



# Carbon, biodiversity & ecosystem services: exploring co-benefits

## Cambodia





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#### ACKNOWLEDGEMENTS

UNEP World Conservation Monitoring Centre would like to thank BMU and BfN for financial support, including for the visit of a Forestry Administration of Cambodia staff member to Cambridge. Special thanks to the Forestry Administration of Cambodia, in particular Omaliss Keo, to Sum Thy and Uy Kumal from the Department of Climate Change, Ministry of Environment of Cambodia, So Vanna from the Department of Geography, Ministry of Land Management, Urban Planning and Construction of Cambodia, Tom Evans and Edward Pollard from Wildlife Conservation Society, Gill Bunting from BirdLife International, Arianna Granziera, Claire Brown, and Susan Walker from UNEP-WCMC. We are grateful to all those who provided datasets and information.

#### Available online at:

<http://www.unep-wcmc.org/climate/publications.aspx> OR  
[www.carbon-biodiversity.net](http://www.carbon-biodiversity.net)

Printed in XXX, by XXX.

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#### CITATION

Leng, C., Ravilious, C., Kapos, V., Bertzky, M., Osti, M., Clements, T., Dickson, B. (2010) *Carbon, biodiversity and ecosystem services: Exploring co-benefits. Cambodia*. UNEP-WCMC, Cambridge, UK.

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## Introduction

The maintenance and enhancement of natural carbon stocks is now considered a key climate change mitigation measure. Land-use change, primarily through tropical forest loss and degradation, is estimated to contribute between 6–17% of all anthropogenic greenhouse gas emissions (van der Werf *et al.* 2009).

Co-benefits are the positive impacts of Reducing Emissions from Deforestation and Forest Degradation, forest conservation, sustainable management of forest and enhancement of forest carbon stocks (REDD+) that are additional to emissions reductions. These include ecosystem and social benefits such as biodiversity and non-timber forest products.

## Cambodia

The Kingdom of Cambodia is located in Southeast Asia and spans 181 035km<sup>2</sup> (Kingdom of Cambodia 2010). It is home to over 13 million people (National Institute of Statistics Cambodia 2009). Cambodia is bordered by Thailand to its West and Northwest, Vietnam to its East and Southwest, and Laos to its Northeast (Map 1).

The climate of Cambodia is tropical, dominated by the annual monsoon cycle, which is accompanied by alternating wet and dry seasons. Cambodia is considered a high forest cover country: in 2006, 59% of the country was covered by forest (Forestry Administration 2007). The country is also home to the largest freshwater lake in Southeast Asia, the Tonle Sap Lake.

Potential co-benefits from REDD+ are widely relevant in Cambodia, where deforestation rates in recent years have been among the highest in the world (FAO 2007), and where

To support planning and decision-making at national and sub-national scales, spatial analyses must be based on data developed at an appropriate scale and should be done in consultation with a wide range of stakeholders to help prioritise among the different benefits and services under consideration.

This report presents results from spatial analyses of carbon distribution in relation to areas of high biodiversity priority, Protected Areas, land use management categories, and pressures (such as forest cover loss). A new national level map of terrestrial carbon in Cambodia has been produced for this analysis.

many people directly depend on forest resources. In 2008, for example, 85% of the country's population was still dependent on fuelwood (Convention on Biological Diversity National Focal Point Cambodia 2009).



**Map 1: Location of the Kingdom of Cambodia**

The Government has made considerable efforts to address the issue of deforestation in recent years. Under Cambodia Millennium Development Goal 7, the country aims to attain forest cover of at least 60% of the country by 2015 (Kingdom of Cambodia 2003).

## Developing a carbon map

### Cambodia's carbon stocks

Generating a map of Cambodia's carbon stocks required combining information from several sources. A map showing the spatial distribution of carbon stored in biomass was created from mapped data on land cover and forest cover and published values of biomass from field studies. This was then combined with a map of carbon stored in soil in order to create a total carbon map.

A map of forest cover in 2005/2006 was provided by the Forestry Administration of Cambodia (Technical Working Group on Forestry & Environment 2007). This map is considered the most recent and accurate for forest extent in the country. Where the dataset classified forest as 'other forest', a land cover map produced by the Japan International Cooperation Agency (JICA 2002) was used to further distinguish these areas. The same map was used for land cover in non-forest areas.

Where the JICA dataset classified areas as forest that were not considered forest according to the more recent forest cover dataset of the Forestry Administration, the closest non-forest land cover class was allocated to the respective pixels on the map.

