Carbon stock of World Heritage Forest Sites

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1. Background and Objectives

As the global community becomes increasingly concerned about climate change, attention has been drawn to the role of forests in this regard. After studying the issue, the IPCC[2] has concluded that deforestation alone accounts for about 17 percent of global greenhouse gas emissions. In an effort to address this serious concern, the global community is in the process of developing a mechanism for reducing emissions from deforestation and forest degradation and enhancing carbon stock of forests by conservation and sustainable management of forests. The mechanism is known as REDD. As part of its contribution to global discussions on the role of forests and forest conservation in the mitigation of climate change impacts, and in the avoidance of further emissions from deforestation and forest degradation, UNESCO's World Heritage Centre commissioned a desk top analysis of the carbon content of World Heritage forest sites. The results of this study, reported below, should serve to illustrate the relative value of carbon stocks in the world's most strictly protected forests. This information is also expected to contribute to discussions on REDD related initiatives taking place in the larger landscapes within which World Heritage forest sites are located.

As of its 36th meeting in 2012, the World Heritage Committee had inscribed 106 World Heritage Forest sites[3] in 56 countries, distributed amongst a wide range of biographic realms around the globe[4]. Each site comprises unique ecosystems and assemblages of plant and animal species. The total area of these sites is close to 79 million ha of which 55 million ha (about the size of Kenya) is under forest cover (UNESCO, 2011, 2012).

A small sample of World Heritage forest sites:

- *Sundarbans National Park, India (mangroves)*
- *Wood Buffalo National Park, Canada (boreal)*
- *Guanacaste National Park, Costa Rica (dry tropical)*
- *Kahuzi-Biega National Park, D.R. Congo (moist tropical)*
- *Tasmanian Wilderness, Australia (temperate)*

The carbon (C) stock in forest ecosystems depends on forest type, forest density and productive capacity of the site and thus varies even within a specific forest ecosystem. The stock may

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[2] The Intergovernmental Panel on Climate Change is a scientific intergovernmental body, set up at the request of member governments. Its task is to assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. Its reports are regularly consulted by the negotiators of the United Nations Framework Convention, UNFCCC and its Kyoto Protocol. See: http://www.ipcc.ch/

[3] A World Heritage Forest is a World Heritage site for which the nomination file provided by the States Parties, of the World Conservation Monitoring Centre forest data reveal substantial amount of forest cover within the terrestrial component of the site and for which forest ecosystems contribute to the site's Outstanding Universal Value. (UNESCO, 2007)

[4] For the complete list, see: http://whc.unesco.org/en/forests/

increase due to growth of young trees as well as regeneration of new ones leading to increase in the density of forest stands. Alternately it may decrease due to forest fires, disease, wind storms, drought, failure in protection/illegal logging or the advance of the agricultural frontier into the site, etc. The accurate measurement of C stock of forest ecosystem is a rigorous exercise, requiring extensive site based survey and measurements of trees and other components – it is thus time consuming and expensive. Various approaches to measuring these stocks exist, typically having to sacrifice accuracy for the sake of affordability (Gibbs et al, 2007). Until such a time comes where generous financing for the measurement of C stocks of World Heritage forests is made available, desk top analyses relying on third party data remains the only method available.

Given the increased importance of forest ecosystem carbon content in international discussions on climate change (beginning with the United Nations Framework Convention on Climate Change's [UNFCCC] 1997 Kyoto Protocol) , the United Nations Food and Agriculture Organization (FAO) has included this theme in its periodic Forest Resource Assessment (FRA) exercise. The FRA exercise is considered the most comprehensive global assessment of forests and forestry available today. The FAO obtains forest ecosystem carbon content from UNFCCC member countries, who are requested to calculate emissions generated from the removal of forest carbon as part of convention obligations. To help UNFCCC member countries in this effort, the IPCC has developed guidelines, methods and default values to estimate C stock in different pools and their changes in forests (IPCC, 2006).

