Policy Briefs 1

Distribution of Terrestrial Carbon Across Developing Countries

Forest and Non-Forest; Vegetation and Soil

Discussion Draft June 2009

The Terrestrial Carbon Group Project

Avoiding dangerous climate change requires tackling the emissions and harnessing the sequestration potential of terrestrial carbon. And to be effective, this needs to be done at scale. In this Policy Brief we analyse the volumes of what we term "volatile" terrestrial carbon across land types (forest and non-forest), carbon pools (vegetation and soil), regions, and country circumstances. For the resulting forest carbon volumes we also make some simple and transparent assumptions to calculate possible emissions of forest carbon over the next 40 years under various scenarios (none of which are predictions). We conclude that in respect of forest carbon, the international climate change response must encompass both vegetation and soil carbon pools. Further, it needs to be flexible enough to incentivise countries with a variety of forest circumstances and histories. Finally, although the carbon richness of forests and their current rate of decline mean that tackling emissions from deforestation and forest degradation is of paramount importance, it is only part of the story: the volumes of carbon in both the vegetation and soil of non-forested land implies that the international climate change response must encompass all sources and all sinks of terrestrial carbon, not just forests.

1 The Critical Role of Terrestrial Carbon

Avoiding dangerous climate change requires a multifaceted response. Terrestrial carbon (carbon that is stored in the terrestrial system including in trees, soil and peat) is a critical element of this. The emission of terrestrial carbon from human land use (including forestry) is currently the second largest source of human-caused greenhouse gas emissions, contributing approximately 20% globally. Furthe, reduced emissions and increased sequestration of terrestrial carbon in forestry and agriculture represents a third of the overall abatement potential to 2030 (and a half to 2020) according to McKinsey's Cost Curve v2.[1]

This critical element is currently untapped. However, it is expected that governments will agree in Copenhagen in December 2009 to include incentives to better manage some range of terrestrial carbon in developing countries for the purposes of climate change mitigation and adaptation.

[1] Pathways to a Low Carbon Economy: Version 2 of the Greenhouse Gas Abatement Cost Curve, McKinsey & Company 2009.

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The objective of the Terrestrial Carbon Group is for terrestrial carbon (including trees, soil, and peat) to be effectively included in the international response to climate change.

The Terrestrial Carbon Group Project is publishing a series of Policy Briefs to inform the United Nations negotiations on how to include terrestrial carbon in developing nations in the overall climate change solution. We welcome your comments.

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This Policy Brief is intended to inform the United Nations negotiations by illustrating how much terrestrial carbon there is and where it is: by carbon pool (by vegetation[2] and soil[3]) and land type (identifying forested and non-forested land[4]) across non-Annex-I countries, on the understanding that these countries might be eligible for incentives to reduce their emissions under the new climate change agreement. This information is of paramount importance when considering possible future business as usual emissions, and the incentive mechanisms to reduce these.

Section 2 presents the results of our analysis for forest carbon (vegetation and soil). We show the volume and distribution of carbon in forested land, across carbon pools and regions. We make certain simple and transparent assumptions to calculate possible emissions of forest carbon over the next 40 years under various scenarios. (Importantly, we do not predict future emissions in this analysis.) And we calculate the cost of avoiding these emissions at different carbon prices (importantly, this analysis assumes that the given carbon prices would be adequate to incentivise changed behaviour across all agents undertaking deforestation, and is therefore not a prediction[5]). We then draw out the implications of the results for policy choices. Section 3 presents the results of our analysis for carbon in non-forested land, again across carbon pools and regions, and goes on to consider the total volume of terrestrial carbon across all land types and carbon pools.

Please note, unless otherwise specified, all of the figures reported below relate to terrestrial carbon in the 139 non-Annex-I countries analysed (see Appendix II for a list of these countries). As we believe that these 139 countries account for the vast majority of the total terrestrial carbon volumes across all 150 non-Annex-I countries, for simplicity we talk in this Policy Brief of the carbon in non-Annex-I countries.[6]

2 Forest Carbon

2.1 Total Forest Carbon Volumes

- Globally, forests cover only 7% of earth's surface, but they represent the most significant store of terrestrial carbon
- At 538 GtC, forest carbon stored in non-Annex-I countries equates to approximately 40 years of annual anthropogenic GHG emissions at 2004 rates

[2] Carbon data from Ruesch, A.S. and H.K. Gibbs 2008. New IPCC Tier-1 global biomass carbon map for the year 2000. Carbon Dioxide Information Analysis Center. Vegetation encompasses both above and below ground biomass.

[3] Soil data from Global Soil Data Task Group (2000). Global gridded surfaces of selected soil characteristics, International Geosphere-Biosphere Programme -- Data and Information System (IGBP-DIS). Data set available on-line [http://www.daac.ornl.gov]. Soil carbon is estimated to a depth of 1 metre, and therefore we potentially underestimates soil carbon in peatland areas.

[4] The classification into forest and non-forest carbon is based on the UNEP-WCMC 2000 Global Distribution of Current Forests.

[5] For our own assessment of likely emissions and costs of avoidance, please see Terrestrial Carbon Group Project Policy Brief Number 3 "Estimating Tropical Forest Carbon at Risk of Emission from Deforestation Globally: Applying the Terrestrial Carbon Group Reference Emission Level Methodology" (available at www.terrestrialcarbon.org).

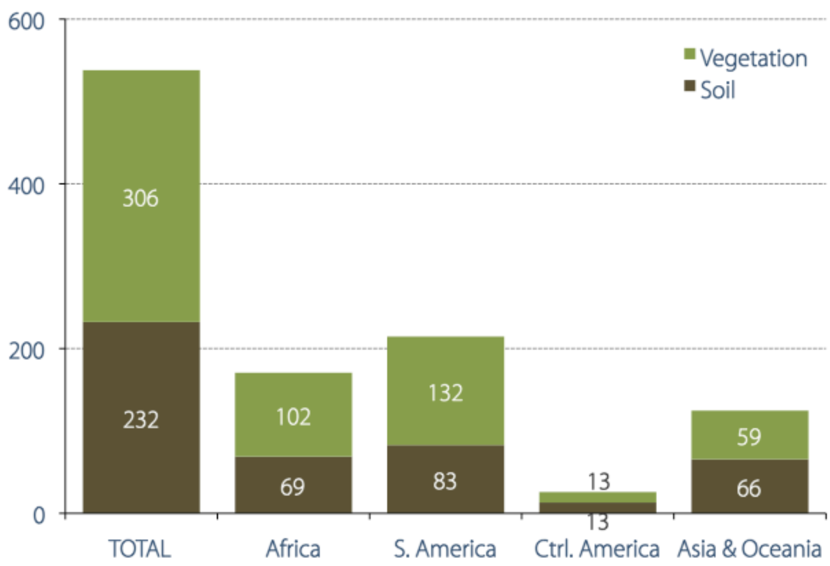
[6] In total, there are 150 non-Annex-I countries. However, terrestrial carbon data was not available for 11 of these: Cape Verde, Cook Islands, Kiribati, Maldives, Marshall Islands, Mauritius, Micronesia, Nauru, Niue, Seychelles and Tuvalu. As these are small island nations, the impact on our total terrestrial carbon estimates in non-Annex-I countries is expected to be small.