Carbon values were assigned to the different land cover classes based on published values for biomass or carbon stocks in different vegetation types in Cambodia (Table 1, for more detail see Leng *et al.* in prep). Where no estimates from Cambodia existed, estimates from similar vegetation types of neighbouring countries were used. Where there were several published biomass or carbon values for a given vegetation type, we averaged the available estimates and applied the result. Biomass carbon values for soils and rocks, urban and built-up areas as well as water features were set to zero. They cover about 3% of the country's total area.

**Table 1: Total carbon (C) stock (Gt) and total carbon density (t/ha) for different land cover classes in Cambodia**

Land cover	Area [km <sup>2</sup> ] (%)	Total C Stock [Mt] (%)	Biomass Carbon Density (t/ha)	Sources used for estimate
Evergreen forest	37228 (20)	1019 (34)	191-211	National
Deciduous forest	47070 (26)	878 (30)	114-126	National
Semi-deciduous forest	13617 (7)	326 (11)	161-211	National
Bamboo & secondary /regrowth forests	2998 (2)	36 (1)	25-92	National
Bamboo	357 (<1)	4 (<1)	49	Regional (China)
Grasslands	10774 (6)	99 (3)	10	Regional (Vietnam)
Shrublands	10618 (6)	95 (3)	13	Regional (Vietnam)
Flooded forest & shrub	4367 (2)	38 (1)	8	National
Evergreen wood- & shrubland	960 (1)	8 (<1)	14	Regional (Vietnam)
Mangrove forest	334 (<1)	7 (<1)	142	Regional
Mixed forest	169 (<1)	4 (<1)	161-178	National
Riparian forest	144 (<1)	4 (<1)	94-205	National
Dry wood- & shrubland	371 (<1)	3 (<1)	11	Regional (Vietnam)
Degraded mangrove forests	176 (<1)	3 (<1)	85	National
Dry deciduous (open) forest	3 (<1)	<1 (<1)	78	National
Plantation (rubber)	854 (<1)	15 (1)	102	Regional
Agricultural lands	46001 (25)	396 (13)	5	IPCC global average

The biomass carbon map was then combined with a map showing the spatial distribution of carbon in different soil types of Cambodia. Due to the lack of national level soil carbon data, soil carbon was added from the Global Map of Terrestrial Soil Carbon Stocks by Scharlemann *et al.* (in prep.). In the resulting total carbon map for Cambodia the coarseness of the soil carbon data obscures the detail of the biomass carbon data and produces a visually misleading result. Therefore, the maps presented here display only data for biomass carbon in five carbon density classes (low, medium low, medium, medium high and high; see Map 2). Each class contains approximately 20% of the total carbon stock in the country. However, the statistical analyses are based on the total carbon data.

According to the carbon datasets generated for this analysis, a total of 2.96 Gt of carbon is stored in Cambodia’s ecosystems. About one third of this carbon is stored in the country’s evergreen forest (See Table 1). The largest areas

of very high carbon density are found in the forests of the South-West of the country. Figure 1 shows that the highest carbon density class, which holds 20% of the country’s carbon, covers 12% of the country’s land area. The two highest carbon density categories combined, which store approximately 40% of Cambodia’s carbon stock, represent 24% of its total land area.

