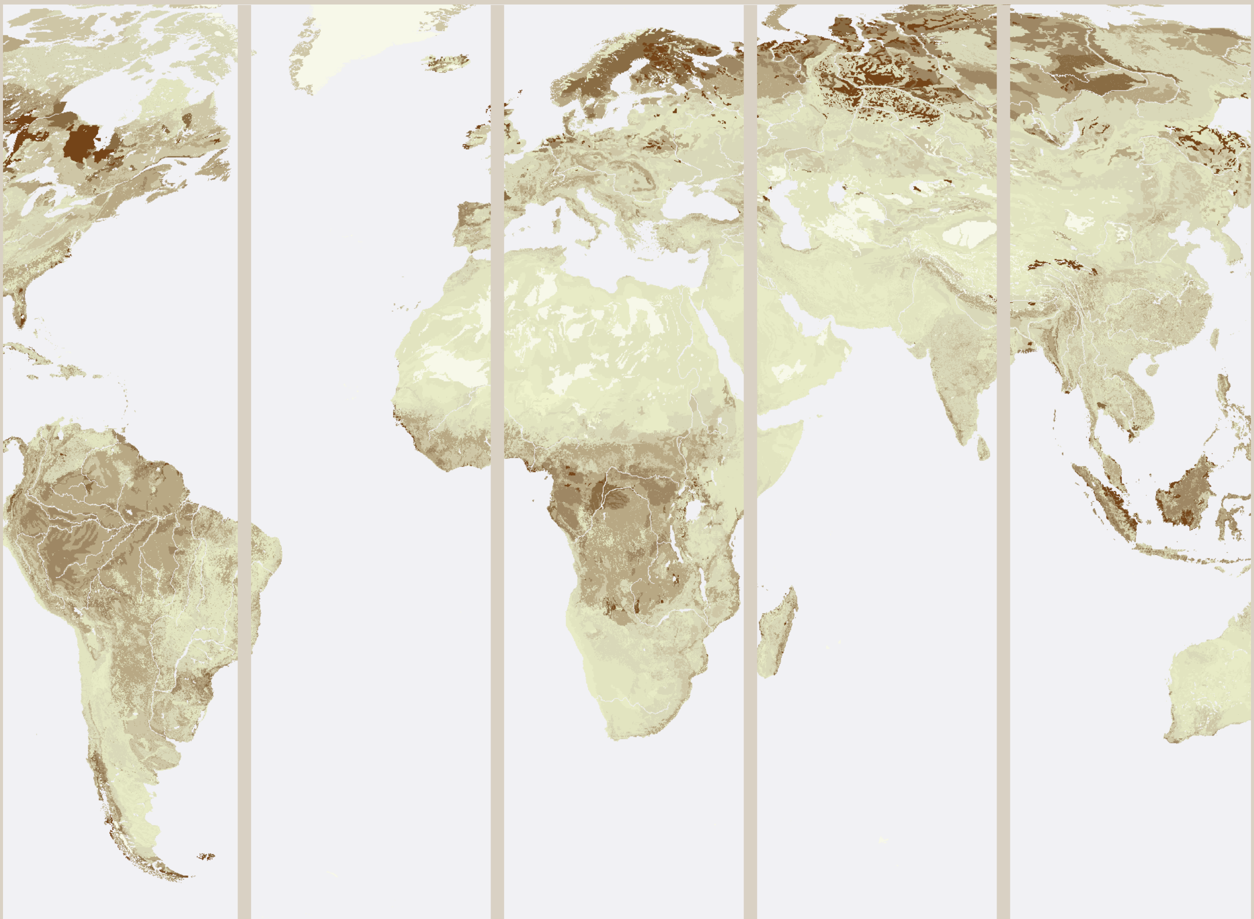
Carbon and **biodiversity**



A demonstration atlas

UNEP WCMC

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Introduction

This atlas demonstrates the potential for spatial analyses to identify areas that are high in both carbon and biodiversity. Such areas will be of interest to countries that wish to reduce greenhouse gas emissions from land use change and simultaneously conserve biodiversity.

BACKGROUND

Emissions from land use change, primarily deforestation, contribute to an estimated 20 per cent of total anthropogenic greenhouse gas emissions (IPCC 2007), equivalent to approximately 5.8 Gigatonnes (Gt) of carbon dioxide (CO_2) a year.

Recognition of the scale of CO_2 emissions from land use change has led to the decision that reduced emissions from deforestation and degradation (REDD) in developing countries should be considered for inclusion under the United Nations Framework Convention on Climate Change (UNFCCC). The Bali Action Plan, adopted by UNFCCC at the thirteenth session of its Conference of the Parties (COP 13) in December 2007, mandates Parties to negotiate a post-2012 instrument, including possible financial incentives for forest-based climate change mitigation actions in developing countries (Decision 1/CP.13). The Parties specified that the development of such an instrument should take into consideration 'the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries'. COP 13 also adopted a decision on 'Reducing emissions from deforestation in developing countries: approaches to stimulate action' (Decision 2/CP.13).

Although REDD is necessarily focussed on reducing carbon loss, the Bali Action Plan recognizes that actions to support REDD can also promote other benefits that may contribute to achieving the aims and objectives of other relevant international conventions such as the Convention on Biological Diversity (CBD). In addition to containing large amounts of carbon, many forests contain high levels of biodiversity and provide essential ecosystem services important for human wellbeing.

Policies and incentives for REDD are still under consideration. By reducing pressure on tropical forests, REDD in almost any form would be likely to have some biodiversity benefits. However, the magnitude of these benefits and the impacts of REDD on other forest values and services would depend on the precise nature of the mechanism adopted and how countries choose to implement it.

If countries wish to maximize biodiversity benefits from reducing emissions from land use change, they will need tools that help to identify the spatial overlap of high carbon and high biodiversity areas. They may further need to identify areas of high biodiversity value but lower carbon stocks, which may be at risk from displacement of land use pressures as a result of REDD interventions.

THE ROLE OF THIS ATLAS

This atlas demonstrates the potential value of spatial analyses as a tool to assist countries in maximising biodiversity benefits whilst reducing carbon emissions from land use change.

The atlas uses global datasets on carbon storage in terrestrial ecosystems and areas of high priority for biodiversity conservation to provide regional overviews of the spatial overlap of these important values in the tropics. National-scale maps for six tropical countries draw, where possible, on finer scale nationally developed biodiversity datasets, and show where existing protected areas coincide with high carbon and biodiversity areas. A variety of statistics are drawn from the national-scale maps to demonstrate the different types of information that these maps can provide.

These maps are intended solely as demonstrations of how combining spatial data can help to identify areas where the opportunities for carbon and biodiversity benefits coincide. REDD-related decision-making at the national scale will need to be based, if at all possible, on nationally developed data for both carbon stocks and biodiversity. In order to reduce emissions effectively, and realize other co-benefits of reducing deforestation, such decisions will also need to incorporate information on the country-specific pressures causing land use change.

Carbon and biodiversity

The global carbon store and biodiversity: global datasets

CARBON STORAGE IN TERRESTRIAL ECOSYSTEMS

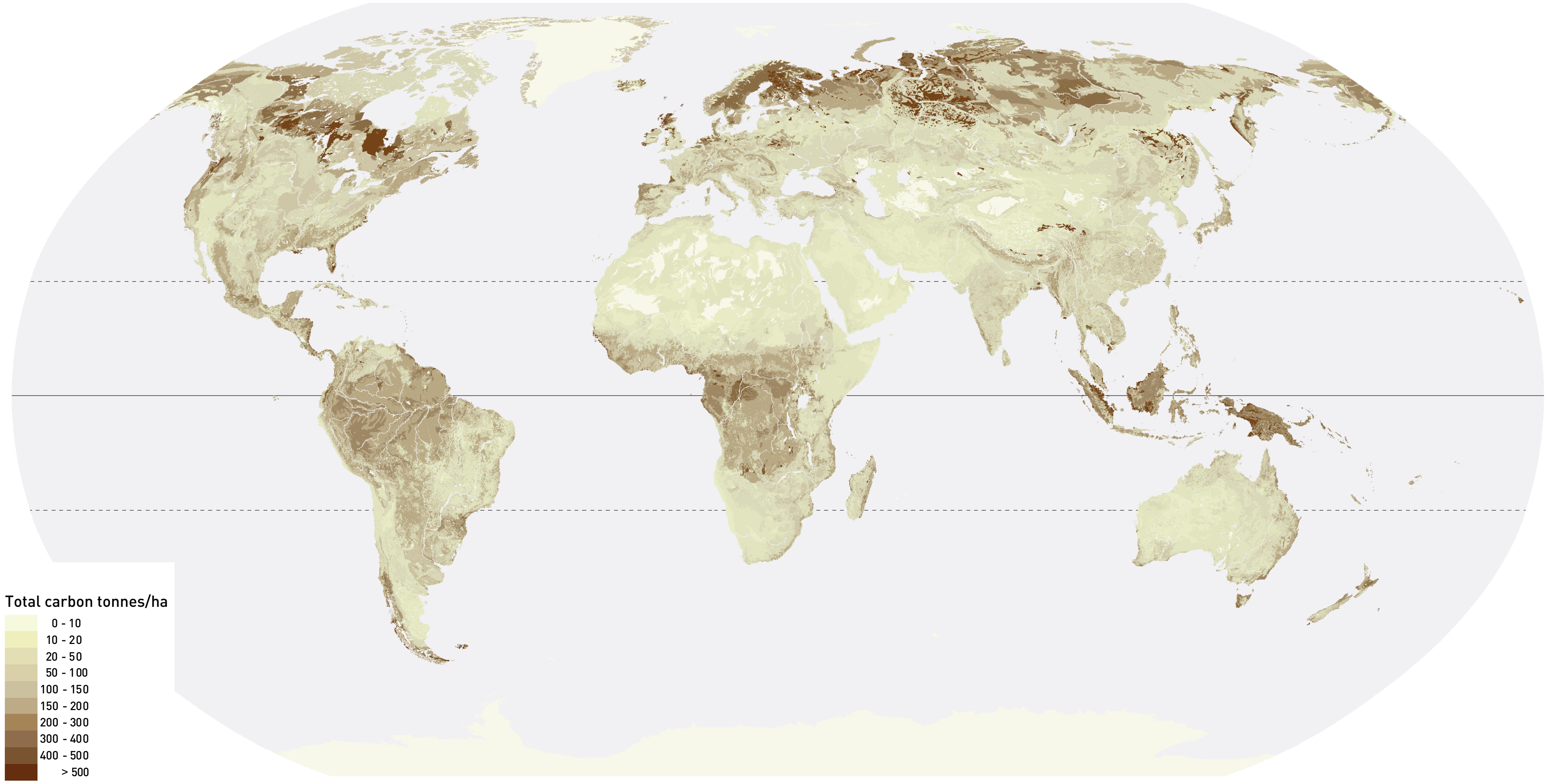
Earth's terrestrial ecosystems are estimated to store over 2,000 Gt of carbon (GtC) in their above- and below-ground biomass and in the soil (Campbell *et al.* 2008a). A significant proportion of this carbon is located within tropical ecosystems. The map of carbon storage in terrestrial ecosystems presented here was produced by combining the best available globally consistent datasets on carbon in live biomass (Ruesch and Gibbs, in review), estimated using the Intergovernmental Panel on Climate Change (IPCC) Tier-1 approach (IPCC 2006, Gibbs *et al.* 2007), and a dataset on soil carbon to 1m depth (IGBP-DIS 2000: this is likely to underestimate the carbon stored in peat soil).