As per IPCC Guidelines, forests are considered to have five distinct carbon pools (2006):

i) Above ground biomass[5] (tree trunk, branches and leaves, climbers, lianas and shrubs)
ii) Below ground biomass (root system)
iii) Deadwood
iv) Litter
v) Soil organic matter /soil carbon

The latest FAO assessment (2010) presents the status of forests for 233 countries and overseas territories which inter alia include C stock of forests. Most of the countries reporting did not have complete data on all the five carbon pools of their forests. The current status of reporting on C stock by countries on different carbon pools is presented in table 1 below.

[5]Biomass is defined as the total dry mass of living organic matter. In case of forests it will be both above ground and below ground (root). The total biomass for this study and also referred elsewhere (GTOS 2009), means vegetation biomass live or dead, above ground and below ground biomass, litter and deadwood (e.g. the first four of the five forest carbon pools).

Table 1. Status of reporting on C stock by countries to FAO in FRA 2010

Reporting details	Number of Countries and Overseas Territories
Included in the assessment of FRA 2010 forest resource report	233
Reporting on carbon in biomass	180
Reporting carbon in deadwood	72
Reporting carbon in litter	124
Reporting on soil carbon (mostly IPCC default values)	121

For filling the data gaps of remaining countries and overseas territories, FAO estimated C stocks by taking the sub-regional averages per hectare and multiplying these by the respective forest areas – a very rough measure indeed. Using this approach, the FAO calculated a total C stock of 652 billion tonnes in the world's forest ecosystem in 2010 of which soil consists 292 billion tonnes or approximately 44%. The global "per hectare" average C stock in forests comes to about 162 tonnes, in which soil would contribute 72 tonnes. Despite a weak data base in most countries on all five carbon pools and uncertainty about accurate values of carbon, this is the best available global scale information on forest carbon stock today.

2. Methodology

The assessment of carbon stock in WHF sites was carried out as a one month desk study. The first step was to estimate the average C stock for four of the five carbon pools (above ground biomass, below ground biomass, deadwood and litter) per hectare, for each WH forest site (WHF). This was followed by the assignation of a carbon content value for soil carbon, the fifth carbon pool (e.g. soil carbon / soil organic matter per hectare) for each WHF site. The latter was based on either country data or, in the absence thereof, on IPCC default value for the specific forest type. The sum of these two C stocks gave the average value of C stock per hectare in WHF sites for the five carbon pools. Multiplication of area of forest cover by the carbon stock per ha provides the estimated total carbon stock of each WHF site. Information base used to carry out this study was mostly obtained from country reports submitted to FAO for FRA 2010[6], shape/KML files of WHF sites superimposed on the Google Earth[7], UNEP-WCMC World Heritage Information Sheets[8] and IPCC guidelines[9] .

[6] www.fao.org/forestry/fra/fra2010/en/
[7] Available here: www.unep-wcmc.org/kml-file-of-world-heritage-sites_812.html
[8] Available here: http://www.unep-wcmc.org/world-heritage-information-sheets_271.html

Countries reporting to FRA 2010 followed the standard FAO format for preparing their forest resources report. These reports focus on seven thematic elements considered as key aspects of sustainable forest management. They include country level data on growing stock, biomass and carbon stock as presented in tables T6, T7, and T8 respectively of the country reports[10]. From these tables average C stock per hectare in the total biomass and soil was derived by dividing the total value of carbon by the total area of natural forests and in some cases by area of a specific forest type. Most of the countries derived biomass/carbon from the growing stock of forests by using biomass expansion factors. Growing stock (tree trunk volume) is the basic country level data available from national forest inventories. IPCC guidelines provide expansion factors for different forest types. So when that factor is applied on the growing stock it expands to include the volume of additional components of above ground vegetation (branch-wood, leaf, climbers and lianas). Subsequently the volumes are converted into biomass by multiplying with a corresponding specific gravity. Biomass was finally converted to carbon by a conversion factor (generally 0.47) as provided in the IPCC guidelines. Below ground (root) biomass was derived using default values of root shoot ratio (generally 0.24) as given in the IPCC guidelines. Many countries have not reported carbon in litter and deadwood. In such cases, the average value obtained for a similar site, or the IPCC default value for the respective forest type was used.