- South American forests store the greatest volume of forest carbon, but the forests of all three major regions (South and Central America, Africa, and Asia & Oceania) are significant stores
- There is more to forest carbon than vegetation: in total, forest soils hold nearly as much carbon as does forest vegetation
- Forests in Asia & Oceania hold greater volumes of carbon in their soil than their vegetation, while for African and South American forests the opposite is true; forests in Central America hold equal volumes of each

As noted in the Eliasch Review[7], in total, forests currently cover about 30% of the earth's land surface (or 7% of the total surface) but due to their carbon richness they represent the most significant terrestrial carbon store.

We estimate that the forests in the non-Annex I countries included in this analysis (see Appendix II) contain 538 Gt of carbon (Figure 1). This equates to 71% of carbon in the atmosphere[8] or, expressed differently, 40 years of annual anthropogenic greenhouse gas emissions at 2004 rates.[9]

Figure 1. Total forest carbon in non-Annex-I countries by region (Gt C)



Forests in all three major regions hold substantial quantities of carbon, although South American forests store the greatest volume with nearly twice as much as Asian & Oceanian forests and one-third more than African forests.

By carbon pool, 57% of total forest carbon in non-Annex-I countries is in the vegetation and 43% in the soil, supporting the argument that there is more to forest carbon than vegetation.

Again, there is some difference by continent: Asian & Oceanian forests hold greater volumes of carbon in their soil than vegetation, while for African and South American forests the opposite is true. Central American forests hold equal volumes of both.

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7 Eliasch Review of the UK Government: 'Climate Change, Financing Global Forests', 2008.

8 Based on estimates of atmospheric carbon of 762 GtC (IPCC, 2007, WG1). (597GtC from pre-industrial levels plus 165 GtC of 'anthropogenic' impact.)

9 Based on total anthropogenic greenhouse gas emissions in 2004 of 49GtCO_2e, as presented in the Eliasch Review, and taken from the IPCC (2007), AR4 Synthesis Report. This equates to approximately 13.4GtC.

2.2 Emissions from Deforestation under Certain Scenarios, and Calculated Costs of Avoidance

- If all forested land in non-Annex-I countries were deforested, 363 Gt of carbon would be emitted: 169 GtC from South and Central American forests, 119 GtC from African forests, and 75 GtC from Asian & Oceanian forests
- If the annual area of deforestation remained constant over the next 40 years at the current rate of approximately 12.5m ha, approximately 24% of the current standing forest would be lost by 2050, with associated average annual emissions of 2.2GtC (500m ha and 88 GtC in total over the 40 years)
- With a flat payment per tC, the total avoided deforestation incentive payment for this would be $22bn at $10/tC to $66bn at $30/tC

Land use change affects terrestrial carbon stocks and associated emissions in two ways that can be characterised in terms of "rate" and "scale". In our analysis we reflect this via a two-step process:

- Rate of emission: We assume that 100% of carbon in forest vegetation and 25%[10] of carbon in forest soil is emitted in the event of deforestation (we do not consider degradation). Applying only these percentage assumptions enables us to estimate maximum emittable forest carbon volumes. In the remainder of this Policy Brief we refer to these volumes as "volatile carbon".
- Scale of emission: We assume varying proportions of this volatile carbon might actually be emitted due to land use change. This results in estimates of possible forest carbon emission scenarios.[11]

Lastly, by assuming a constant and common carbon price incentive for avoided deforestation we calculate the associated cost of avoiding these possible forest carbon emissions.[12]

Under these assumptions, total volatile carbon in the forested land of non-Annex-I countries is 363 GtC: 169 Gt in South and Central American forests, 119 Gt in African forests, and 75 Gt in Asian & Oceanian forests (Figure 2).

In reality, even taking into account the projected increases in population and demand for food, fibre and fuel, due to a combination of biophysical, economic and legal factors, it is highly unlikely that all forested land will be deforested.

There is currently no commonly accepted forecast for national, regional, or global deforestation. A variety of models and studies have produced contradictory results in terms of whether global deforestation might be expected to increase, remain stable or decline[13]. For a description and analysis of some of these models

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[10] Current literature shows there is uncertainty over the proportion of soil carbon that is released during land use change. Conversion from forest land to cropland is believed to cause significant loss of soil carbon, whereas conversion from forest land to grassland does not. Estimates of the proportion of soil carbon emitted in the event of deforestation range from approximately 25% (in the 2002 meta-analysis by Guo and Gifford, the OSIRIS model, and the McKinsey cost curve 2.2) up to 40% (in IIASA's G4M model).

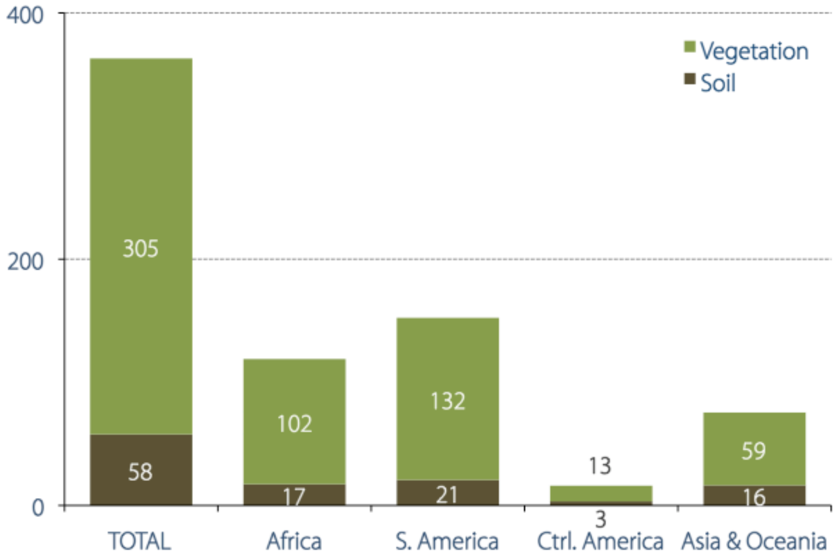
[11] For this scenario element of the analysis we have not specified in which countries emissions will occur, and therefore we use the average carbon density across all countries to estimate possible emissions.

[12] This analysis assumes that the given carbon prices would be adequate to incentivise changed behaviour across all agents undertaking deforestation. It is not a prediction.

