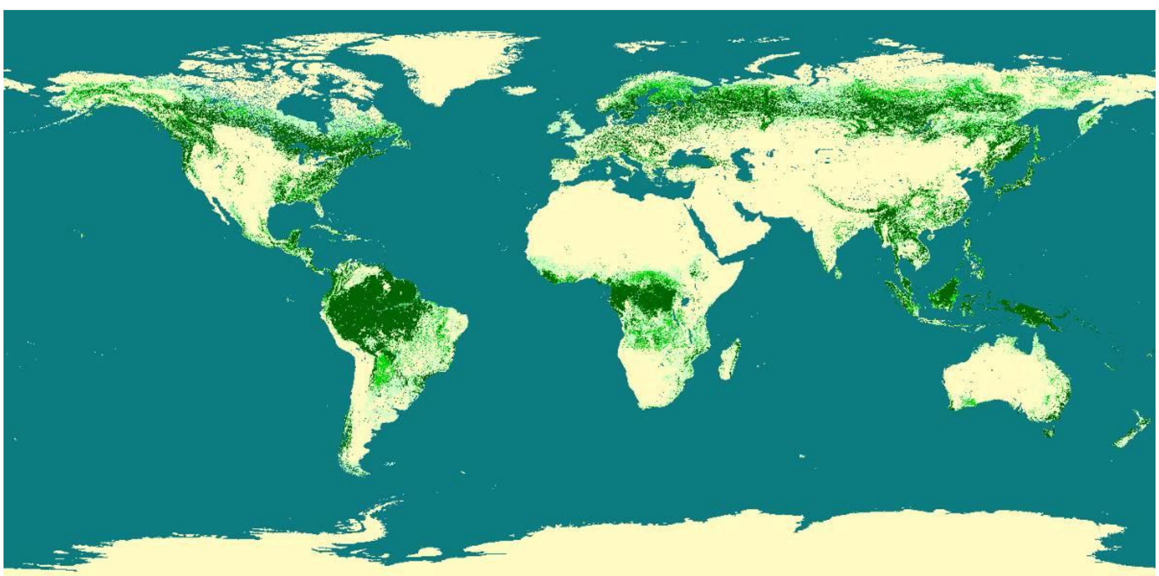
- A tree canopy density layer from the VCF product (Hansen et al., 2003), showing the percent tree canopy density per pixel. In the VCF product tree canopy density is measured on trees taller than 5 m.

Both products were averaged from the MODIS sinusoidal pixel grid (250m for forest cover product and 500m for VCF product) to the project's pixel grid.

A forest mask was derived from the percent tree cover per pixel dataset using a threshold of 50 percent. A closed forest class was produced within this forest mask, using the VCF product and a 45 percent tree canopy cover threshold.

It is not possible to specify an exact threshold in the global MODIS vegetation continuous fields product as the root mean square error is 11.5 percent for the sites evaluated to date (Hansen et al., 2002). The 45 percent threshold was therefore selected by visually examining the product and finding the threshold that would balance the errors of commission and omission for closed forests.

Outside areas of closed and open forests, the VCF dataset with a threshold of 10 percent canopy cover was used to map the extent of woodlands. Some manual corrections were also made. The closed forest class was reclassified as open forests within the dry tropical forest biome, and tundra and desert areas erroneously mapped as woodlands were eliminated. The manual correction did not change the forest area per class more than 1 percent.



Current forest extent (closed forests, open forests, woodlands, and non-forest areas)

5. Comparison between potential and current forest extent maps

A comparison of the maps of potential and current forest extent makes it possible to identify areas of historical forest loss and degradation.