Land/forest cover under polygons[7] of each WHF site was visualized through Google Earth images. Images of the other forest areas of the country were also seen for comparison. In general the assessment was visual but in a few cases areas of different types of forest were estimated by digitizing boundaries between such forest types within the WHF polygon. In a large number of cases, Google Earth has uploaded high resolution satellite image of Digital Globe/Geo-eye which provide a clear view of the land/forest cover of each sites. The UNEP-WCMC information sheets for each WHF site were also available from the web site[8]. They provided good descriptions of the sites including topography, climate and vegetation type. Using the country's C stock data as a base, the author combined visual assessment of Google Earth image with site description to assign C stock value based on his experienced judgment. Since a precise comparison of forest density of WHF sites with the average forest density of the country was not possible, an approximate increase/decrease of 25, 50 or 100% was attributed, again based on the author's experienced judgment wherever required.

For some sites where country average data was not available, the data of the neighboring countries matching the climate, topography and vegetation was used. For example Venezuela, Dominica and Ecuador have not reported growing stock, biomass or carbon for their forests. The Canaima National Park WHF site of Venezuela has broadly two types of forests- *great*

[9] Available here: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index/html

[10] Each country report submitted to FRA 2010 has the same format and has 17 tables, where each table gives country data for a specific theme. Table T6 consists of data on total growing stock, T7 on total biomass and T8 on total carbon stock of country's forests.

savanna and *highland moist forests* also known as highland Guyana moist forests. In this case the data of Cerrado Protected Area WHF site in Brazil for savanna ecosystems and of Guyana forests for highland ecosystems were used to estimate the C stock of Canaima National Park.

Only three countries in the study have estimated C stock of their national forests by forest type - Australia, Canada and India. For these countries, the average value of the C stock by forest type was used to estimate the same for the WHF site falling in the specific type. Three other countries, New Zealand[11], Russian Federation[12] and the United States of America[13] provided site specific data of their sites and have been accordingly used. Brazil has also given continental biome-wise forest C stock based on assumed data of growing stock of each biome (its national forest inventory is not yet complete). The average C stock of these biomes was used to estimate the C stock of WHF sites falling in the corresponding biomes.

Brief comments in the excel sheet accompanying this study have been made against each estimated value of C stock of the total biomass and soil giving estimation steps and the rationale. [14]

3. Findings and analysis

Based on the findings of this study, there are 10.5 billion tonnes of C stock found in the 106 WHF sites (see Annex 1 for the site by site results). On a per hectare of forest cover basis (using the figure of 55 million hectares of forest cover in WHF sites), this is equivalent to an average of 191 tonnes per hectare carbon stock locked up in WHF sites. This is 18% higher than the global carbon stock average for forests as calculated by FAO. The share of soil carbon is 4.2 billion tonnes or 40 percent of the total C stock giving average of 76 tonnes per ha whereas C stock in the total biomass (all four pools) is 6.3 billion tonnes, averaging 115 tonnes per ha. The values for C stock per hectare in i) total biomass; ii) soil as well as iii) the total C stock in the forest ecosystem is provided on a site by site basis in the excel sheet attached.

The C stock of WHF sites varies between 56 t/ha to 625 t/ha. About 65 percent WHF sites have lower C stock than the average (191 t/ha). The distribution of WHF sites within different C stock levels in a group interval of 50 (50 to 100, 100 to 150, 150-200 t/ha etc) is shown in figure 1 below.