[13] For example, McKinsey's projections of business as usual emissions assume a nearly constant deforestation area annually, with a total decline of just approximately 3% per annum by 2030 ('Pathways to a Low Carbon Economy: Version 2 of the

and studies, please see Terrestrial Carbon Group Project Policy Brief Number 2 "Tools for Setting Reference Emission Levels: A review of existing tools that can be used to set a benchmark for rewarding reduced emissions and increased sequestration of greenhouse gasses in the terrestrial system" (available at www.terrestrialcarbon.org).

Figure 2. Volatile forest carbon in non-Annex-I countries by region (Gt C)



The purpose of this analysis is not to predict future emissions from deforestation. Rather, it is intended to provide some boundaries to the debate by showing possible emissions under certain scenarios. For our own assessment of likely emissions and costs of avoidance, please see Terrestrial Carbon Group Project Policy Brief Number 3 "Estimating Tropical Forest Carbon at Risk of Emission from Deforestation Globally: Applying the Terrestrial Carbon Group Reference Emission Level Methodology" (available at www.terrestrialcarbon.org).

To guide the selection of appropriate boundaries for possible emissions rates over the 40 years to 2050, we present a number of possible scenarios.

First, we ran two constant deforestation scenarios. For both of these scenarios, we used FAO data on total forest area and net deforestation area by country[14] (ie, deforestation net of afforestation and reforestation). Our aim was to estimate emissions from deforestation, without netting off afforestation / sequestration potential, because our analysis is focussed on estimating emissions of existing carbon volumes. Therefore, we took into account the net deforestation areas of only those countries with more deforestation than total afforestation and reforestation. We excluded the net increases in forest area of the 29 nations with net afforestation / reforestation (of which China accounts for approximately 88% or approximately 4m hectares per annum). Even in a constant deforestation scenario, this underestimates volumes of possible gross emissions from deforestation in two ways: (i) it excludes the deforestation occurring in countries that are net afforesters / reforesters, and (ii) it includes (and nets off) the afforestation and reforestation of countries that are net deforesters.

With all that in mind, for the first scenario we assumed that the gross deforestation area remains constant at approximately 12.5m ha each year over the period 2010 to 2050. For the second we assumed that the gross

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Global Greenhouse Gas Abatement Cost Curve', 2009, McKinsey & Company). As referenced in the Eliasch Review (2009), Houghton's projections estimate forest emissions around 2.2 GtC in 2000, declining over time to around 0.6 GtC in 2100. In contrast, the IPCC SRES A2 projections using the IMAGE model estimate emissions at around 1.1 GtC in 2000, increasing from around 2050 and reaching around 2.7 GtC in 2100.

[14] Total forest area (2005) and net deforestation area (2000-2005) were taken from the Forest Resource Assessment (2006). Although neither of these variables is free from criticism, this is the standard source.

deforestation rate as a percentage of total forest area at the start of each year remains constant at 0.59% per annum for the period 2010 to 2050 (so areas of deforestation per year fall slightly as the forest base declines).

Under the first scenario of constant area, 24% of the standing forest in 2010 will be deforested by 2050, with associated average annual emissions of 2.2GtC. The total avoided deforestation incentive payment for this would be $22bn at $10/tC to $66bn at $30/tC (Figure 3).

Under the second scenario of constant deforestation rates, approximately 21% of the standing forest in 2010 will be deforested by 2050, with associated average annual emissions of 1.9GtC The total avoided deforestation incentive payment for this would be $19bn at $10/tC to $57bn at $30/tC.

Figure 3. Estimates of possible future emissions from deforestation in non-Annex-I countries and associated avoided deforestation costs

		Forest carbon emissions p.a.			at	Cost of avoided emissions p.a.		
		Vegetation	Soil	Total		At $10/tC	At $20/tC	At $30/tC
		Gt C	Gt C	Gt C		bn $	bn $	bn $
Forest deforested over next 40 years	50%	3.8	0.7	4.5		45.5	90.9	136.4
	30%	2.3	0.4	2.7		27.3	54.6	81.8
	24%	1.8	0.3	2.2		21.8	43.6	65.5
	21%	1.6	0.3	1.9		19.1	38.2	57.3
	15%	1.1	0.2	1.4		13.6	27.3	40.9

(Importantly, this analysis assumes that the given carbon prices would be adequate to incentivise changed behaviour across all agents undertaking deforestation, and is therefore not a prediction.[15])

For illustration purposes, we have also estimated the impact of a number of alternative emissions scenarios in Figure 3. As noted above, there is no commonly accepted global deforestation projection. The three models of global land use and management (namely the Global Forest Model – formerly the Dynamic Integrated Model of Forestry and Alternative Land Use, the Generalized Comprehensive Mitigation Assessment Process Model, and the Global Timber Model) estimate average annual deforestation areas across non-Annex-I countries between 2005 and 2030 of between 10.6m ha and 12.2m ha per annum[16]. We calculate that this equates to a loss of between 13% and 15% of the standing forest in 2005 over this 25-year period.

It should also be noted that none of these estimates or scenarios incorporate forest degradation, which increase total emissions levels from the forests.[17]

[15] For our own assessment of likely emissions and costs of avoidance, please see Terrestrial Carbon Group Project Policy Brief Number 3 "Estimating Tropical Forest Carbon at Risk of Emission from Deforestation Globally: Applying the Terrestrial Carbon Group Reference Emission Level Methodology" (available at www.terrestrialcarbon.org).

[16] Global Cost Estimate of Reducing Carbon Emissions Through Avoided Deforestation, Kindermann et al, 2008, PNAS.

[17] Although it should be noted that degradation results in different emissions rates from vegetation and soil than does deforestation, so the calculation to estimate volatile carbon would need to be adjusted to fully incorporate degradation.

Based on our analysis, if 30% of volatile carbon were emitted by 2050, then average emissions per year would be 2.7 GtC, with a total associated avoided emission incentive payment of $27bn at $10/tC to $82bn at $30/tC. If 50% of volatile carbon were emitted by 2050, then average emissions per year would rise to 4.5GtC and associated avoided emission incentive payments would be $46bn at $10/tC and $136bn at $30/tC.

2.3 Implications for Policy Choices

- Just ten countries account for two thirds of volatile forest carbon
- These countries represent a range of forest circumstance (in terms of forest cover and recent deforestation history)
- If incentives schemes for REDD effectively exclude historically low deforesters, then 85Gt of volatile carbon in low deforesting countries will be outside of the REDD system

As noted above, there is currently no commonly accepted forecast for national, regional, or global deforestation. However, even if, for the sake of argument, we assume that global deforestation remains constant or even declines, the complexity of deforestation trends in different countries means that a reliance on global averages masks important implications for the design of a REDD mechanism.