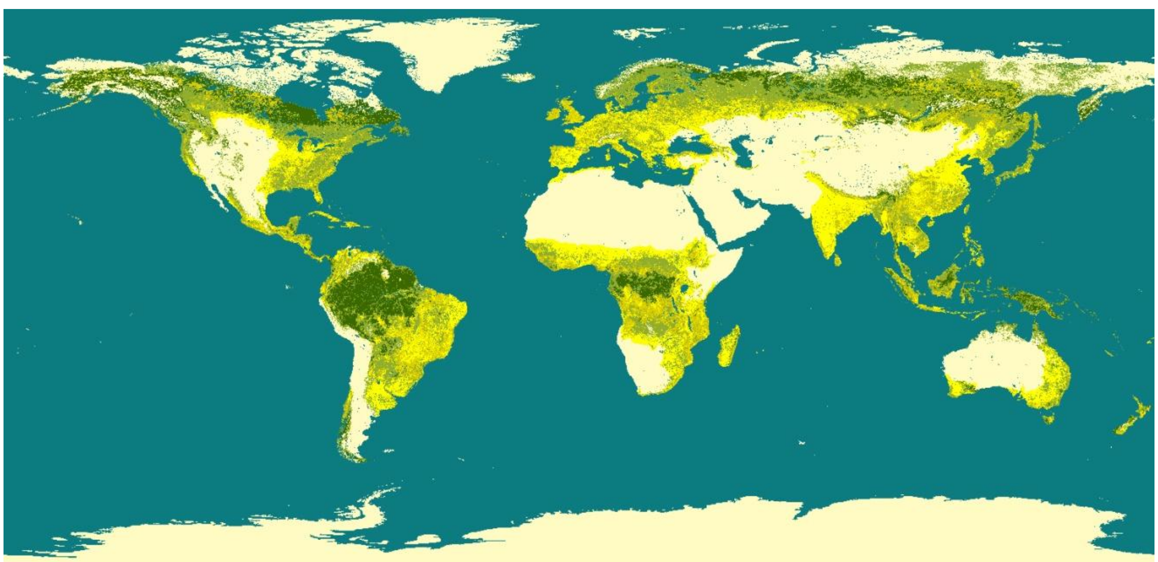
After aggregating the potential and current forest maps, a set of comparison classes was created, including

- No change;
- Deforestation;
- Closed and open forests converted to woodlands; and
- Closed forests converted to open forests.

No classes of increased forest cover or density were allowed in our comparison. Areas with a current density above potential (because of under-estimation of the potential forest extent) were classified as not having changed, and the potential forest mask was adjusted accordingly.

Each comparison class that showed a loss or reduction in tree cover was checked manually, using global MODIS data layers and existing land-cover datasets as a reference. Areas of forest degradation were mapped manually within each class and separated from areas with naturally low or absent tree cover. Naturally treeless areas were eliminated from the map of potential forest extent.

Intact forest areas were identified within the no-change classes using the Global IFL Map (Potapov et al., 2008).



Forest condition status (intact, deforested, partially deforested, fragmented/managed)

Legend to forest condition map

Class	Potential Vegetation	Current Vegetation
Intact		
1	woodlands	woodlands
2	open forests	open forests
3	closed forests	closed forests
Deforested		
4	woodlands	nonforest
5	open forests	nonforest
6	closed forests	nonforest
Partially deforested		
7	open forests	woodlands
8	closed forests	woodlands
9	closed forests	open forests
Fragmanted/managed		
12	woodlands	woodlands
13	open forests	open forests
14	closed forests	closed forests

6. Current land use intensity

Opportunities for restoration of degraded lands were assessed by creating a map of land use intensity (human pressure) which in turn was used to classify degraded lands by suitability for different types of restoration.

Several, separately mapped land-use classes, were combined to make the land use intensity map.

1. Urban areas were mapped by aggregating the built-up class from Vmap-0 (NIMA, 1997), the "artificial surfaces and associated areas" class from GLC 2000 (Bartholomé, Belward, 2005), and areas with a population density above 1000 persons/km according to the LandScan 2005 Global Population Database (developed by Oak Ridge National Laboratory).

2. Areas with dense rural population were mapped as having a population density above 100 person/km according to the LandScan 2005 Global Population Database.