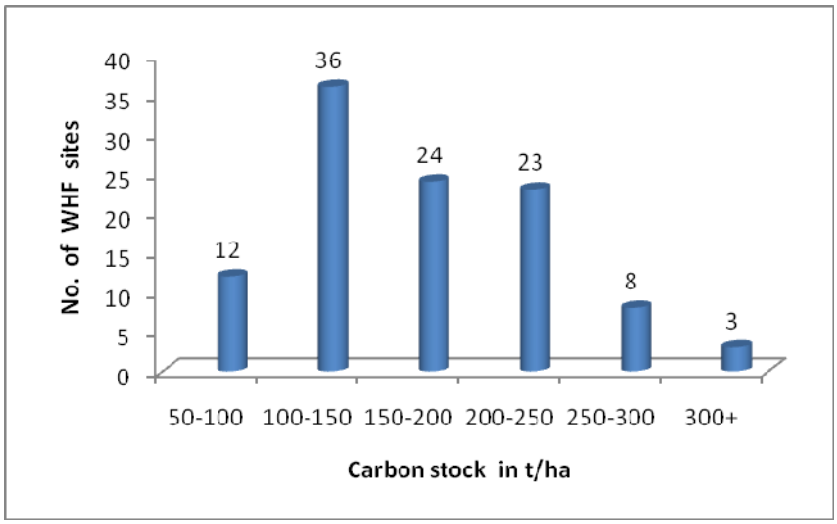
[11] Richard Earl of Natural Heritage Planning of New Zealand provided C stock of both the sites of NZ.

[12] Anatoly Shvidenko provided the site specific C stock per ha of each of the four WHF sites of the Russian Federation, which was calculated by Dmitry Schepaschenko based on Russia's Integrated Land Information System.

[13] Christopher W. Woodall calculated C stock for each of the six USA sites based on work recently published (Health at al 2011; Woodall et al 2012), their contribution and support is gratefully acknowledged.

[14] These are visible only as comments on the on-line MS Excel spreadsheet.

Fig 1. Distribution of WHF sites according to average C Stock content



The C stock in the total biomass alone varies between 19 to 573 t/ha. The five WHF sites having highest value of C density in total biomass per hectare are; Redwood National and State Parks of USA (573 t), Olympic National Park of USA (419 t), Te Wahipounamu-South West New Zealand (253 t), Central Suriname Reserve of Suriname (227 t) and Tongariro National Park of New Zealand (208 t). It is essential to mention here that both the sites of USA are located in the West Coast and have rare ecological attributes with the largest trees on the earth giving very high C stock in the site. Even deadwood and litter on these sites constitute about 50% of the above ground Carbon. Such sites are, therefore outliers and it is difficult to achieve so much C stock even with the best management practices. Further, the value for C stock in the soil for most of the sites is based on assumptions made by reporting bodies, or is adapted from IPCC default values. These values vary between 30 to 141 t/ha. It is worth mentioning here that soil carbon mainly depends on the climate and other physical and geological factors and to a lesser extent influenced by the manipulation of forest cover and management practices and is thus more stable.

3.1 Carbon Stock in Tropical WH Forests

Tropical forests are generally under greater conservation pressure than forests in sub-tropical, temperate and boreal zones. These forests tend to be of greater focus for REDD related initiatives. There are 62 WH forest sites in tropical zones. These have a total area of 42.4 million ha of which 31.4 million ha are forested. The total C stock of these sites is 5.7 billion tonnes giving an average of 181 tonnes per hectare C stock. The share of soil carbon is 2.1 billion tonnes or 37 percent of the total C stock giving an average of 67 tonnes per hectare where as in the biomass (all four pools) it is 3.6 billion tonnes with an average of 115 tonnes per ha. There are 32 sites whose average C stock is less than 100 tonnes per hectare. The top ten WHF sites having highest C density per ha in this zone are listed in the table 2.

Table 2. Top ten WHF sites of the tropical zone having highest C stock in total biomass per hectare (excludes soil carbon)

S.No.	Name of World Heritage Forest site	Country	Carbon in total biomass per ha (tonnes)
1.	Central Suriname Nature réserve	Suriname	227
2	Tai National Park	Cote d'Ivoire	188
3	Gunung Mulu National Park	Malaysia	167
4	Kinabalu Park	Malaysia	167
5	Sangha Trinational	Cameroon/ Central African Rep/ Rep of Congo	163
6	Puerto-Princesa Subterranean River National Park	Philippines	163
7	Central Amazon Conservation Complex	Brazil	158
8	Tropical Rainforest Heritage of Sumatra	Indonesia	152
9	Atlantic Forest South-East Reserves	Brazil	147
10	Discovery Coast Atlantic Forest Reserves	Brazil	147

3.2 Other WHF sites

The remaining 44 sites fall in sub-tropical, temperate and boreal region and generally do not face severe protection challenges. The total area of WHF sites under this category is 36.5 million ha of which 23.4 million ha are forested. The total C stock of these sites is 4.8 billion tonnes giving an average of 205 tonnes per hectare. The share of soil carbon is 2.1 billion tonnes or 43 percent of the total C stock giving an average of 89 tonnes per hectare. The C stock in biomass gives an average of 116 tonnes per hectare which is more or less same as in the tropical region.