Many countries are at different stages of economic development, and are facing their own particular circumstances and pressures for land use change. As one country is exhausting the limits of forest resources, another country may be only beginning to harness the potential of its forests. Therefore, even assuming stable levels of global deforestation, the "migratory" potential of deforestation in this context means that analysis of carbon volumes and potential emissions needs to take into account all countries individually, regardless of recent or current national deforestation. In a similar vein, studies have shown that international leakage is a real threat[18] and therefore excluding some nations from a REDD mechanism would seriously undermine the effectiveness and efficiency of the mechanism.

Therefore, it is necessary not just to consider carbon volumes in aggregate, but also on a disaggregated basis to both understand where the future limits and future potential for deforestation may lie, and by extension to gain some insight into the implications of different proposals for the structure of a future REDD mechanism.

[18] Including 'Reduced Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report' (2009), Angelsen, Brown, Loisel, Peskett, Streck, Zarin. Prepared for The Government of Norway by The Meridian Institute. See Ch 3. Findings in respect of international leakage based on the OSIRIS model: Busch, J., B. Strassburg, A. Cattaneo, R. Lubowski, F. Boltz, R. Ashton, A. Bruner, D. Rice, (2009). Open Source Impacts of REDD Incentives Spreadsheet (OSIRIS v2.3). Collaborative Modeling Initiative on REDD Economics (April 2009).

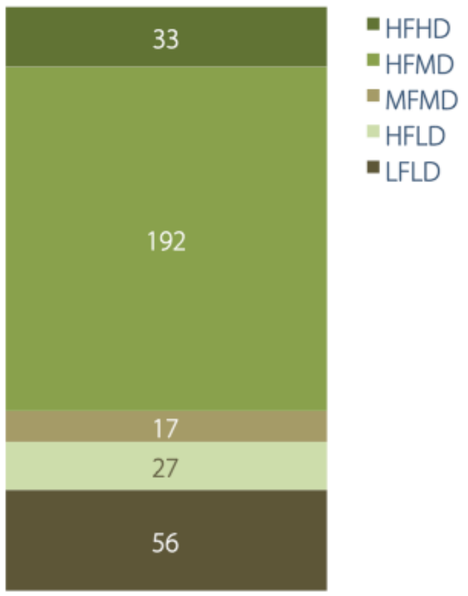
For the analysis below we utilise the country classifications derived by The Nature Conservancy[19] which identified five main groupings of 55 non-Annex-I country forest nations based on their level of forest cover and their deforestation history (average deforestation rate between 1990 and 2005):[20]

- High forest, high deforestation (HFHD)
- High forest, medium (HFMD)
- High forest, low deforestation (HFLD)
- Medium forest, medium deforestation (MFMD), and,
- Low forest, low deforestation (LFLD).

Information on the derivation of these groupings and the resulting individual country classifications is given in Appendix I.

The total number of countries classified in this schematic is 55, not the full 139 we analyse in this Policy Brief. However, in terms of volumes of volatile carbon captured, these 55 countries account for 90% of volatile forest carbon (91% of the volatile carbon in vegetation and 84% of that in soil). That is, 330 Gt of volatile forest carbon in non-Annex-I countries. Figure 4 illustrates the breakdown of these volumes by TNC grouping.

Figure 4. Volatile forest carbon in non-Annex-I countries by classification type (GtC)



10%, or 33 Gt, of volatile forest carbon is in countries classified as "high forest, high deforestation", the majority of which is in Indonesia. This would be captured by a REDD mechanism that set reference emission levels using purely historical emissions rates.

A further 5%, or 17 Gt, of volatile forest carbon is in countries classified as "medium forest, medium deforestation", including Cameroon, Liberia and Paraguay. This also would likely be captured by a REDD mechanism that set reference emission levels using purely historical emissions rates.

17%, or 56 Gt, is in countries classified as having 'low forest' cover. It is debateable how much of this volatile carbon might be at risk of emission. It could be argued that these low forest countries may be at or near the "trough" of the so-called forest transition curve. For the

[19] B Griscom, B., Shoch, D., Stanley, B., Cortez, R., Virgilio, N. Implications of methods for establishing baseline forest carbon emissions levels for different non-Annex-I country circumstances during an initial performance period. Submitted to Journal of Environmental Science and Policy, March, 2009. Based on this cluster analysis, countries are classified according to their deforestation rates and amount of remaining forest as a proportion of their original forest area.

[20] Both of these variables are in relation to original forest cover.

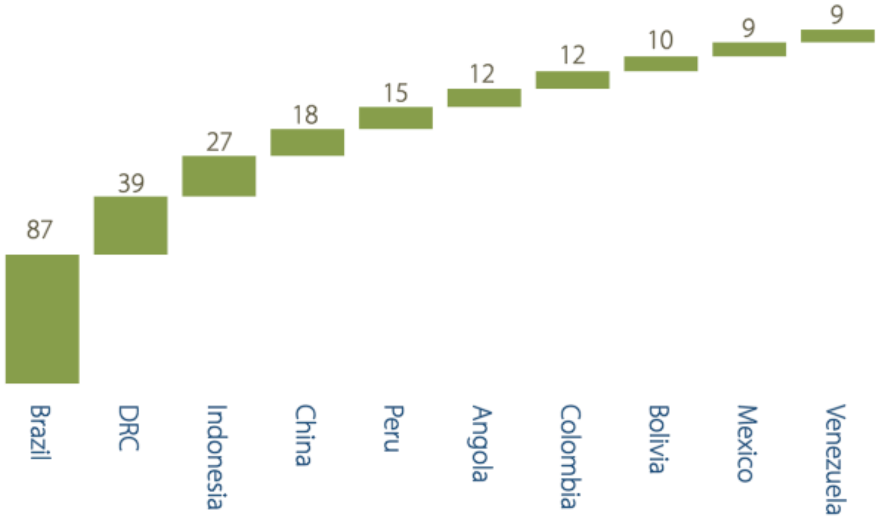
purpose of this analysis, we take a conservative approach. Although it is worth noting that The Nature Conservancy's threshold for this category is a 35% forest cover, which might be considered well above the "trough", we assume that none of this volatile carbon in these low forest countries is at risk of emission.