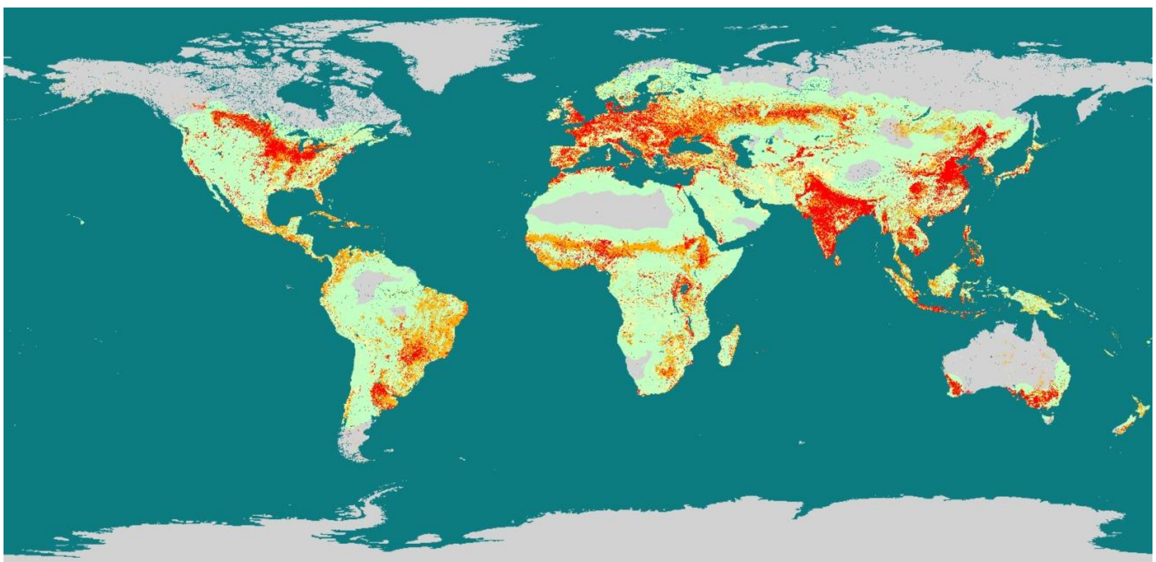
3. Cropland areas were mapped according to the SDSU global cropland dataset (Pittman et al., 2010).

4. Mosaics of croplands and cultivated areas were mapped according to the GLC 2000 dataset (aggregation of "Cultivated and managed areas", "Mosaic: Cropland / Tree Cover / Other Natural Vegetation", and "Mosaic: Cropland / Shrub and/or Herbaceous cover" classes). This class shows mosaic cultivation areas outside main croplands mapped as class 3.

5. Other intensively used areas were mapped using the Human Footprint Dataset (Sanderson et al., 2002) with a threshold index value of 28. This class mostly includes pastures, scattered croplands, and developed areas with moderate population density, other than those mapped as classes 1-4. The threshold index value was chosen after visual examination of the overlap between the Human Footprint Dataset index map and the MODIS spectral bands composite to identify intensively used lands that were not picked up by other datasets used.

6. Unpopulated lands. Mean population density within a floating window with a 500km radius was calculated based on the LandScan 2005 Global Population Database. This map was used to identify areas with population density below 1 person per square km, which were subsequently mapped as unpopulated lands.

7. Remaining lands. These are areas without signs of intensive land use and with moderate population density (above 1 person per square km).