4. Conclusion

WHF sites represent many of the best protected and undisturbed forest ecosystems of the world. In this capacity, they play an important role as baselines for studies relating to C stock of other managed forests and ecosystems. Similarly, they may represent a very large carbon stock which, under normal circumstances, can generally be assumed to be safe from release into the atmosphere through deforestation and forest degradation. When they are threatened, the World Heritage Convention can be leveraged to help implement appropriate conservation measures. But above all, these forests are prized for their outstanding ecosystems and species composition and as such, they have been formally recognized by the international community as humanity's common heritage – these are mankind's collective "sacred sites". The international community, through the mechanism of the World Heritage Convention, has committed to cooperating in helping conserve these sites. As the effects of climate change will be increasingly felt, these forests will be subjected to various pressures which may compromise their natural resilience to the usual set of threats with which they have to cope – such as forest fires, blow down from hurricanes or cyclones, disease amongst others. In such circumstances, WHF site management agencies have to be encouraged to bolster their site's ecological connectivity, through the maintenance, strengthening or creation of biological corridors linking them to the broader landscape. To this end, recognizing and compensating, through a functional REDD+ mechanism, the contributions to climate change mitigation brought about by such corridors will achieve objectives not only under the UNFCCC, but also under the WH Convention.

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Country	Name of World Heritage Forest Site	WH Site Size (ha)	% Forest cover WH	Estimated Forest WH (ha)	Carbon stock / hectare (metric tonnes)			Total Carbon stock in WH site (x 1000 mt)		
					Biomass	Soil	Total	Biomass	Soil	Total
Argentina	Iguazu National Park	55 500	90%	49 950	118	100	218	5 894	4 995	10 889
Australia	Fraser Island	184 000	90%	165 600	166	132	298	27 490	21 859	49 349
Australia	Gondwana Rainforests of Australia	370 000	100%	370 000	166	132	298	61 420	48 840	110 260
Australia	Greater Blue Mountains Area	1 032 649	97%	1 001 669	166	132	298	166 277	132 220	298 497
Australia	Kakadu National Park	1 980 994	50%	990 497	60	50	110	59 430	49 525	108 955
Australia	Tasmanian Wilderness	1 374 000	30%	412 200	166	132	298	68 425	54 410	122 836
Australia	Wet Tropics of Queensland	894 420	90%	804 978	166	132	298	133 626	106 257	239 883
Bangladesh	The Sundarbans	139 699	100%	139 699	56,3	54	110,3	7 865	7 544	15 409
Belarus/ Poland	Beloveshskaya Pushcha/Bialowieza Forest	92 669	100%	92 669	125	75	200	11 584	6 950	18 534
Bolivia	Noel Kempff Mercado NP	1 523 446	80%	1 218 757	84	65	149	102 376	79 219	181 595
Brazil	Atlantic Forest South-East Reserves	468 193	100%	468 193	147	93	240	68 824	43 542	112 366
Brazil	Brazilian Atlantic Islands (Fernando Noronha archipelago and Atoll das Rocas)	42 270	90%	38 043	78,5	93	171,5	2 986	3 538	6 524
Brazil	Central Amazon Conservation Complex	5 232 018	50%	2 616 009	158	100	258	413 329	261 601	674 930
Brazil	Cerrado PAs: Chapada dos Veadeiros and Empas NPs	367 356	60%	220 414	69	133	202	15 209	29 315	44 524
Brazil	Discovery Coast Atlantic Forest Reserves	111 930	95%	106 334	147	93	240	15 631	9 889	25 520
Brazil	Iguacu National Park	170 086	90%	153 077	118	100	218	18 063	15 308	33 371
Brazil	Pantanal Conservation Area	187 818	70%	131 473	81	141	222	10 649	18 538	29 187
Bulgaria	Pirin National Park	40 060	60%	24 036	56	95	151	1 346	2 283	3 629
Cameroon	Dja Faunal Reserve	526 000	90%	473 400	144,4	65	209,4	68 359	30 771	99 130