This leaves 66%, or 219 Gt, of volatile forest carbon. 27 Gt is in countries classified as "high forest, low deforestation" and 192 Gt in countries classified as "high forest, medium deforestation", including Brazil and the Democratic Republic of the Congo. As the range of deforestation rates in the "high forest, medium deforestation" category is wide, ranging down to 0.04%, we estimate that 85 Gt of this 219 Gt of volatile carbon is in countries which could be described as historically low deforesters based on recent deforestation rates. This includes Belize, Gabon, Guyana, Peru, and Suriname in the "high forest, low deforestation" category (26 GtC in total), and Colombia (12 Gt), the Congo (6 Gt), the Democratic Republic of the Congo (39 Gt) and Panama in the "high forest, medium deforestation" category.[21]

As noted above, international leakage is a real threat and would undermine the effectiveness of the REDD mechanism. If REDD only incentivises a subsection of forest nations, and/or if some of those countries that are currently high deforesters run out of forest shortly, it is plausible that the equivalent deforestation and emissions may move to countries with currently low rates of deforestation. For example, on a very simplistic analysis in which Indonesia (the second greatest deforester by area in 2000-2005 after Brazil) continues to deforest a constant area per annum as they have over the period 2000 to 2005, they would hit a 15% land cover threshold in 2038, and run out of forest in 2053.

Therefore, forward looking reference emissions levels could be set which take account of future deforestation pressures and constraints. Alternatively, if reference emission levels are to be set based only on historical emissions rates, complementary "stabilisation funds" will be required to incentivise the avoided emission of up to 85Gt of volatile carbon in historically low deforesting countries (that is arguably most at risk of emission over the medium to long run).

Figure 5. Non-Annex-I countries with the highest volume of volatile forest carbon (GtC)



Top 10 represent 66%

[21] In their paper, The Nature Conservancy describe the HFMD category is having medium to low deforestation. For information on the boundaries of the identified categories see Appendix I.

Lastly, as is suggested in the analysis above, volatile forest carbon is highly concentrated in a relatively small number of nations (with a variety of forest profiles).

Specifically, ten countries account for 66% of this total volatile forest carbon (Figure 5). This includes historically low rate deforesters with medium or high forest cover (The Democratic Republic of the Congo, Peru and Colombia), as well as China, a net afforester / reforester today.

3 Non-Forest Carbon

- In total, non-Annex-I countries store 571 Gt of carbon in non-forested land, the vast majority in the soil rather than vegetation.
- This is marginally more carbon than is stored in forested land.
- However, due to their carbon rich vegetation (a greater proportion of which will be emitted in the event of deforestation than soil carbon), forested lands hold a greater volume of *volatile* carbon than do non-forested lands
- South and Central America contains the greatest volume of volatile carbon, the majority in forested lands. Africa and Asia & Oceania both also contain large volumes of volatile carbon, but notably, more in non-forest than forest land
- Just ten countries account for nearly half of volatile non-forest carbon, which is less concentrated than the distribution of voilatile forest carbon (where the top ten countries account for two-thirds)

Forests are undoubtedly an important source and sink for carbon emissions. However, there is more to terrestrial carbon than forests. Other land types also can and do house considerable volumes of carbon. We estimate that there is more carbon stored in non-forested land than forested land in non-Annex-I countries, at 571 GtC and 538 GtC respectively (1,109 GtC in total). This compares to Houghton's worldwide (Annex-I and non-Annex-I) estimate of 2,050 Gt of terrestrial carbon.[22]

While forest carbon is split more evenly between vegetation and soil, non-forest carbon is predominantly stored in the soil (Figure 6). This makes a significant difference when considering the proportion of total carbon volumes that are volatile in non-forest versus forest land.

[22] Balancing the Global Carbon Budget, Houghton, 2007.

Figure 6. Total terrestrial carbon in non-Annex-I countries (GtC)

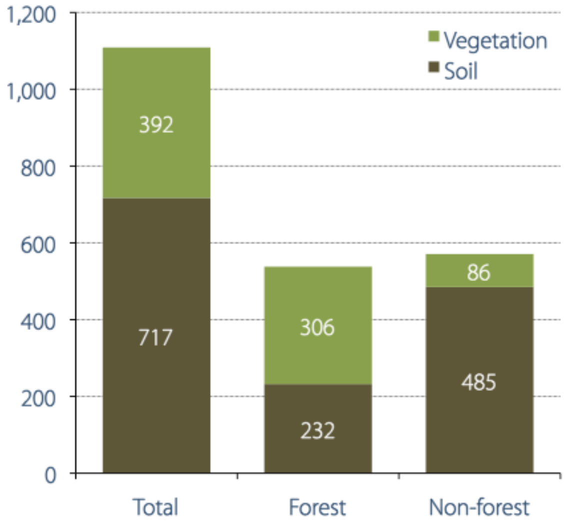
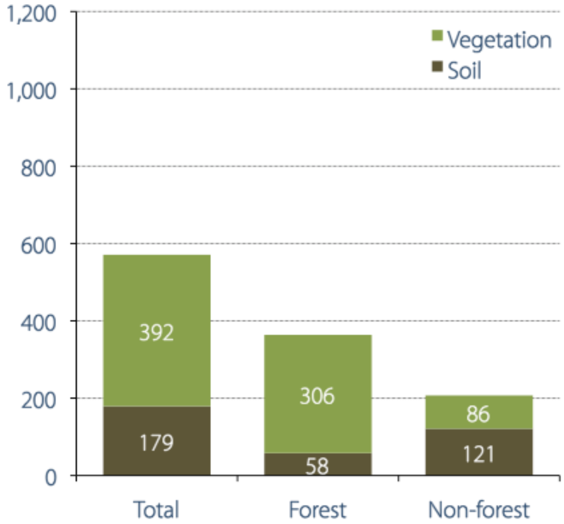


Figure 7. Total volatile terrestrial carbon in non-Annex-I countries (GtC)

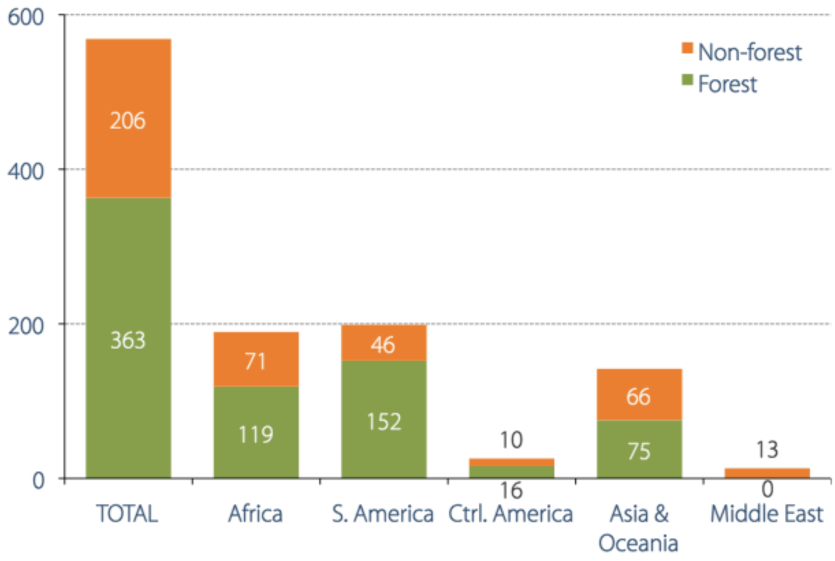


Applying the percentage rate assumptions we applied to forest land equally to non-forested land (ie, assuming that 100% of carbon stored in vegetation and 25% of carbon stored in the soil would be emitted in the event of land use change) we arrive at an estimate of 206 Gt of volatile carbon in non-forested land of non-Annex-I countries. This compares to 363 GtC in forest land in these countries. This is due to the relatively carbon rich content of the forest vegetation.