These data form the basis of each map presented in this atlas, which focuses on tropical regions. Although global scale data are likely to be less accurate than those produced at national or regional scales, they provide a globally consistent picture of carbon storage; suitable for the illustrative purposes intended here.

For the regional and national demonstration maps, carbon stocks are divided into 'high' 'medium' and 'low' carbon density categories. As decisions about priorities and actions for reducing emissions from deforestation will be made by countries, it may be helpful if the data are scaled appropriately for their own national contexts. Therefore, the categories of carbon density have been defined separately for each of the regional and national maps. The 'high' carbon category includes the carbon density values for the most carbon rich third of the total land area within that map. The medium and low categories similarly include the carbon density values for the relevant third of the land area.

GLOBAL BIODIVERSITY PRIORITY SCHEMES

Conservation scientists have used several different approaches to identify areas of global importance for biodiversity conservation. Each approach depends on measures of the distribution of particular components of biodiversity, and many incorporate measures of threat.



Carbon storage in terrestrial ecosystems.

The prioritization schemes included in this assessment are shown overleaf. **Conservation International's Hotspots** are areas of the world in which there are large numbers of endemic plant species, and where less than 30 per cent of the natural habitat remains (Mittermeier *et al.* 2004). **WWF Global 200 ecoregions** are the most biologically distinct terrestrial and freshwater ecoregions of the planet, selected for exceptional levels of biodiversity (Olson *et al.* 2001). **Birdlife International Endemic Bird Areas (EBAs)** are areas where two or more bird species with ranges smaller than 50,000 km^2 co-occur (Birdlife International 2008). **WWF/IUCN Centres of Plant Diversity (CPDs)** are areas of key significance for global plant biodiversity (WWF and IUCN 1994), and **Amphibian Diversity Areas** represent the areas significant for global amphibian diversity (Duellman 1999).

In the regional maps that follow, 'high' biodiversity areas are those identified by four or more of these global prioritisation schemes. These are areas with the greatest degree of consensus as to their importance (areas included in fewer prioritisation schemes are also important for biodiversity conservation). **Alliance for Zero Extinction (AZE)** sites, considered key sites for conservation to safeguard the last remaining refuges of Endangered or Critically Endangered species (Ricketts et al. 2005), are also shown.

The national-scale examples illustrate a variety of different approaches to identifying areas of high biodiversity value at a national level, as detailed for each map.

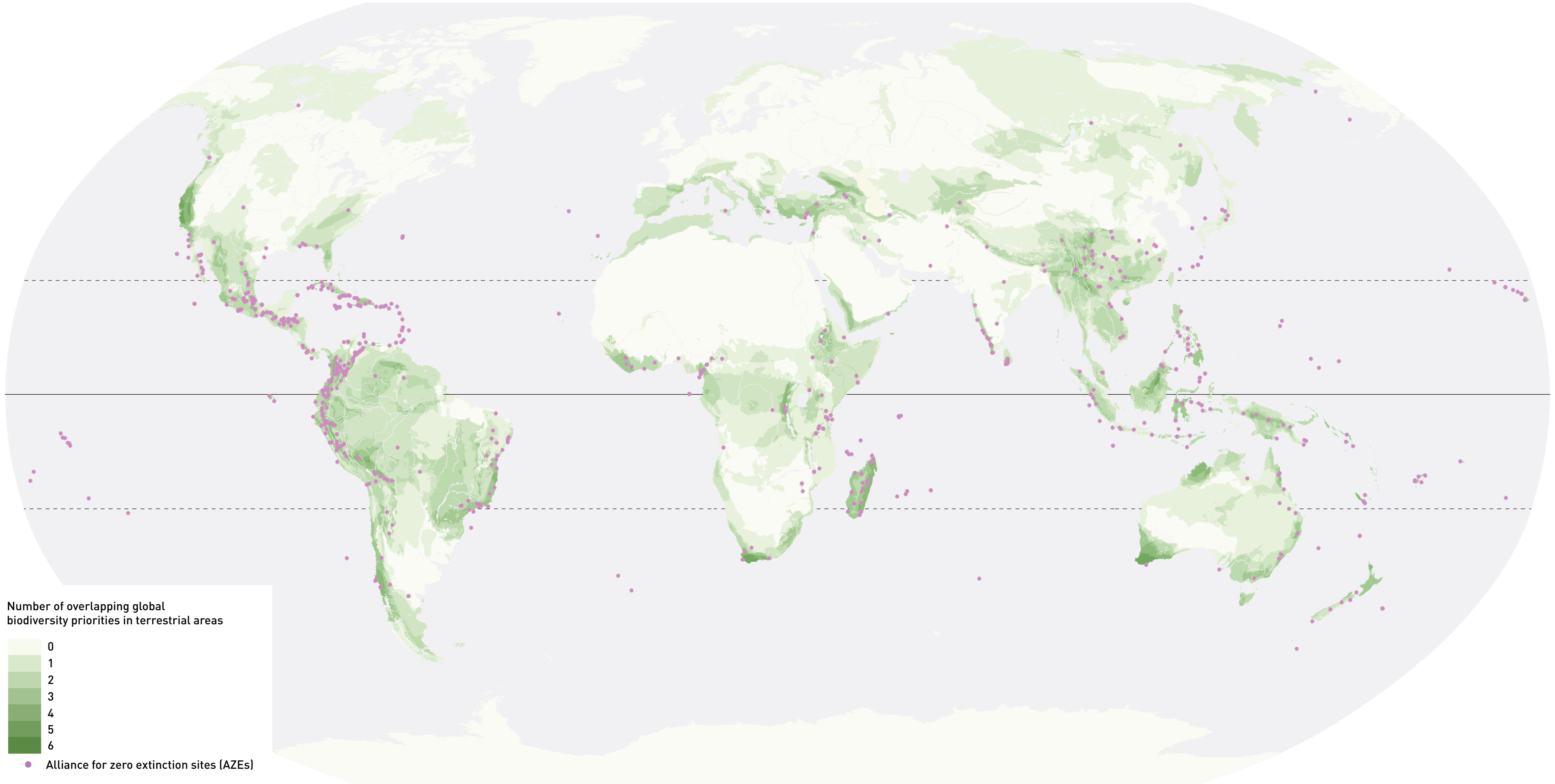
PROTECTED AREAS

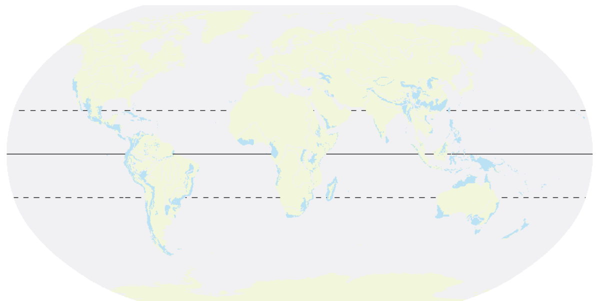
Although protected areas are designated for the purpose of biodiversity conservation, they also confer some level of protection on the carbon stocks contained within them. It has been estimated that globally, ecosystems within protected areas store over 312 GtC, or 15 per cent of the terrestrial carbon stock (Campbell *et al.* 2008a).

Protected areas are likely to make up just part of a national climate change mitigation strategy, and the role of protected areas in REDD is still up for debate. It may be useful for countries to know where protected areas lie in relation to the national carbon stocks. Protected area data from the World Database on Protected Areas (WDPA; UNEP-WCMC, IUCN 2007) are included on the national-scale maps.

Carbon and biodiversity

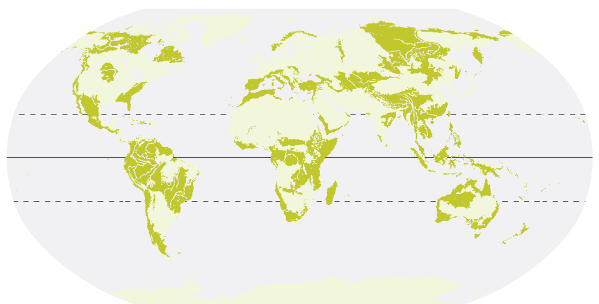
The spatial overlap of the global terrestrial biodiversity priority areas used for the regional maps, and the original priority schemes from which this map was derived. Areas where 4 or more priority schemes overlap are considered here to be 'high biodiversity'. Alliance for Zero Extinction sites (AZEs) are also shown.



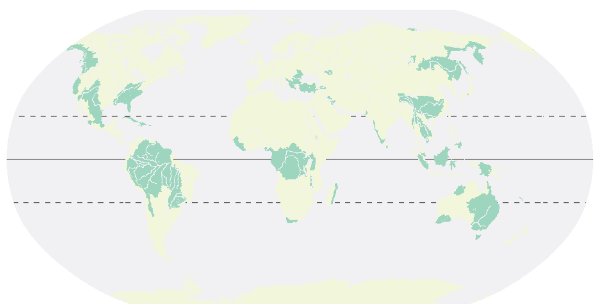


Endemic bird areas (EBAs) (BirdLife International)

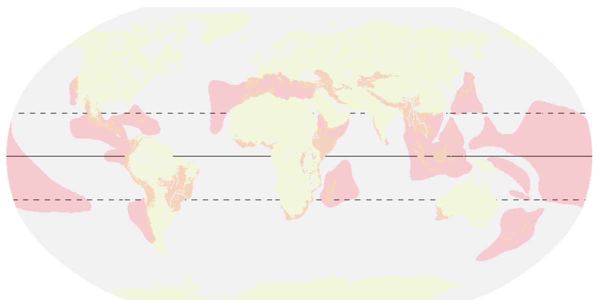
Amphibiam diversity (Duellman 1999)



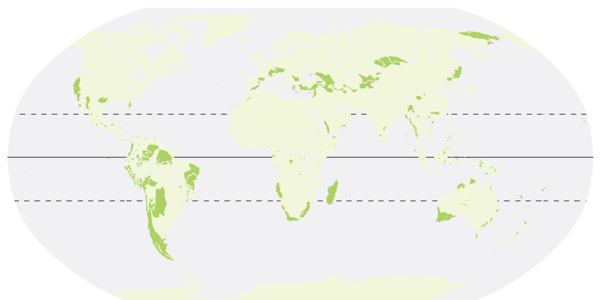
Global 200 terrestrial ecoregions (WWF)



Global 200 freshwater ecoregions (WWF)



Biodiversity hotspots (Conservation International)



Centres of plat diversity (WWF/IUCN)

The Neotropics

The terrestrial ecosystems of the Neotropics cover 15.8 million km^2 of land and contain 321 Gt of carbon (GtC). The vast majority of this store is in the humid tropical forests, where high deforestation rates accounted for approximately 60 per cent of deforestation across the whole humid tropical forest biome between 2000 and 2005 (Hansen *et al.* 2008). The high deforestation in this region reflects both the large total remaining forest area and the high land use pressures acting upon it.