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Cameroon/ Central African Rep/Rep of Congo	Sangha Trinational	746 309	97%	723 920	163	65	228	117 999	47 055	165 054
Canada	Canadian Rocky Mountain Parks	2 306 884	40%	922 754	109	91	200	100 580	83 971	184 551
Canada	Gros Morne National Park	180 500	60%	108 300	62	38	100	6 715	4 115	10 830
Canada	Nahanni National Park	476 560	80%	381 248	141	79	220	53 756	30 119	83 875
Canada	Wood Buffalo National Park	4 480 000	70%	3 136 000	115	70	185	360 640	219 520	580 160
Canada / USA	Waterton Lakes Glacier International Peace Park	457 614	70%	320 330	99	42	141	31 713	13 454	45 167
China	Huanglong Scenic and Historical Interest Area	60 000	90%	54 000	37,5	50	87,5	2 025	2 700	4 725
China	Jiuzhaigou Valley Scenic and Historic Interest Area	72 000	65%	46 800	37,5	50	87,5	1 755	2 340	4 095
China	Mount Emei Scenic Area, including Leshan Giant Buddha Scenic Area	15 400	52%	8 008	37,5	50	87,5	300	400	701
China	Mount Huangshan	15 400	56%	8 624	47	50	97	405	431	837
China	Mount Sanqingshan National Park	22 950	97%	22 262	47	50	97	1 046	1 113	2 159
China	Mount Taishan	25 000	80%	20 000	37,5	50	87,5	750	1 000	1 750
China	Mount Wuyi	99 975	100%	99 975	47	50	97	4 699	4 999	9 698
China	Sichuan Giant Panda Sanctuaries - Wolong, Mt Siguniang and Jiajin Mountains	924 500	64%	591 680	37,5	50	87,5	22 188	29 584	51 772
China	Three Parallel Rivers of Yunnan Protected Areas	939 441	70%	657 609	37,5	50	87,5	24 660	32 880	57 541
Colombia	Los Katios National Park	72 000	50%	36 000	123	93	216	4 428	3 348	7 776
Costa Rica	Area de Conservación Guanacaste	147 000	100%	147 000	79	60	139	11 613	8 820	20 433

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					Biomass	Soil	Total	Biomass	Soil	Total
Costa Rica	Cocos Island National Park	199 790	11%	21 977	105	60	165	2 308	1 319	3 626
Costa Rica/Panama	Talamanca Range-La Amistad Reserves / La Amistad NP	567 845	90%	511 061	113	60	173	57 750	30 664	88 413
Cote d'Ivoire	Comoe National Park	1 149 250	85%	976 863	94	56	150	91 825	54 704	146 529
Cote d'Ivoire	Taï National Park	330 000	30%	99 000	188	56	244	18 612	5 544	24 156
Cote d'Ivoire / Guinea	Mount Nimba Strict Nature Reserve	14 760	80%	11 808	106	56	162	1 252	661	1 913
Croatia	Plitvice Lakes National Park	19 200	70%	13 440	145	50	195	1 949	672	2 621
Cuba	Alejandro de Humboldt National Park	69 341	97%	67 261	87	65	152	5 852	4 372	10 224
Democratic Rep. of Congo	Kahuzi-Biega National Park	600 000	30%	180 000	102	65	167	18 360	11 700	30 060
Democratic Rep. of Congo	Okapi Wildlife Reserve	1 372 625	100%	1 372 625	136	65	201	186 677	89 221	275 898
Democratic Rep. of Congo	Salonga National Park	3 600 000	100%	3 600 000	136	65	201	489 600	234 000	723 600
Democratic Rep. of Congo	Virunga National Park	790 000	65%	513 500	68	65	133	34 918	33 378	68 296
Dominica	Morne Trois Pitons National Park	6 857	100%	6 857	105	93	198	720	638	1 358
Ecuador	Sangay National Park	271 925	70%	190 348	67,5	63	130,5	12 848	11 992	24 840
France	Pitons, cirques and remparts of Reunion Island	105 838	91%	96 313	104	47	151	10 017	4 527	14 543
Gabon	Ecosystem and Relict Cultural Landscape of Lopé-Okanda	491 291	100%	491 291	137,5	65	202,5	67 553	31 934	99 486
Germany / Slovakia / Ukraine	Primeval Beech Forests of the Carpathians and the Ancient Beech Forests of Germany	33 670	87%	29 293	135	77,5	212,5	3 955	2 270	6 225
Guatemala	Tikal National Park	57 600	20%	11 520	85	65	150	979	749	1 728
Honduras	Rio Platano Biosphere Reserve	500 000	77%	385 000	88	65	153	33 880	25 025	58 905