South & Central America, Africa and Asia & Oceania all store significant quantities of volatile carbon: South & Central America contains the highest volume at 224 GtC, the majority in forest lands. Africa and Asia & Oceania both also contain large volumes (with 190 Gt and 141 Gt respectively), but notably, with larger proportions in non-forest land (Figure 8). In the case of Asia, this may reflect the relatively high deforestation that has occurred there to date.

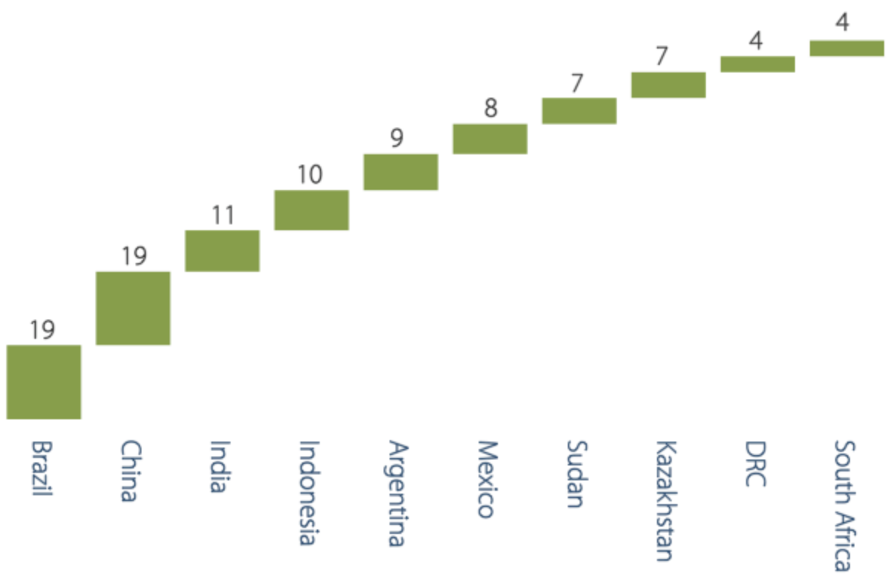
Based on these regional profiles, a REDD system that is restricted to avoided emissions of forest land is comparatively better for South and Central America than for Africa and Asia & Oceania, and vice versa. (Although the benefit distribution will change again if sequestration is taken into account.)

Figure 8. Volatile terrestrial carbon in non-Annex-I countries, by region (GtC)



As in the case of volatile forest carbon volumes, the majority of volatile carbon in non-forested land is concentrated in a limited number of countries. Just ten countries account for 48% of volatile carbon in non-forested land (Figure 9). This is slightly less concentrated than the distribution of volatile carbon in forested land, where ten countries account for 66% of those volumes (Figure 5).

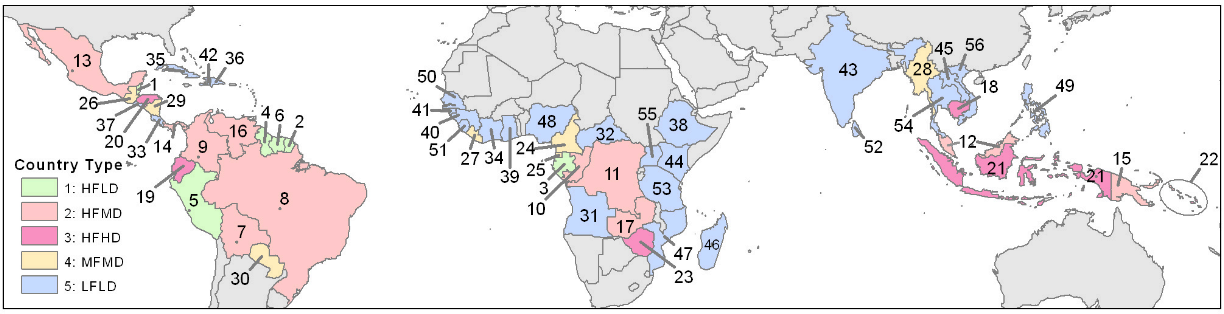
Figure 9. Non-Annex-I countries with the highest volume of volatile non-forest carbon (GtC)



Top 10 represent 48%

Finally, five of the countries in the top ten for volatile carbon in non-forested lands do not appear in the equivalent top ten of volatile carbon on forested lands. These countries are India, Argentina, Sudan, Kazakhstan, and South Africa.

Appendix I: TNC Country Classification



Type 1: HFLD
1 - Belize
2 - French Guiana
3 - Gabon
4 - Guyana
5 - Peru
6 - Suriname

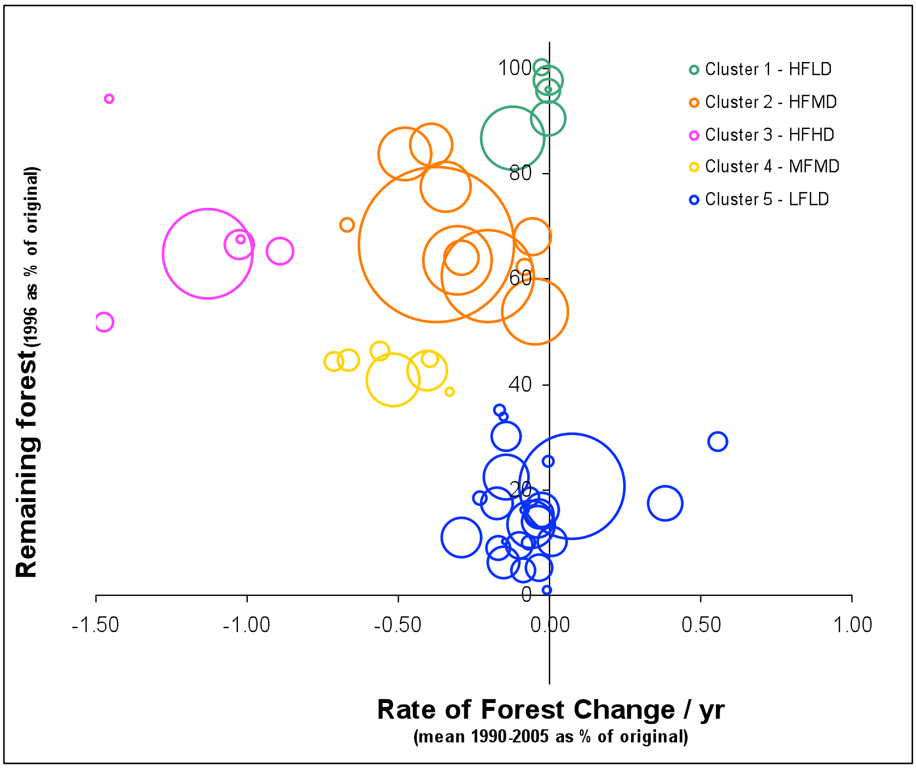
Type 2: HFMD
7 - Bolivia
8 - Brazil
9 - Colombia
10 - Congo
11 - Congo, DRC
12 - Malaysia
13 - Mexico
14 - Panama
15 - Papua New Guinea
16 - Venezuela
17 - Zambia