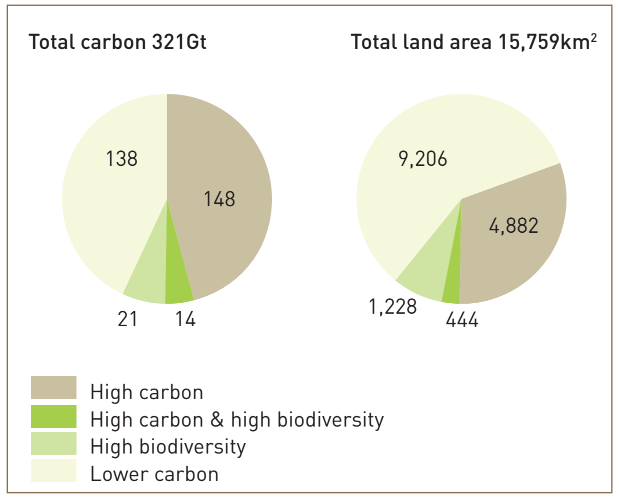
Both the high carbon stocks and the biodiversity values of the Neotropics are threatened by this deforestation, which is largely driven by pasture expansion (Chomitz *et al.* 2006, Nepstad *et al.* 2008). Recently, large scale soybean production has also become a very important contributor to deforestation in the Brazilian Amazon (Cerri et al. 2007).

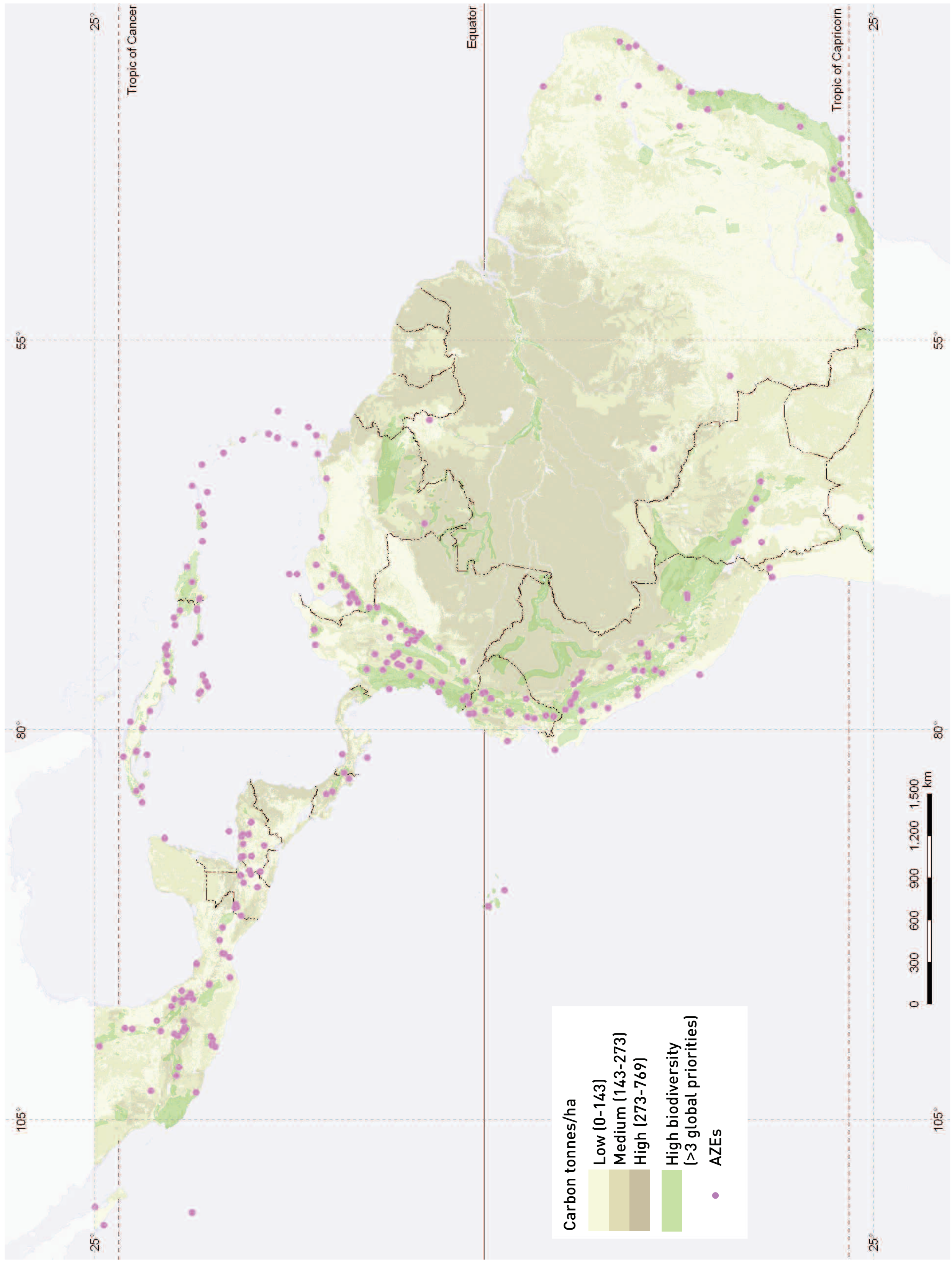
In addition to containing a large carbon store, the Neotropics are extremely high in biodiversity. The tropical Andes is the richest and most diverse biodiversity hotspot in the world (Mittermeier *et al.* 2004); and the Amazon rainforest, the world's largest continuous rainforest area, is estimated to host a quarter of the world's terrestrial species. Six of the world's 17 'megadiversity' countries (Mittermeier *et al.* 1997) are in the Neotropics.

Areas of high biodiversity value, where at least four global biodiversity priority schemes overlap, are shown on the map in green. These areas, which are largely concentrated over the tropical Andes and Amazon River, cover 1.6 million km^2 and contain an estimated 35 GtC, accounting for 11 per cent of the total regional carbon stock. The Alliance for Zero Extinction sites (AZEs) shown on the map are the last refuges for endangered and critically endangered species, and also highlight areas in which biodiversity benefits could be gained through conservation of carbon stocks.

Christian Ziegler

The areas of the map in darkest green, those where high biodiversity value overlaps areas of high carbon density (more than 273 t/ha; represented by dark brown), cover more than 0.4 million km^2 or 3 per cent of the total land area of the region. These high carbon and high biodiversity areas contain 14 Gt of carbon, or 4 per cent of the total regional carbon stock (see diagram, left). In such areas REDD-related interventions could also produce significant biodiversity conservation benefits. However, the precise locations of such 'priority areas' would be far better determined by finer scale analysis than derived from global scale data. It would also be useful to identify a sliding scale of biodiversity value in relation to the carbon stock, including those areas that are low in carbon but high in biodiversity.





Tropical Africa

The varied ecosystems of the African Tropics cover 24.3 million km^2 and store 321 GtC, the bulk of which is held in the humid tropical forests. The areas with the highest carbon stocks, which account for 63 per cent of the total carbon stock, store 202 GtC.

Lower rates of deforestation have been reported in Africa than for other tropical regions, accounting for only 5 per cent of total global humid tropical forest loss between 2000 and 2005 (Hansen *et al.* 2008). This could in part be due to lower levels of large scale deforestation in this region, and the difficulty of detecting small scale, patchy deforestation and forest degradation with relatively coarse resolution remote sensing. The land use pressures in tropical Africa are a combination of agricultural expansion and subsistence scale resource use; both of which lead to forest degradation. This is exacerbated by the growing commercial logging operations. The carbon implications of forest degradation are less well known than those of deforestation, but it is clear that degradation can cause significant levels of carbon loss (Asner *et al.* 2005) and can have major negative impacts on forest biodiversity.

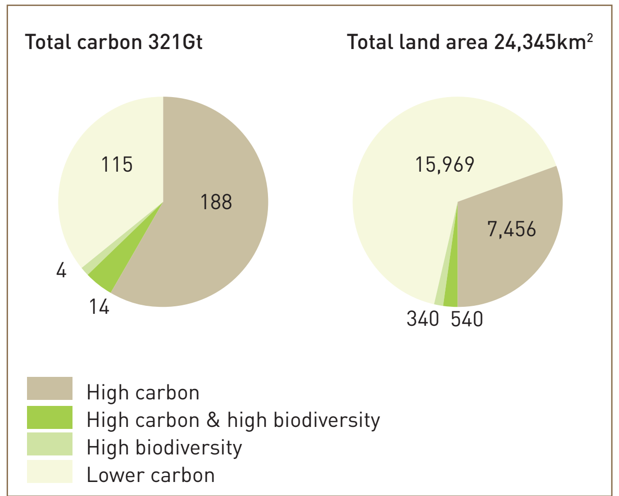
The large number of habitat types in the African tropics represent most of the world's tropical biomes and support varying levels of unique biodiversity. The land cover ranges from dry and wet Miombo woodlands and tropical savanna to the Congo Basin rainforests, the second largest expanse of continuous rainforest in the world. High levels of biodiversity are found in the Congo, which is particularly rich in primates, and in the Eastern Arc mountains.