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India	Manas Wildlife Sanctuary	39 100	64%	25 024	19	37,5	56,5	475	938	1 414
India	Nanda Devi and Valley of Flowers Natio	71 783	20%	14 357	60	61,5	121,5	861	883	1 744
India	Sundarbans National Park	133 010	65%	86 457	56,3	54	110,3	4 868	4 669	9 536
India	Western Ghats	795 315	100%	795 315	59	76	135	46 924	60 444	107 368
Indonesia	Lorentz National Park	2 350 000	52%	1 222 000	100	86	186	122 200	105 092	227 292
Indonesia	Tropical Rainforest Heritage of Sumatra	2 595 125	56%	1 453 270	152	86	238	220 897	124 981	345 878
Indonesia	Ujung Kulon National Park	76 119	79,9%	60 819	115	86	201	6 994	5 230	12 225
Japan	Ogasawara Islands	7 939	70%	5 557	84	65	149	467	361	828
Japan	Shirakami-Sanchi	16 939	82%	13 890	84	50	134	1 167	694	1 861
Japan	Shiretoko	71 100	93%	66 123	67	50	117	4 430	3 306	7 736
Japan	Yakushima (Yaku - island)	10 747	80%	8 598	84	65	149	722	559	1 281
Kenya	Mount Kenya National Park/Natural Forest	142 020	80%	113 616	147	65	212	16 702	7 385	24 087
Madagascar	Rainforests of the Atsinanana	479 661	92%	441 288	138	47	185	60 898	20 741	81 638
Madagascar	Tsingy de Bemaraha Strict Nature Reserve	152 000	50%	76 000	69	47	116	5 244	3 572	8 816
Malaysia	Gunung Mulu National Park	52 864	100%	52 864	167	65	232	8 828	3 436	12 264
Malaysia	Kinabalu Park	75 370	70%	52 759	167	65	232	8 811	3 429	12 240
Mexico	Monarch Butterfly Biosphere Reserve	13 552	87%	11 790	52,8	67	119,8	623	790	1 412
Mexico	Sian Ka'an	528 000	70%	369 600	35,2	67	102,2	13 010	24 763	37 773
Montenegro	Durmitor National Park	32 100	80%	25 680	73,1	50	123,1	1 877	1 284	3 161
Nepal	Chitwan National Park	93 200	70%	65 240	140,7	65	205,7	9 179	4 241	13 420
New Zealand	Te Wahipounamu – South West New Zealand	2 600 000	95%	2 470 000	253	65	318	624 910	160 550	785 460
New Zealand	Tongariro National Park	79 596	40%	31 838	208	65	273	6 622	2 069	8 692