Type 3: HFHD
18 - Cambodia
19 - Ecuador
20 - Honduras
21 - Indonesia
22 - Solomon Is.
23 - Zimbabwe

Type 4: MFMD
24 - Cameroon
25 - Equatorial Guinea
26 - Guatemala
27 - Liberia
28 - Myanmar
29 - Nicaragua
30 - Paraguay

Type 5: LFLD
31 - Angola
32 - Central African Republic
33 - Costa Rica
34 - Cote d'Ivoire
35 - Cuba
36 - Dominican Republic
37 - El Salvador
38 - Ethiopia
39 - Ghana
40 - Guinea
41 - Guinea-Bissau
42 - Haiti
43 - India
44 - Kenya
45 - Laos
46 - Madagascar
47 - Mozambique
48 - Nigeria
49 - Philippines
50 - Senegal
51 - Sierra Leone
52 - Sri Lanka
53 - Tanzania
54 - Thailand
55 - Uganda
56 - Vietnam

Key to Country Groupings in Map



Countries are colour coded by groups generated using cluster analysis, and graphed according to the two variables used in the cluster analysis. A third variable, original source of forest cover, was used to determine the size of the circle for each country. Groups are High Forest Low Deforestation, High Forest Medium Deforestation, High Forest High Deforestation, Medium Forest Medium Deforestation, and Low Forest Low Deforestation.

Source: The Nature Conservancy (2009)

Note: French Guiana is shown on TNC map and cluster diagram, but excluded from the analysis in this Policy Brief because it is part of France, an Annex-I country.

Appendix II: Estimated Volatile Terrestrial Carbon by Country by Pool

Volatile carbon is the carbon that would be emitted in the event of land use change. We assume this is 100% of carbon in vegetation, and 25% of carbon in soil.

Ranked by volatile forest carbon, then by all volatile terrestrial carbon, then by country name

(Gt C)	Forest			Non-Forest			All
Country	Vegetation	Soil	Total	Vegetation	Soil	Total	Total
Brazil	76.6	10.4	86.9	9.8	9.5	19.3	106.2
DRC	34.0	5.1	39.2	3.1	1.0	4.1	43.3
Indonesia	21.5	5.7	27.3	6.4	4.0	10.4	37.7
China	13.5	4.6	18.1	3.2	15.9	19.1	37.2
Peru	12.8	2.0	14.8	1.0	1.9	2.9	17.7
Angola	10.9	1.4	12.3	1.8	1.3	3.1	15.4
Colombia	10.2	1.6	11.8	1.9	1.8	3.7	15.5
Bolivia	8.5	1.5	10.0	1.0	1.6	2.6	12.6
Mexico	7.4	2.1	9.5	4.3	3.5	7.8	17.3
Venezuela	7.3	1.3	8.5	1.0	1.1	2.1	10.7
CAR	7.1	1.2	8.3	0.3	0.2	0.5	8.7
PNG	6.5	1.5	8.0	1.2	0.6	1.8	9.7
Zambia	6.0	1.2	7.1	1.1	1.0	2.1	9.2
Cameroon	5.8	1.0	6.8	0.4	0.3	0.7	7.5
India	4.8	1.4	6.2	4.2	6.5	10.8	16.9
Argentina	4.8	1.2	6.0	3.8	5.7	9.4	15.5
Congo	5.0	1.0	6.0	0.5	0.2	0.8	6.8
Mozambique	4.7	0.9	5.6	1.2	0.7	1.8	7.5
Gabon	4.6	0.7	5.3	0.2	0.1	0.3	5.6
Malaysia	3.8	0.8	4.5	1.1	0.6	1.6	6.2
United Republic of Tanzania	3.4	0.7	4.0	1.2	1.5	2.7	6.7
Guyana	3.3	0.5	3.8	0.1	0.1	0.1	4.0
Myanmar	2.8	0.7	3.4	1.4	1.2	2.6	6.1
Nigeria	2.9	0.4	3.3	2.0	1.3	3.3	6.6
Paraguay	2.6	0.5	3.1	0.7	0.5	1.2	4.3
Sudan	2.4	0.5	3.0	2.0	4.8	6.8	9.8
Suriname	2.3	0.4	2.7	0.0	0.0	0.1	2.7
Chile	1.5	0.9	2.4	0.8	2.1	2.9	5.2
Ecuador	1.7	0.4	2.1	0.5	0.6	1.2	3.3
Madagascar	1.7	0.4	2.1	1.5	1.2	2.7	4.7
Cote d'Ivoire	1.8	0.2	2.0	1.9	0.4	2.4	4.4
South Africa	1.3	0.4	1.7	2.2	1.9	4.1	5.8
Guinea	1.4	0.2	1.7	1.0	0.4	1.4	3.1
Philippines	1.4	0.2	1.6	1.5	0.6	2.1	3.7
Nicaragua	1.2	0.3	1.4	0.1	0.2	0.3	1.7
Zimbabwe	1.0	0.3	1.3	0.7	0.5	1.2	2.5
Thailand	1.1	0.2	1.3	1.0	1.2	2.2	3.5
Honduras	1.1	0.2	1.3	0.1	0.2	0.2	1.5
Ghana	1.1	0.1	1.3	1.3	0.3	1.6	2.8
Guatemala	0.9	0.2	1.1	0.1	0.2	0.2	1.3