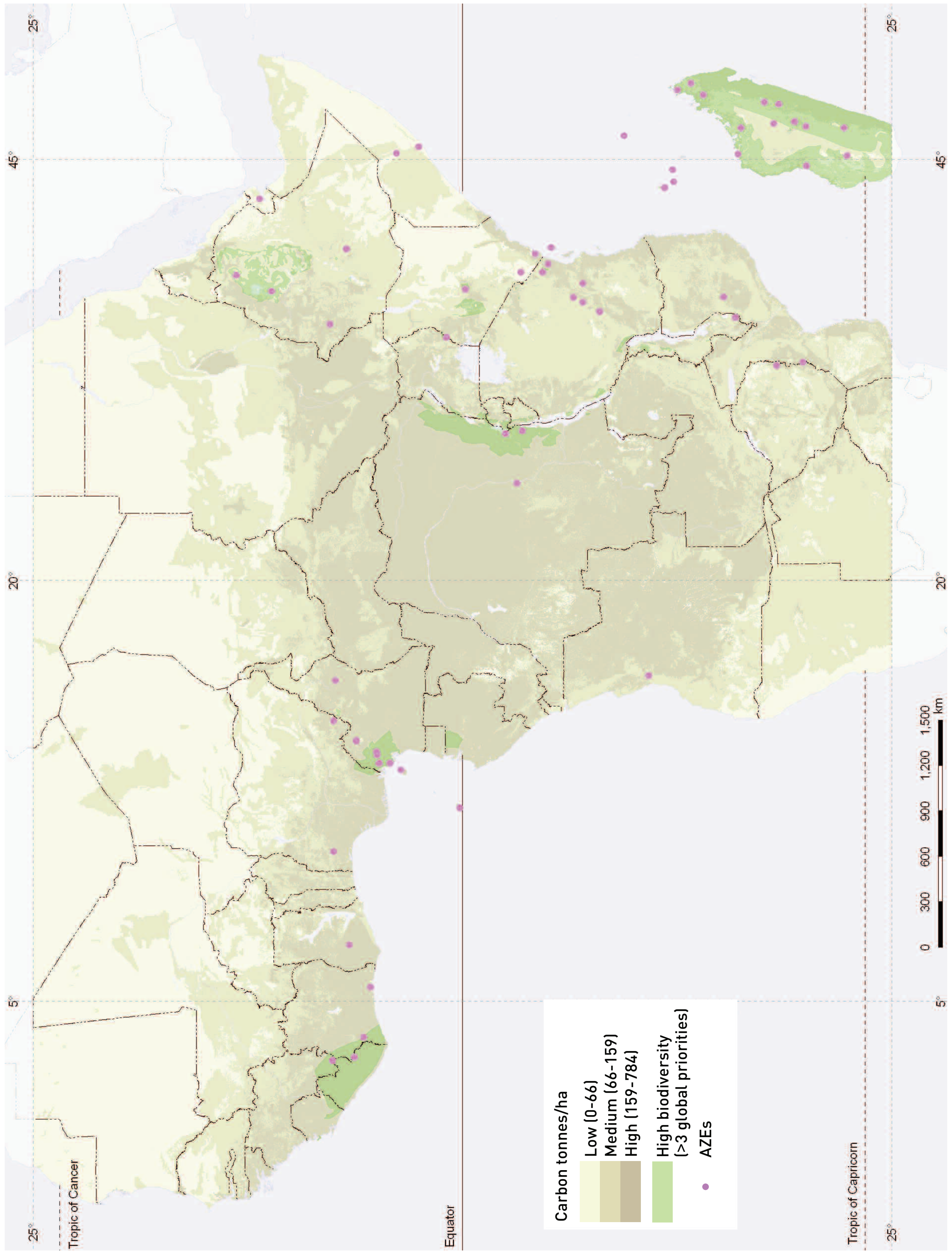
Charles Besançon

The areas of high carbon stocks (shown in dark brown) and the areas in which they overlap with high biodiversity (shown here in dark green) can clearly be seen. The eastern edge of Madagascar is one such area of overlap, as are the hotspot areas of the Eastern Afromontane and the Guinean Forests. The small area of Africa identified by the global priority schemes used here may not reflect the regional biodiversity priorities. This highlights the need to scale data relative to regional or national circumstances and to identify clear sets of priorities accordingly.

The high biodiversity areas shown here contain a total of 18 GtC, accounting for 6 per cent of the total carbon stock in tropical Africa. The areas with highest carbon and high biodiversity hold 14 Gt of carbon, accounting for 4 per cent of the total regional carbon stock. High biodiversity lands cover 7% of the high carbon land areas. This suggests that the high biodiversity areas of Africa in general have a high carbon density, and that significant biodiversity benefits could be gained from reducing carbon loss in these areas (see diagram, left). This is further supported by the overlap between high carbon areas and a number of the AZE sites (shown in purple on the map), which indicates that REDD actions could be targeted to benefit endangered and critically endangered species.

Although the global data used here may not fully represent regional priorities for tropical Africa, these simple mapping tools could be applied to improve biodiversity benefits in a number of ways. For example, areas of high carbon density and high density of great apes could be identified if the aim was to identify where REDD implementation could potentially have the added benefit of conserving great apes of the Congo Basin.





Tropical Asia and Oceania

FAO/Masakazu Kashio

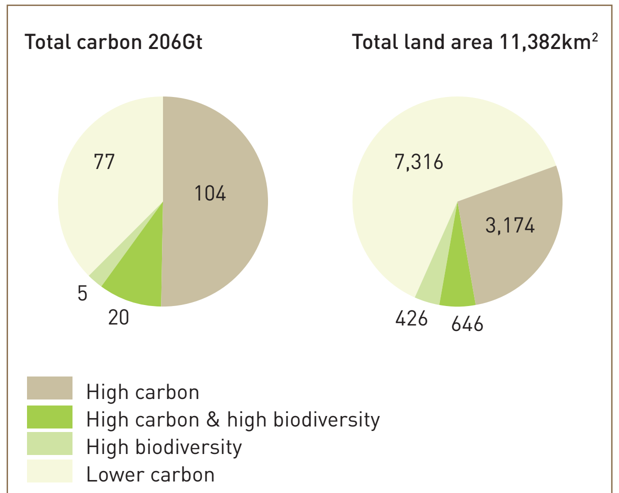
The tropical regions of Asia and Oceania cover a large geographical area, from the continental land mass of south Asia to the Pacific Islands in the east, with a total land area of 11 million km². They store approximately 206 GtC, 60 per cent of which is contained within high carbon areas. Malaysia, Indonesia, and Papua New Guinea are particularly notable for their high carbon density land.

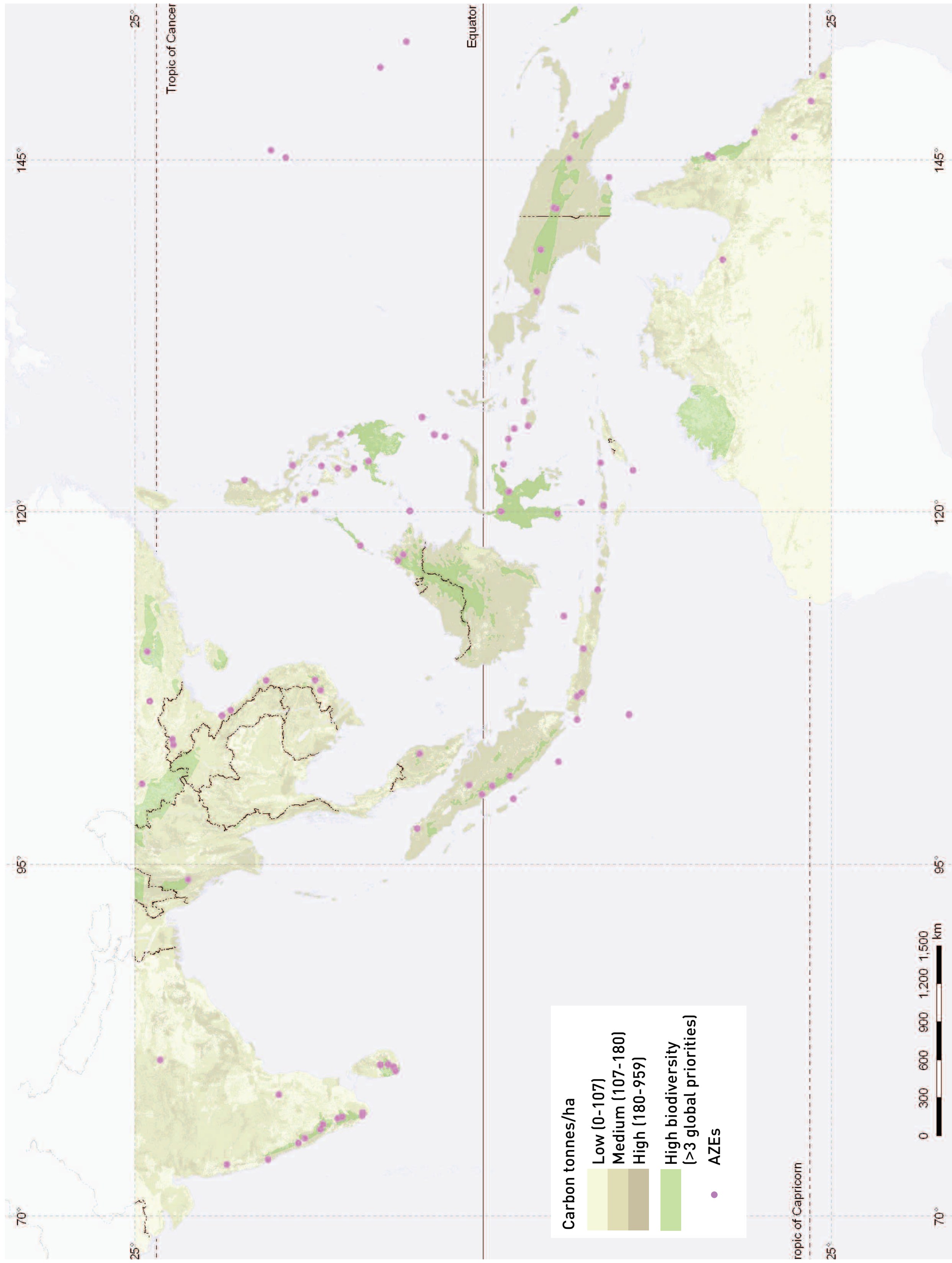
This region has a large total area of tropical forest, second only to the Neotropics, and a high rate of deforestation. Approximately one third of global humid tropical forest loss between 2000 and 2005 occurred in Asia (Hansen *et al.* 2008). This high deforestation rate reflects the extremely high land use pressures acting in this region (Laurance 2007). The expansion of oil palm plantations has already replaced a large area of carbon rich and high biodiversity tropical peat forest, resulting in significant greenhouse gas emissions (Hooijer *et al.* 2006).

Tropical Asia and Oceania include seven 'megadiverse' countries (Mittermeier *et al.* 1997) and a number of biodiversity 'hotspots', including the Sundaland area of the Indo-Malayan realm, which has an estimated 25,000 species of vascular plants and a high number of endemics. High species richness and endemism are found across the lowland forests of the island archipelagos and in mountainous areas of the islands and continental land masses.

The areas of high biodiversity value, shown by the green areas of the regional map (defined as in the other regional maps), cover 9 per cent of the land area and contain 12 per cent (25 Gt) of the regional carbon stock. The high carbon density areas show particularly high levels of coincidence with the high biodiversity areas in this region, with 20 Gt, or 10 per cent of the total carbon stock contained within high carbon, high biodiversity lands (see diagram, left). This is particularly true of the mountainous areas of the Western Ghats and the island archipelagos. The AZE sites (shown in purple), representing the last refuges of endangered and critically endangered species, also show high levels of coincidence with the high carbon areas in tropical Asia and Oceania.

These regional scale maps have all been analysed using the same global carbon data and biodiversity priority layers to highlight the high levels of spatial coincidence between areas of high carbon and high biodiversity. In contrast, the national-scale maps that follow draw on a diverse range of finer scale sources of data on biodiversity value, and demonstrate several different possible ways of deriving and presenting statistical data using these simple mapping tools.





Country profile
Panama

With a land area of 75,500 km², Panama is home to more than 10,000 species of plants and 1,000 species of birds along with hundreds of mammal and amphibian species.

The demonstration map for Panama combines global carbon storage data with detailed information on distributions of species richness of mammals (CIESIN 2008a), birds (CIESIN 2008b) and amphibians (CIESIN 2008c) at a national level obtained from NatureServe (www.NatureServe.org). For this map, areas of high biodiversity value are defined as those with the greatest levels of species richness (the top third of cells). It should be noted that this definition of high biodiversity value does not encompass any measure of threat.

According to the data presented here, Panama stores 2 GtC in the vegetation and soil of its terrestrial ecosystems. Approximately 1 Gt of carbon (51 per cent) is in the 'high carbon' areas shown on the map in darker brown. These are areas of high carbon soils in mountainous regions and coastal swamps and the high biomass lowland forests.