Carbon stock of World Heritage Forest Sites

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Country	Name of World Heritage Forest Site	WH Site Size (ha)	% Forest cover WH	Estimated Forest WH (ha)	Carbon stock / hectare (metric tonnes)			Total Carbon stock in WH site (x 1000 mt)		
					Biomass	Soil	Total	Biomass	Soil	Total
Panama	Coiba National Park and its special Zone of Marine Protection	270 125	20%	54 025	121	60	181	6 537	3 242	9 779
Panama	Darien National Park	597 000	12%	71 640	121	60	181	8 668	4 298	12 967
Peru	Historic Sanctuary of Machu Picchu	32 592	80%	26 074	67,2	63	130,2	1 752	1 643	3 395
Peru	Manu National Park	1 716 295	100%	1 716 295	134,4	60	194,4	230 670	102 978	333 648
Peru	Rio Abiseo National Park	274 520	90%	247 068	67,2	63	130,2	16 603	15 565	32 168
Philippines	Puerto-Princesa Subterranean River National Park	5 753	50%	2 877	163	65	228	469	187	656
Portugal	Laurisilva of Madeira	15 000	67%	10 050	74	38	112	744	382	1 126
Russian Federation	Central Sikhote-Alin	1 553 928	100%	1 553 928	102,5	90,1	192,6	159 278	140 009	299 287
Russian Federation	Lake Baikal	8 800 000	40%	3 520 000	67,6	129,8	197,4	237 952	456 896	694 848
Russian Federation	Putorana Plateau	1 887 251	30%	566 175	24,3	97,4	121,7	13 758	55 145	68 904
Russian Federation	Virgin Komi Forests	3 280 000	92%	3 017 600	65,9	104,5	170,4	198 860	315 339	514 199
Senegal	Niokolo-Koba National Park	913 000	40%	365 200	43,7	38	81,7	15 959	13 878	29 837
Seychelles	Vallée de Mai Nature Reserve	18	100%	18	96	39	135	2	1	2
Solomon Islands	East Rennell	37 000	25%	9 250	99	47	146	916	435	1 351
South Africa	iSimangaliso Wetland Park	239 566	90%	215 609	75,3	63	138,3	16 235	13 583	29 819
Spain	Garajonay National Park	3 984	99%	3 944	99	38	137	390	150	540
Sri Lanka	Central Highlands of Sri Lanka	56 844	90%	51 160	46	63	109	2 353	3 223	5 576
Sri Lanka	Sinharaja Forest Reserve	8 864	60%	5 318	74	60	134	394	319	713
Suriname	Central Suriname Nature Reserve	1 600 000	100%	1 600 000	227	47	274	363 200	75 200	438 400

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Country	Name of World Heritage Forest Site	WH Site Size (ha)	% Forest cover WH	Estimated Forest WH (ha)	Carbon stock / hectare (metric tonnes)			Total Carbon stock in WH site (x 1000 mt)		
					Biomass	Soil	Total	Biomass	Soil	Total
Thailand	Dong Phayayen-Khao Yai Forest Complex	615 500	100%	615 500	69	60	129	42 470	36 930	79 400
Thailand	Thungyai-Huai Kha Khaeng Wildlife Sanctuaries	622 200	90%	559 980	51	60	111	28 559	33 599	62 158
Uganda	Bwindi Impenetrable National Park	32 092	95%	30 487	61	65	126	1 860	1 982	3 841
Uganda	Rwenzori Mountains National Park	99 600	60%	59 760	51	65	116	3 048	3 884	6 932
United Rep. of Tanzania	Selous Game Reserve	5 000 000	80%	4 000 000	65,5	47	112,5	262 000	188 000	450 000
USA	Great Smoky Mountains National Park	209 000	100%	209 000	137	58	195	28 633	12 122	40 755
USA	Olympic National Park	369 660	100%	369 660	419	96	515	154 888	35 487	190 375
USA	Redwood National and State Parks	56 883	70%	39 818	573	52	625	22 816	2 071	24 886
USA	Yellowstone National Park	898 349	80%	718 679	79	30	109	56 776	21 560	78 336
USA	Yosemite National Park	308 283	85%	262 041	185	44	229	48 478	11 530	60 007
Venezuela	Canaima National Park	3 000 000	70%	2 100 000	92	63	155	193 200	132 300	325 500
Total		**78 933 480**		**54 802 901**				**6 327 283**	**4 177 178**	**10 504 461**