(Gt C)	Forest			Non-Forest			All
Country	Vegetation	Soil	Total	Vegetation	Soil	Total	Total
Uganda	0.9	0.2	1.1	0.5	0.5	1.0	2.1
Viet Nam	0.8	0.2	1.0	0.7	0.8	1.5	2.5
Cambodia	0.8	0.2	0.9	0.3	0.3	0.6	1.5
Lao People's Democratic Republic	0.8	0.2	0.9	0.6	0.4	1.0	1.9
Liberia	0.8	0.1	0.9	0.6	0.2	0.7	1.6
Panama	0.6	0.1	0.8	0.1	0.1	0.2	1.0
Costa Rica	0.6	0.1	0.7	0.0	0.1	0.1	0.8
Nepal	0.5	0.2	0.7	0.2	0.3	0.5	1.1
Ethiopia	0.5	0.2	0.7	1.0	2.5	3.5	4.2
Kenya	0.5	0.2	0.7	0.5	1.1	1.5	2.2
Benin	0.6	0.1	0.6	0.4	0.1	0.5	1.2
Solomon Islands	0.5	0.1	0.5	0.0	0.0	0.0	0.5
Equatorial Guinea	0.4	0.1	0.5	0.1	0.0	0.1	0.6
Malawi	0.4	0.1	0.4	0.2	0.2	0.3	0.8
Guinea-Bissau	0.3	0.1	0.4	0.1	0.0	0.1	0.5
Togo	0.3	0.0	0.4	0.2	0.1	0.3	0.7
Cuba	0.3	0.1	0.4	0.1	0.3	0.4	0.7
Chad	0.3	0.0	0.4	0.8	1.9	2.7	3.0
Mongolia	0.2	0.2	0.3	0.3	3.2	3.6	3.9
Democratic People's Republic of Korea	0.1	0.2	0.3	0.0	0.1	0.2	0.5
Sri Lanka	0.2	0.1	0.3	0.1	0.1	0.2	0.5
Belize	0.2	0.1	0.3	0.0	0.0	0.0	0.3
Sierra Leone	0.2	0.0	0.3	0.5	0.2	0.7	1.0
Botswana	0.2	0.1	0.2	1.4	1.0	2.4	2.6
Republic of Korea	0.1	0.1	0.2	0.0	0.1	0.2	0.4
Georgia	0.2	0.1	0.2	0.1	0.2	0.2	0.5
Bhutan	0.2	0.1	0.2	0.1	0.1	0.1	0.4
Dominican Republic	0.2	0.0	0.2	0.1	0.1	0.2	0.4
Iran (Islamic Republic of)	0.1	0.0	0.2	0.9	2.4	3.3	3.5
Bosnia and Herzegovina	0.1	0.1	0.2	0.0	0.1	0.1	0.3
Senegal	0.1	0.0	0.2	0.3	0.3	0.6	0.8
Algeria	0.1	0.0	0.2	0.6	2.3	2.8	3.0
Uruguay	0.1	0.0	0.1	0.4	0.6	1.0	1.1
Pakistan	0.1	0.0	0.1	1.0	1.2	2.2	2.3
El Salvador	0.1	0.0	0.1	0.0	0.0	0.1	0.2
Serbia	0.0	0.1	0.1	0.0	0.2	0.3	0.4
Swaziland	0.1	0.0	0.1	0.0	0.0	0.0	0.1
Kazakhstan	0.1	0.1	0.1	0.5	6.2	6.7	6.8
Mali	0.1	0.0	0.1	0.7	1.4	2.1	2.2
Bangladesh	0.1	0.0	0.1	0.2	0.5	0.6	0.7
The former Yugoslav Republic of Macedonia	0.0	0.0	0.1	0.0	0.1	0.1	0.2
Jamaica	0.1	0.0	0.1	0.0	0.0	0.0	0.1
Burkina Faso	0.1	0.0	0.1	0.4	0.5	0.8	0.9
Morocco	0.0	0.0	0.1	0.3	0.8	1.1	1.2
Trinidad and Tobago	0.1	0.0	0.1	0.0	0.0	0.0	0.1
Burundi	0.0	0.0	0.1	0.1	0.1	0.1	0.2
Montenegro	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Timor-Leste	0.0	0.0	0.0	0.1	0.0	0.1	0.1
Rwanda	0.0	0.0	0.0	0.0	0.1	0.1	0.2

(Gt C)	Forest			Non-Forest			All
Country	Vegetation	Soil	Total	Vegetation	Soil	Total	Total
Albania	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Afghanistan	0.0	0.0	0.0	0.3	1.0	1.3	1.4
Bahamas	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Kyrgyzstan	0.0	0.0	0.0	0.1	0.5	0.5	0.6
Tunisia	0.0	0.0	0.0	0.1	0.3	0.4	0.4
Azerbaijan	0.0	0.0	0.0	0.1	0.4	0.5	0.5
Haiti	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Namibia	0.0	0.0	0.0	1.3	1.4	2.6	2.6
Comoros	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sao Tome and Principe	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Armenia	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Syrian Arab Republic	0.0	0.0	0.0	0.1	0.3	0.4	0.4
Libyan Arab Jamahiriya	0.0	0.0	0.0	0.2	1.6	1.8	1.8
Gambia	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Saint Lucia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Republic of Moldova	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Israel	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Saint Vincent and Grenadines	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lesotho	0.0	0.0	0.0	0.1	0.1	0.2	0.2
Grenada	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Antigua and Barbuda	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lebanon	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saint Kitts and Nevis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tajikistan	0.0	0.0	0.0	0.0	0.2	0.3	0.3
Yemen	0.0	0.0	0.0	0.2	0.5	0.7	0.7
Dominica	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saudi Arabia	0.0	0.0	0.0	0.3	2.3	2.5	2.5
Uzbekistan	0.0	0.0	0.0	0.1	0.5	0.6	0.6
Singapore	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Barbados	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mauritania	0.0	0.0	0.0	0.1	0.9	1.0	1.0
Niger	-	-	-	0.2	1.1	1.3	1.3
Egypt	-	-	-	0.1	1.1	1.2	1.2
Turkmenistan	-	-	-	0.1	0.5	0.5	0.5
Oman	-	-	-	0.0	0.4	0.4	0.4
Eritrea	-	-	-	0.0	0.3	0.3	0.3
Fiji	-	-	-	0.2	0.0	0.2	0.2
Jordan	-	-	-	0.0	0.1	0.2	0.2
Vanuatu	-	-	-	0.1	0.0	0.1	0.1
United Arab Emirates	-	-	-	0.0	0.0	0.1	0.1
Djibouti	-	-	-	0.0	0.0	0.0	0.0
Kuwait	-	-	-	0.0	0.0	0.0	0.0
Qatar	-	-	-	0.0	0.0	0.0	0.0
Samoa	-	-	-	-	0.0	0.0	0.0
Palau	-	-	-	0.0	-	0.0	0.0
Tonga	-	-	-	-	0.0	0.0	0.0
Bahrain	-	-	-	0.0	0.0	0.0	0.0
Malta	-	-	-	0.0	0.0	0.0	0.0
San Marino	-	-	-	0.0	0.0	0.0	0.0
TOTAL	305.6	58.1	363.7	85.9	121.2	207.1	570.9