Areas of high biodiversity value (green shading) cover 31 per cent of the land area of Panama and contain 36 per cent of the total carbon stock. Of particular interest are those areas where high biodiversity values coincide with high carbon density areas, which cover 9,000 km² in total and contain 20 per cent (or 0.38 GtC) of the Panamanian carbon stock. This accounts for 40 per cent of the carbon stock in high carbon areas, showing considerable spatial overlap between high carbon stocks and high biodiversity (see diagram. above right) The map also shows that many, but not all of the areas with high carbon and high biodiversity values fall within protected areas.

While this illustrative material shows that areas of high carbon and high biodiversity values can be identified through spatial analyses, the use of such information for prioritising REDD related actions would depend on national policies and priorities. Ideally, national-scale maps would be based on more detailed information on biodiversity and carbon stocks available at national level. As with the regional maps, it should also be emphasized that the 'high', 'medium' and 'low' density bands are scaled relative to national carbon stocks, and are not directly comparable.

Total carbon 1.9Gt

- High carbon
- High carbon & high biodiversity
- High biodiversity
- Lower carbon

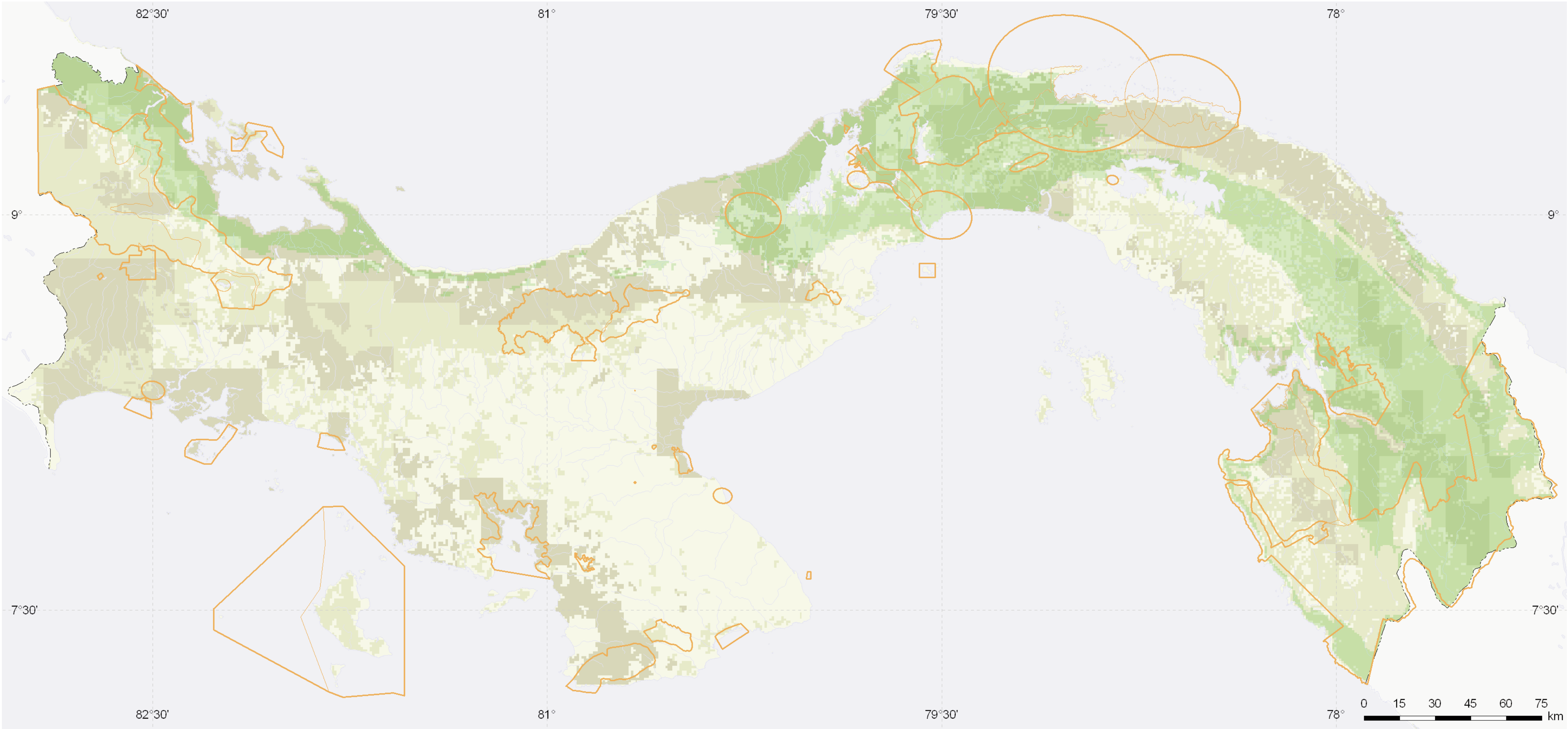
Above

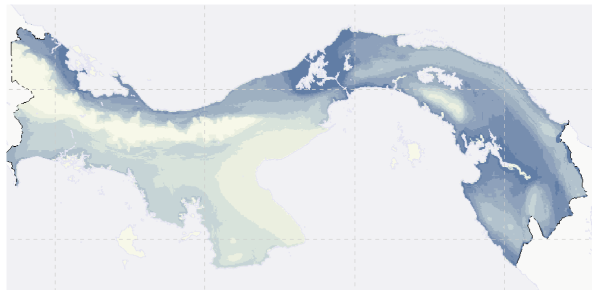
Carbon tonnes/ha
- Low (0-175)
- Medium (175-313)
- High (313-626)

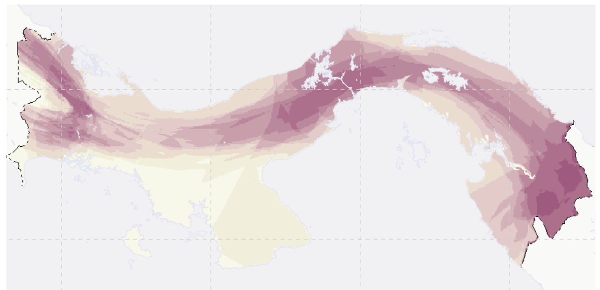
- High biodiversity (>584 species)
- National protected areas

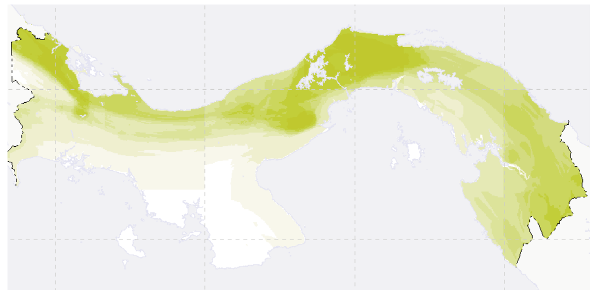
Below

Bird diversity	Mammal diversity	Amphibian diversity
5 - 238	1 - 125	0 - 20
238 - 291	125 - 129	20 - 30
291 - 316	129 - 135	30 - 47
316 - 340	135 - 138	47 - 59
340 - 360	138 - 141	59 - 69
360 - 373	141 - 144	69 - 76
373 - 386	144 - 148	76 - 83
386 - 397	148 - 156	83 - 94
397 - 458	156 - 174	94 - 125