Land-use intensity map

Legend to land-use intensity map

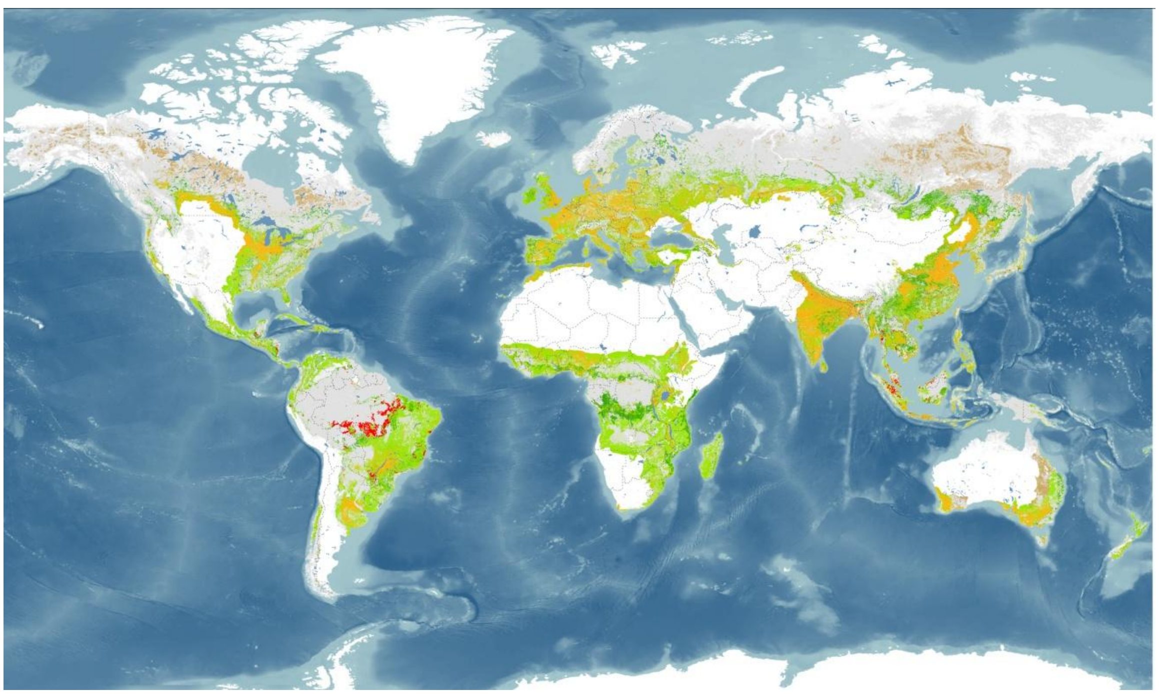
Class	Land-use type
Intensive	
1	Urban
2	Dense rural
3	Croplands
Mosaic	
4	Other cultivation
5	Other footprint
Not intensive	
6	Unpopulated
7	Other

7. Aggregated areas with forest restoration potential

A sequence of steps was used to map areas with opportunities for forest and landscape restoration.

All areas with lost or degraded tree cover were initially classified as providing restoration opportunities. These areas were then divided into three categories based on potential forest cover density: dense forests, open forests and woodlands. Each of these categories was then subdivided with regard to land-use intensity as shown in the table below.

	Land-use intensity			
Potential vegetation	**High**	**Medium**	**Low**	**Minimal**
Woodlands	1	4	7	10
Open forest	2	5	8	11
Closed forest	3	6	9	12



Restoration opportunity types (recent deforestation shown in red)

Legend to the restoration opportunity map

Wide scale			Remote	
Mosaic			Croplands	

Croplands, i.e. former forest lands which have been converted to croplands, are not considered as providing restoration opportunities.

8. Carbon assessment

The carbon assessment mapped the difference between a current and a potential carbon stocking (the floor and the ceiling)

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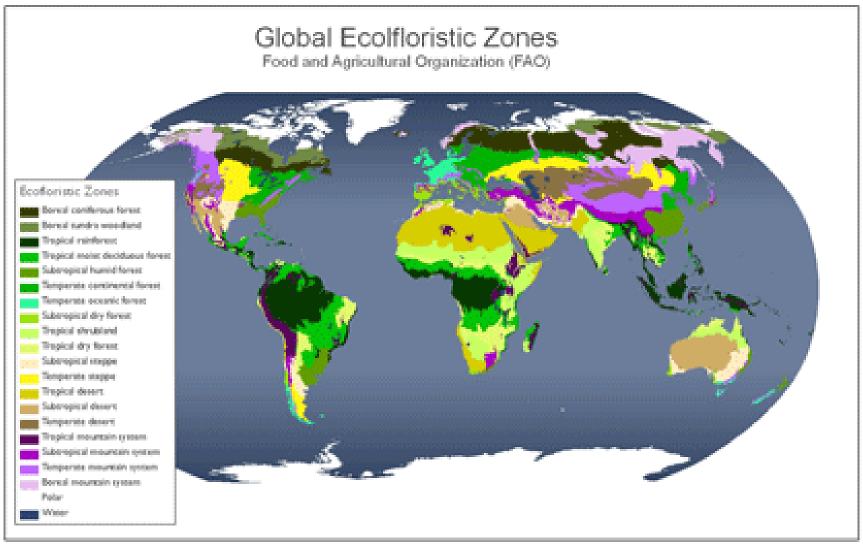
To define our “ceiling”, we used the polygon dataset of global ecofloristic zones created by FAO (and referenced in Ruesch and Gibbs). These ecoregions are characterized by temperature (tropical, subtropical, temperate, boreal, and polar), vegetation type, and continental region.