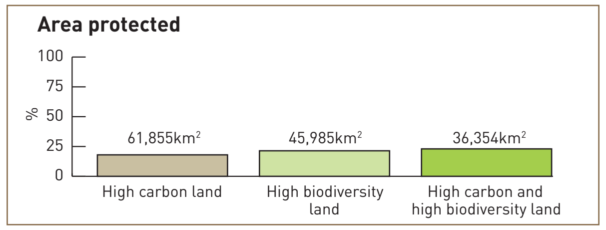






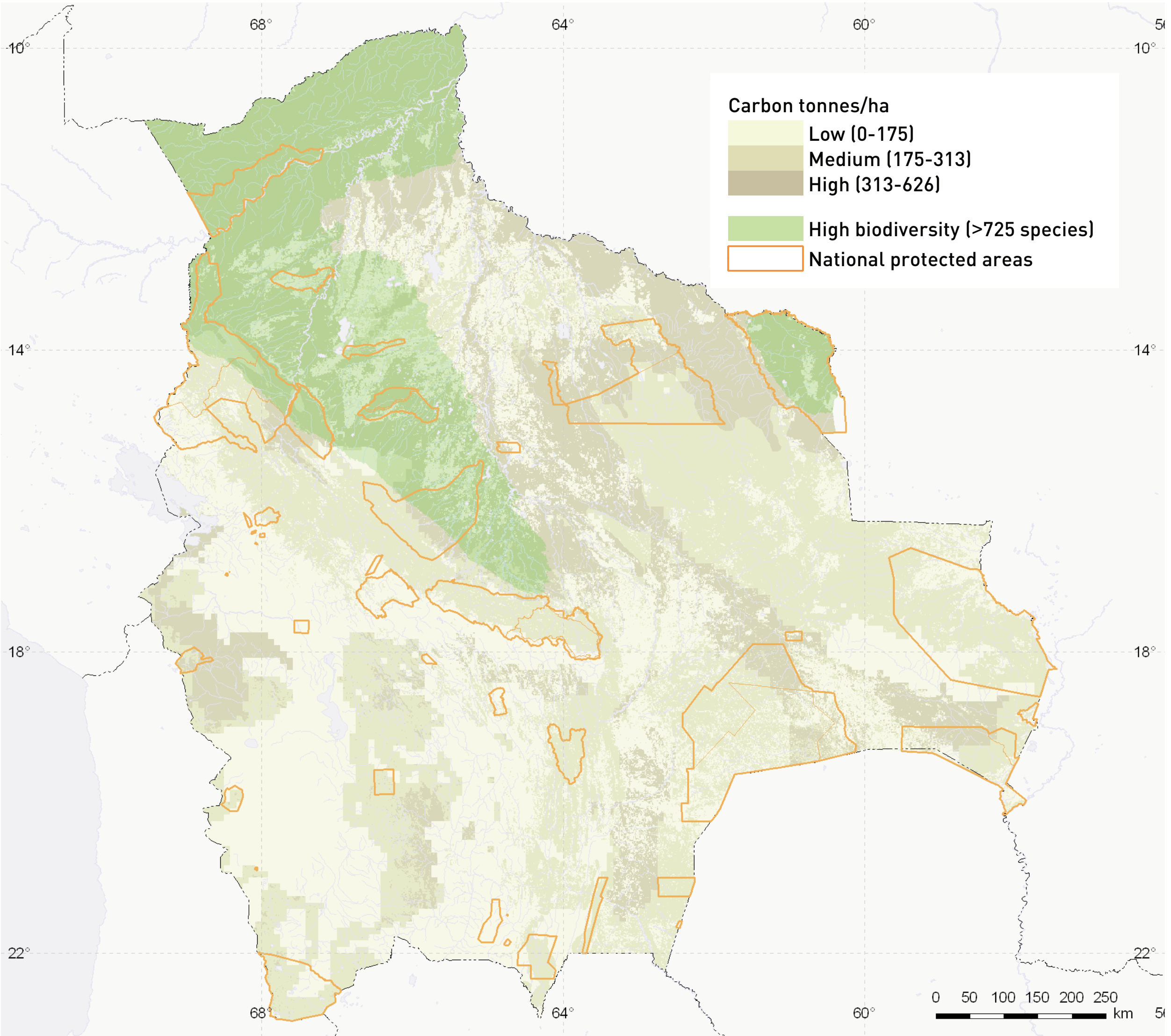


Country profile
Bolivia

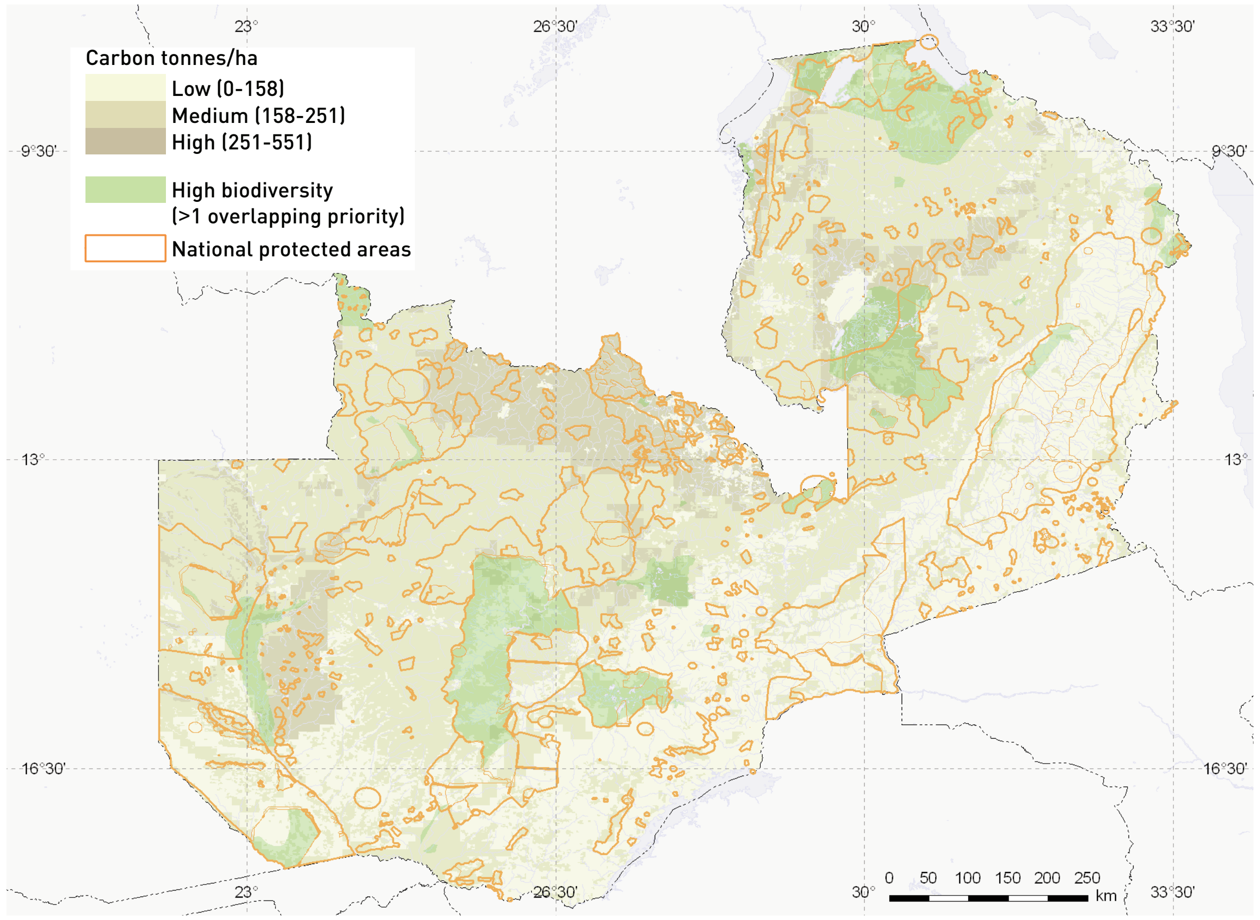


Bolivia covers 1.1 million km² of land across such varied terrain as the tropical Andes and Amazon rainforest, and is one of the most biodiverse countries in the world. The terrestrial ecosystems of Bolivia contain 21.8 GtC, of which 10 Gt are in the highest carbon areas. Protected areas cover 18 per cent of the high carbon land.

As for Panama, areas of high species richness in Bolivia have been identified using NatureServe data. A higher threshold of species richness was used in this case (the top fifth of cells - more than 725 species) to reflect the high levels of biodiversity in Bolivia. Of the high biodiversity areas identified according to this criterion, 21 per cent are contained within protected areas, as is 22 per cent of the land that is high in both carbon and biodiversity (see diagram, above).

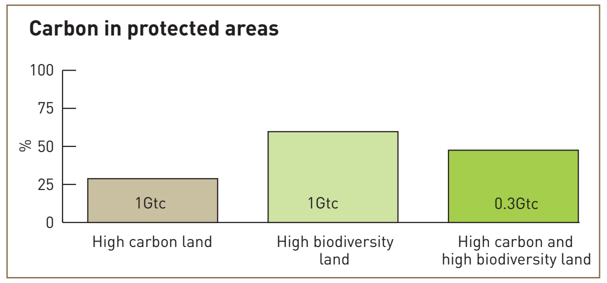


Country profile
Zambia



The land area of Zambia covers 750,000 km², and contains 15.6 GtC. The same global prioritisation schemes used for the regional maps are used to define high biodiversity in this case, with the addition of Important Bird Areas (IBAs; Birdlife International 2008b). IBAs hold large numbers of globally threatened, restricted range, and migratory bird species and are selected at the national scale using international criteria. Due to the low levels of overlap between global prioritisation schemes in Zambia, areas of 'high' biodiversity in this case are defined as any area in which two of the prioritisation schemes overlap. This illustrates the problems with scaling global data down to the national level.

The diagram (right) illustrates the extent to which protected areas cover high carbon and high biodiversity areas. It shows that 29 per cent of the carbon in high carbon areas and 60 per cent of the carbon in high biodiversity land is protected. Of the carbon that is stored in areas high in both carbon and biodiversity, 47 per cent is in protected areas.

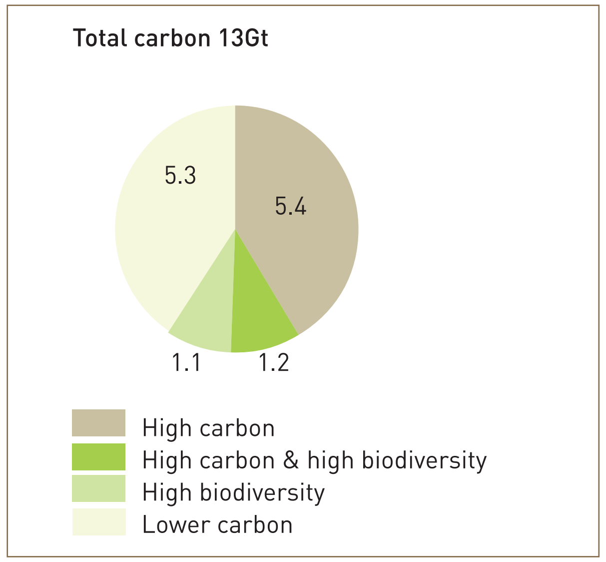


Country profile
Tanzania

Tanzania, on the east coast of Africa, covers a broad biogeographic range from the flat coastal plains and inland plateau regions to the mountainous regions of the Eastern Arc. Approximately one third of the country is covered by woodland and forest. The total land area of 950,000 km^2 contains a total carbon stock of over 13 Gt. More than half of this carbon is contained within high carbon areas (shown on the map in dark brown), principally in the mountainous regions, the Miombo forest of the west and south, and the coastal forest mosaic in the east.

Tanzania has more than 10,000 species of higher plants, and hundreds of vertebrate species. Particularly high levels of biodiversity are supported by the Eastern Arc Mountains, which form part of Conservation International's Eastern Afromontane hotspot, and the Coastal Forest hotspot region.

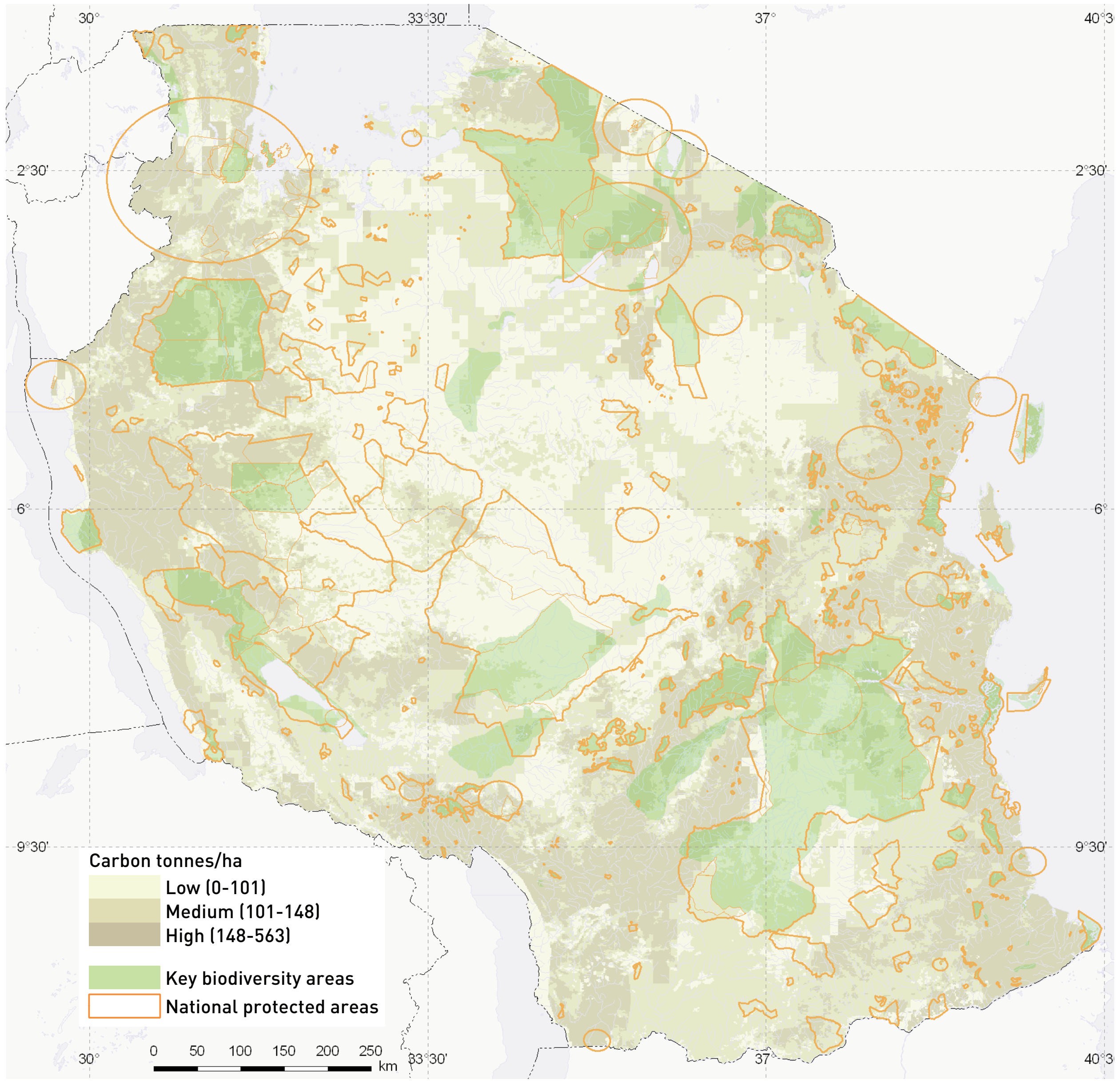
The biodiversity data shown in green on the demonstration map are based on Tanzania's Key Biodiversity Areas (KBAs; WCST *et al.* 2003), which include previously identified Important Bird Areas (Baker and Baker 2002). KBAs are places of international importance for the conservation of biodiversity; identified at a national level using simple, internationally defined criteria, based on their importance in maintaining populations of species. The international criteria relate to factors such as the global threatened status, range size, and distribution of species. It should be noted that the KBAs identify important sites for birds over



the entire country, but only include important sites for plants in the Eastern Arc and Coastal Forests hotspots.

The KBAs of Tanzania cover 17 per cent of the land area and contain 18 per cent (2 GtC) of the total carbon stock. It can be seen from the demonstration map that these high biodiversity areas coincide with high carbon areas across most of the country (see diagram, left). Areas high in both

Neil Burgess



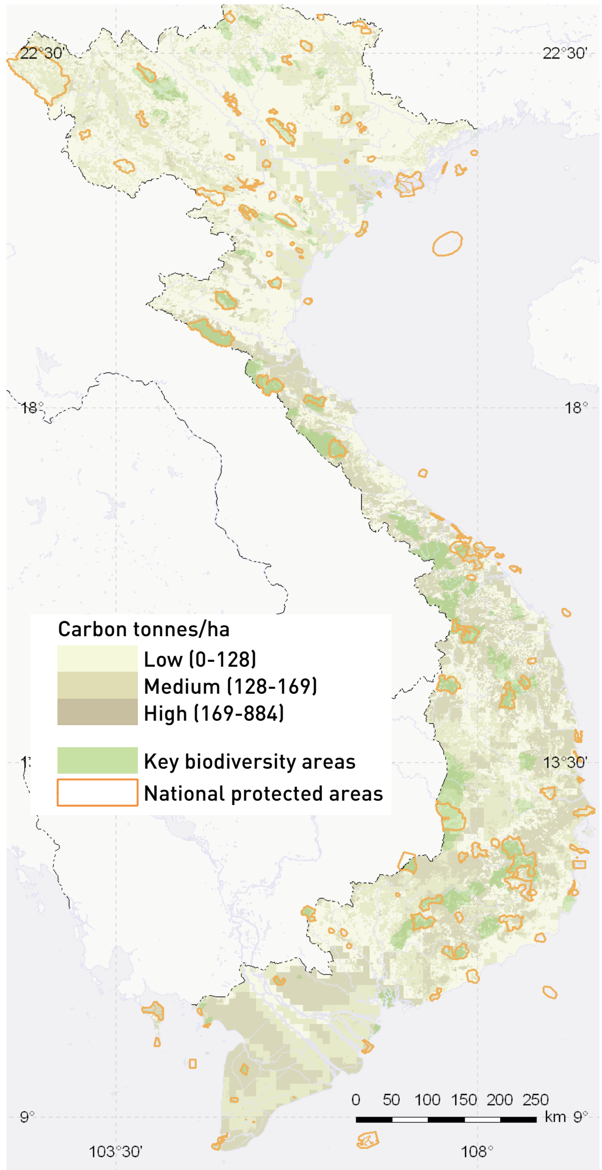
carbon and in biodiversity contain 9 per cent (1 GtC) of the total national carbon stock. Protection of carbon stocks in such areas could produce significant biodiversity conservation benefits.

It can further be seen that much of the high carbon, high biodiversity area in Tanzania is included in the protected area network, which includes an important network of forest reserves. However, there is a significant area of high carbon land that is not covered by any form of protected area, particularly to the west, southwest and east of the country, in the Miombo woodland and coastal forest mosaic habitats. It may be useful to assess how these high carbon areas relate to other measures of biodiversity (KBAs are just one approach) in order to identify the potential biodiversity benefits of REDD actions in these areas, and also to consider whether REDD actions there might displace land use pressures to areas of high biodiversity importance.

In addition, this analysis makes no assumptions as to how effectively the carbon and biodiversity within the protected area network are conserved. Significant amounts of carbon may still be released from these areas, particularly as some forest reserves allow timber extraction, and there is continuing loss of Miombo and forest habitats; including from within protected sites. This issue is further discussed in a case study of forest loss from within the protected areas of tropical Asia on page 22.

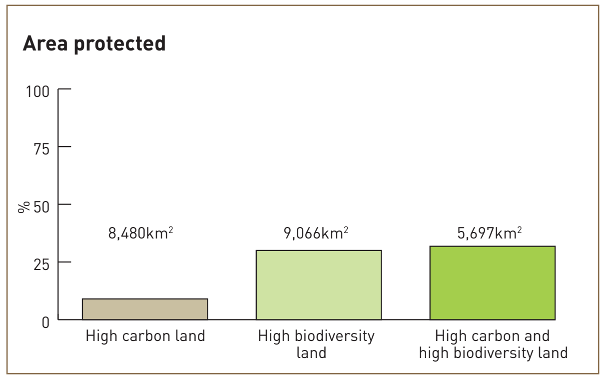
Country profile
Viet Nam

Viet Nam lies along the south-eastern margin of the Indo-Chinese peninsula. Three quarters of its 329,000 km² land area is hilly or mountainous, with river deltas and marshlands prominent in the coastal lowlands. Viet Nam's terrestrial ecosystems contain approximately 5.4 Gt of carbon. High carbon areas (shown in dark brown) run the entire length of Viet Nam, largely tracking the distribution of rain and monsoon forest, but are particularly prevalent in the carbon rich soils in the south in the delta of the Mekong River.

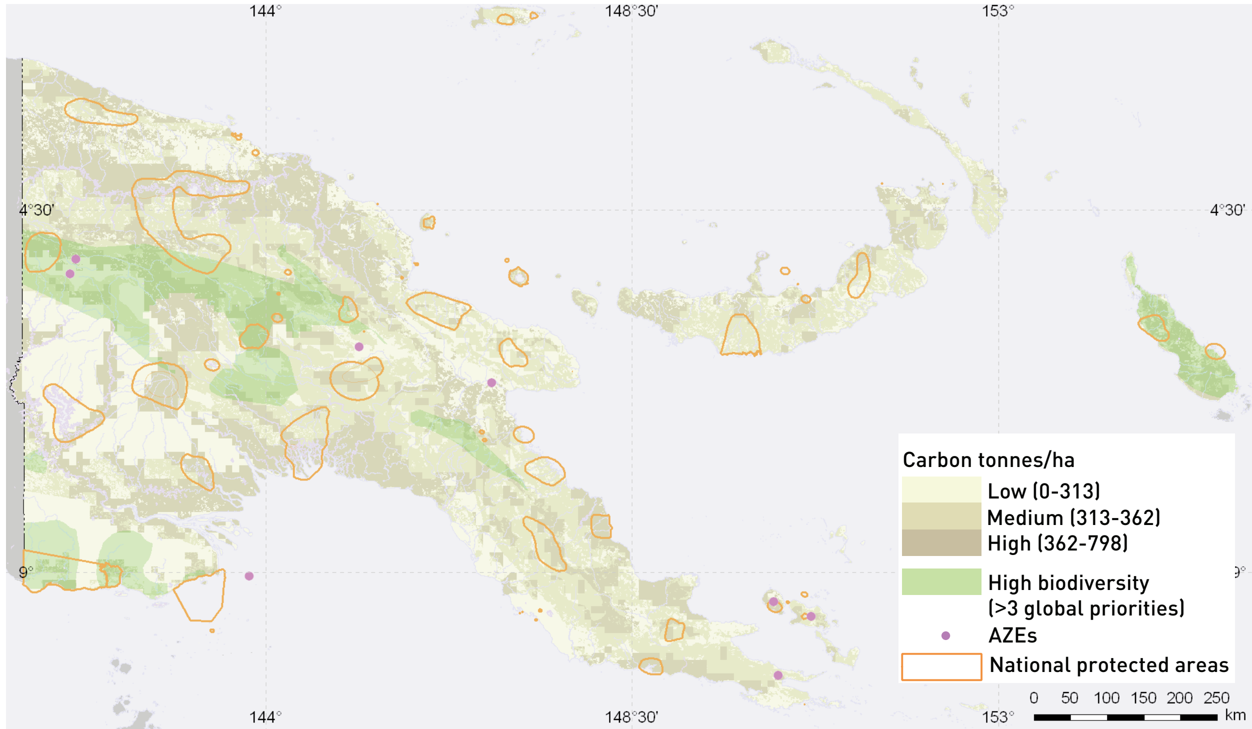


Viet Nam is high in biodiversity and endemicity, with more than 12,000 species of higher vascular plants, and hundreds of recorded species of mammals, birds, fish, amphibians, and reptiles, including several new species only recently discovered. The high biodiversity areas shown in green on the demonstration map are based on Viet Nam's Key Biodiversity Areas (KBAs; Birdlife Indochina *et al.* 2004), which have been identified at the national level using simple, internationally defined criteria, based on their importance in maintaining populations of species of birds, mammals, reptiles, amphibians, freshwater fish and plants (see page 18 for further details on KBAs). The map shows that much of Viet Nam's high biodiversity land (58%) is also high in carbon, and 19 per cent of the area with the highest carbon stocks is also important for biodiversity. Therefore, actions to reduce emissions from land use change in Viet Nam could have significant biodiversity benefits. In total, 0.4 Gt of carbon is stored in the areas with high values of both carbon and biodiversity.

Protected areas, shown on the map in orange, cover about 30 per cent of the land area that is of high importance for biodiversity. However, they overlap with only 9 per cent of the area with the highest carbon stocks. The diagram (below) shows that Viet Nam's protected area network covers 32 per cent of the land area that has been classified as having high values for both carbon and biodiversity.