We gave default IPCC carbon values to each of these ecofloristic zones. These carbon values are available in the global biomass carbon look up tables in Ruesch and Gibbs. The tables have carbon values for broad vegetation classes stratified by ecoregions, continent, vegetation age (frontier vs. non-frontier), based on IPCC guidelines for estimating national level carbon stocks.

We used carbon values from the tables for Broadleaf Forest Classes, Needleleaf Forest Classes, and Mixed Forest classes from the GLC 2000. We used broadleaf forest carbon values for ecofloristic zones in tropical and subtropical regions, needleleaf forest carbon values for boreal and polar regions, and mixed forest values for most temperate regions. A number of temperate regions were given carbon values for broadleaf or needleleaf forests where verified by GLC 2000 landcover.

Thus each ecofloristic zone had an estimated default carbon stock value based on IPCC methods for aboveground biomass.

We converted this polygon dataset to a 1 km resolution raster dataset. The raster value for each pixel is given in t/ha *100.

We then subtracted the Ruesch and Gibbs 1 km resolution 2000 carbon stock dataset, representing the "floor". This resulted in our "carbon differential" dataset which shows the difference between the potential aboveground carbon stocks and the "current" (2000) carbon stocks at 1 km resolution.

This global dataset was clipped to the extent of our Forest Landscape Restoration Opportunities dataset which only shows opportunity lands in the four restoration classes: (1) wide scale, (2) mosaic, (3) remote, and (4) agricultural lands.

The carbon differential dataset we provided is only on the lands identified as having opportunities for restoration. We then added this carbon differential dataset to a reclassified Forest Landscape Restoration where the new class values were 1,000,000; 2,000,000; 3,000,000; and 4,000,000. This resulted in a 1 km raster dataset with values that indicated both the type of restoration opportunity available on that pixel along with the maximum carbon value that could be reached if such forest restoration were to take place. Thus, the first digit of the raster value indicates the restoration type (1,2,3, or 4) while last 5 digits of the raster value indicate the maximum carbon that can potentially be restored to the landscape.

The dataset itself contains the following attribute fields:
VALUE : The first digit indicates the restoration code, the final five digits constitute the carbon value
R_CODE : Restoration type identifier: 1 = Wide-scale, 2 = Mosaic, 3 = Remote, 4 = Agricultural
R_TYPE : The name of restoration type corresponding to the restoration code
CARBON: The difference between the carbon ceiling and floor, in t/ha * 100

As a result of converting the polygon ecofloristic zone dataset to fairly coarse 1 km raster dataset, a number of pixels received incorrect carbon values. This occurred exclusively along ecofloristic zone boundaries. Thus when calculating our carbon differential dataset, about 15,000 out of 44 million pixels had negative carbon values. In other words, our "ceiling" dataset was actually lower than our "floor" dataset in those few areas. In the interest of time, these negative pixels were reclassified to zero.

There may be a better solution to this issue. One option would be to adjust the "floor" dataset with regard to whether the land is deforested or degraded. Alternatively, since WCMC already has the ForestStatus dataset, the same adjustment could perhaps be built directly into the carbon calculator query.

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