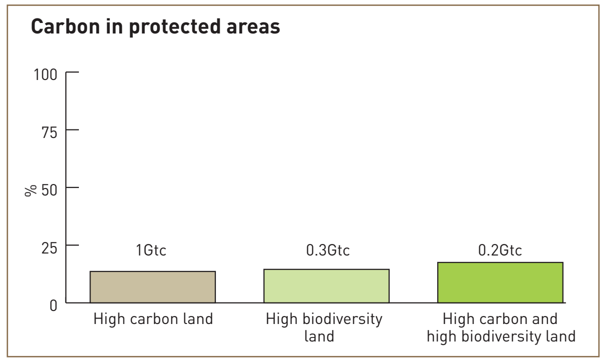
Country profile
Papua New Guinea



Papua New Guinea (PNG), a group of islands between the Coral Sea and the South Pacific Ocean, covers a land area of 463,000 km², including the largest tract of primary tropical forest remaining in the Asia-Pacific region; the third largest in the world. Reflecting this forest richness, the terrestrial ecosystems contain 16 GtC. The highest carbon densities, shown in dark brown on the map, are found in the mountains and coastal swamps, where high carbon contents in organic soils combine with large amounts of biomass carbon in high stature forests.

PNG has a high level of species richness, with a range of habitats including tropical heaths and grasslands, cloud forests, savannas, mangroves and swamp forest. The high biodiversity areas, shown in green, are areas in which four or more global biodiversity priority areas overlap (as in the regional maps). AZE sites, the last refuges for endangered species, are shown in purple. It can be seen that the centre of the country, which is high in biodiversity, also contains large areas of high carbon stock.

Protected areas, outlined in orange, overlap only a small proportion of the highest carbon areas. The diagram (below) illustrates some of the kinds of data that can be drawn from a spatial overlay of carbon and biodiversity with protected areas. It can be seen that protected areas contain 14 per cent of the carbon stock within high carbon land, and 14 per cent of the carbon in high biodiversity land. Of the total carbon stock in land that is high in both carbon and biodiversity, 17 per cent lies within protected areas.



Deforestation in protected areas: tropical Asia

Although the role of the existing protected area network within climate change mitigation policy (including REDD) is still under discussion, it is likely that establishment and management of protected areas is one of the strategies that countries will consider in seeking to reduce their emissions from land use change. The national maps show that many protected areas coincide with significant carbon stocks and areas of high biodiversity.

However, the designation of a protected area does not in itself guarantee protection of the carbon it contains. UNEP-WCMC has recently undertaken a study combining new MODIS-derived data on deforestation between 2000 and 2005 (Hansen *et al.* 2008) and data on protected areas established prior to 2000 from the World Database on Protected Areas (WDPA) to estimate the forest loss within protected areas of the tropical humid forest biome (Campbell *et al.* 2008b).

These analyses showed that although deforestation rates within protected areas (0.81 per cent) were lower than those outside (2.13 per cent), a significant area of forest (1.7 million ha), and therefore carbon, was still lost from protected areas in the humid tropical forest biome between 2000 and 2005. The greatest forest area loss was from the Neotropics, with Asia suffering the highest percentage loss. The estimates provided by this study are likely to be conservative, as they do not use the finer-scale Landsat calibrated data presented in the original study (Hansen *et al.* 2008).

It is clear, therefore, that the high carbon and high biodiversity lands already included within the protected area networks are not necessarily secure, and should not be ignored in climate change mitigation policy discussions. In some cases, actions to strengthen management of existing protected areas may be necessary and efficient measures for reducing carbon loss from land use change.

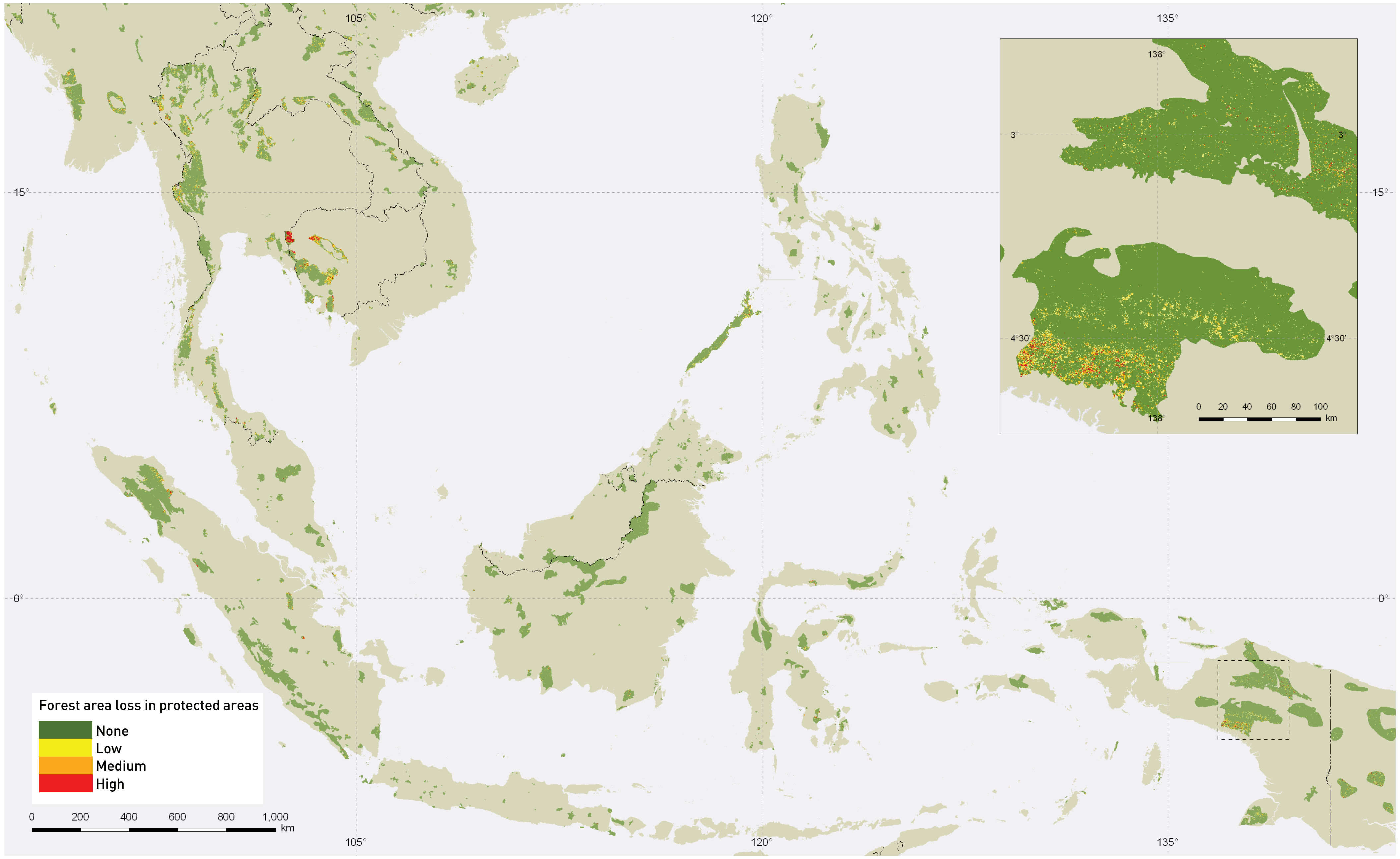
FOREST LOSS FROM PROTECTED AREAS

Tropical Asia had high overall rates of deforestation between 2000 and 2005 at 2.9 per cent, accounting for one third of all humid tropical forest area losses (Hansen *et al.* 2008). It also had the greatest percentage of forest loss within protected areas during the same period (1.33 per cent). These high rates of loss reflect the limited extent of remaining forests and the strong pressures to which they are subject.

The map presented here shows the spatial incidence of forest loss within the protected areas of humid tropical forest for a snapshot of tropical Asia. The green areas on the map illustrate land within protected areas in which no deforestation took place according to the MODIS deforestation data. The yellow, orange, and red areas are areas of low, medium, and high deforestation respectively.

Although many of the protected areas of tropical Asia show little or no forest loss, there are a number of areas of high deforestation, which mostly appear to occur at the edges of protected areas. In particular, loss of forest from protected areas can be seen on the southwest edge of the Indo-Chinese peninsula. Based on the carbon maps and a range of scenarios for land use following deforestation, the loss of forest from protected areas in humid tropical Asia between 2000 and 2005 has been estimated to have resulted in the loss of between 10 and 43 Mt of stored carbon (Campbell *et al* 2008b).

Whilst mapping is clearly an important tool for planning and monitoring conservation, it is only through effective management on the ground and monitoring of outcomes that policies aimed at preventing land use change can be effective in reducing emissions.



Next steps

The maps shown here demonstrate the potential of spatial analyses to assist in identifying areas where reducing emissions from land use change could help to secure important biodiversity values.

These approaches need to be developed further using national scale data on the distribution of carbon and biodiversity (and potentially other ecosystem services) that take into account national priorities and country-specific pressures. A particularly important aspect of REDD is the potential to affect local livelihoods, and it may be possible to incorporate socio-economic data into future mapping. It will also be important to develop an understanding of those areas with high importance for biodiversity but lower carbon stocks that may be vulnerable to land use pressures displaced by REDD actions in high carbon areas.

UNEP-WCMC will be developing these spatial analyses in 2009 in ways that will:

- be more comprehensive, covering a larger number of countries;
- include more accurate, national data on carbon and biodiversity where available;
- examine options for including ecosystem services and livelihood impacts;
- include mapping across the range of biodiversity value and carbon stocks, including areas of low carbon with high biodiversity and vice versa.

UNEP-WCMC aims to work closely with national authorities in developing this work, and will collaborate with other partners who are undertaking related spatial analyses. The atlas will be developed in a way that can take account of new information as it becomes available and it is likely that it will be primarily web-based. The aim is to produce a flexible tool that can assist countries in their decision-making in order to deliver multiple benefits from climate mitigation policies. We aim to launch a new atlas at UNFCCC COP 15 in December 2009, where a post-2012 agreement is to be decided.

FAO

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Carbon and biodiversity

Emissions from land use change, primarily deforestation, contribute to an estimated 20 per cent of total anthropogenic greenhouse gas emissions. Reducing these carbon emissions is likely to be important in climate change mitigation. The ways in which reduced emissions from deforestation and degradation (REDD) in developing countries can be included in a post-2012 agreement under the United Nations Framework Convention on Climate Change are currently being explored.

Many ecosystems that are high in carbon are also high in biodiversity, particularly in tropical regions. Tropical forest has the highest levels of terrestrial species richness on Earth. This gives tropical nations the opportunity to realise significant biodiversity benefits through reducing carbon loss.

This demonstration atlas shows the potential value of spatial analyses as a tool to assist tropical countries in maximizing biodiversity benefits whilst reducing carbon emissions from land use change. Using global data sets on carbon storage in terrestrial ecosystems and areas of high priority for biodiversity conservation, it provides regional overviews of the spatial overlap of these important values in the tropics. National-scale maps for six countries draw, where possible, on finer-scale nationally developed datasets and show where existing protected areas overlap with high carbon and biodiversity areas.

These maps illustrate how combining spatial datasets can help to identify areas where the opportunities for carbon and biodiversity benefits coincide. This approach needs to be developed further using national scale data on the distribution of carbon and biodiversity, taking into account national priorities and country-specific pressures.

UNEP-WCMC intends to expand this atlas in 2009, incorporating a wider range of country-based mapping, with the aim of assisting countries in their decision-making and informing climate change mitigation policy.

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