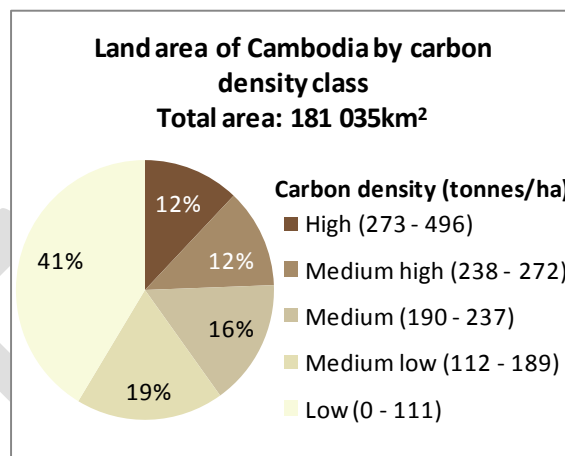
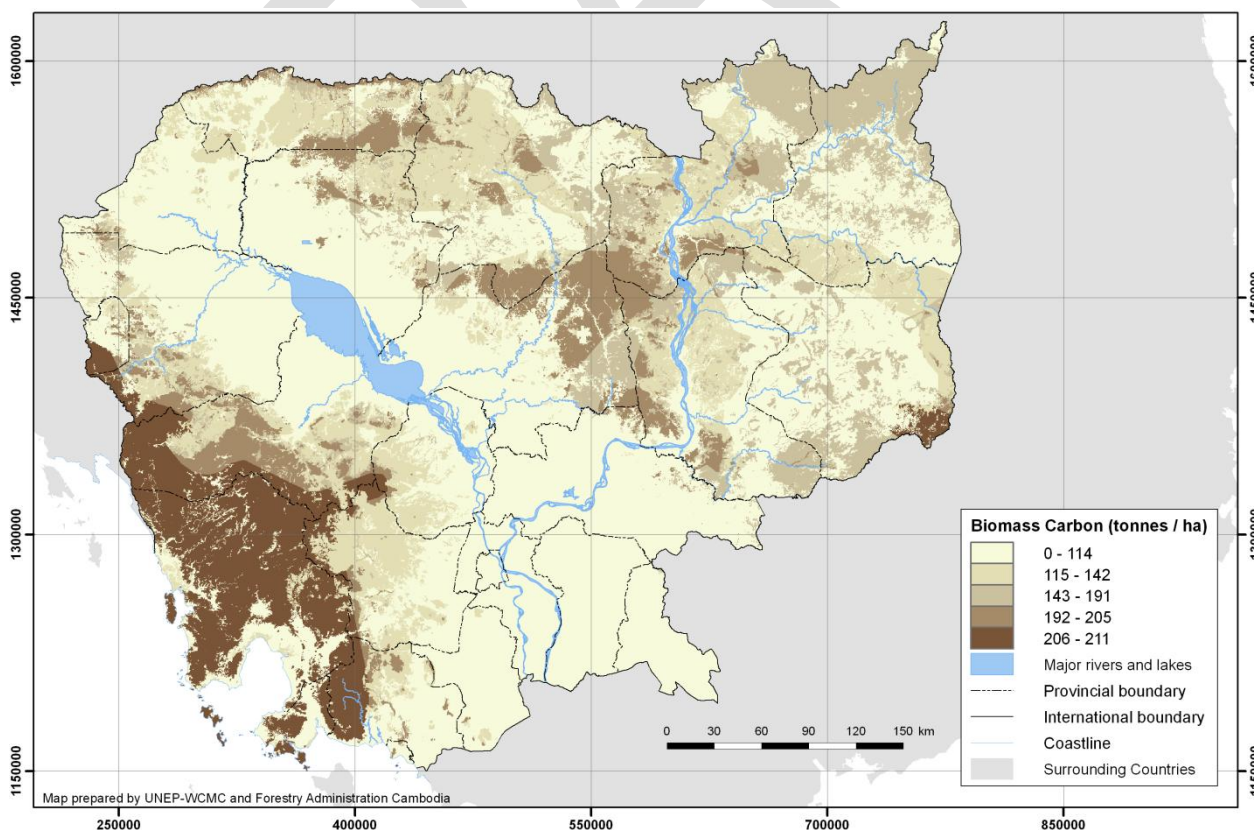


Figure 1: Distribution of land area in Cambodia according to carbon density classes.



Map 2: Biomass Carbon Map of Cambodia (Underlying data from Kingdom of Cambodia 2007, JICA 2002)

## Carbon and biodiversity

Cambodia is considered a country rich in biodiversity, and forms part of the Indo-Burma biodiversity hotspot (Myers *et al.* 2000). It is home to more than 2 000 known plant species, 500 birds, 100 mammals and 800 fish (Table 2).

**Table 2: Number of known and threatened species by taxon (Convention on Biological Diversity National Focal Point Cambodia 2009; IUCN 2010, modified by Wildlife Conservation Society Cambodia)**

Taxon	Known species	Threatened species
Vascular plants	2 308	31
Mammals	123	37
Birds	545	23
Amphibians	63	3
Reptiles	88	13
Fish	874	28

In order to determine how carbon distribution relates to areas of importance for biodiversity in Cambodia, datasets for Important Bird Areas (IBAs) and Key Biodiversity Areas (KBAs) (BirdLife International and Conservation International 2010) were combined and then overlaid with the carbon data. IBAs are nationally identified areas of importance for bird species. The IBA concept was developed in the early 1980s by Birdlife International (Osieck and Morzer Bruyns 2010), and has been applied in many countries worldwide since then. In 2009, there were almost 11 000 sites in 200 countries that had IBA status (BirdLife International 2010). A site can only be recognised as an IBA if it fulfils certain criteria, including whether key bird species are vulnerable to global extinction, or if their populations are otherwise irreplaceable.

KBAs include all IBAs but may also be nationally identified areas of importance for taxa other than birds. The identification of KBAs is based on a set of standardised criteria similar to those for birds but adapted to suit other taxa (Eken *et al.* 2004). KBAs and IBAs are not formally

Protected Areas; however, some or all of a KBA or IBA may fall under other formal national and/or international protection regimes.

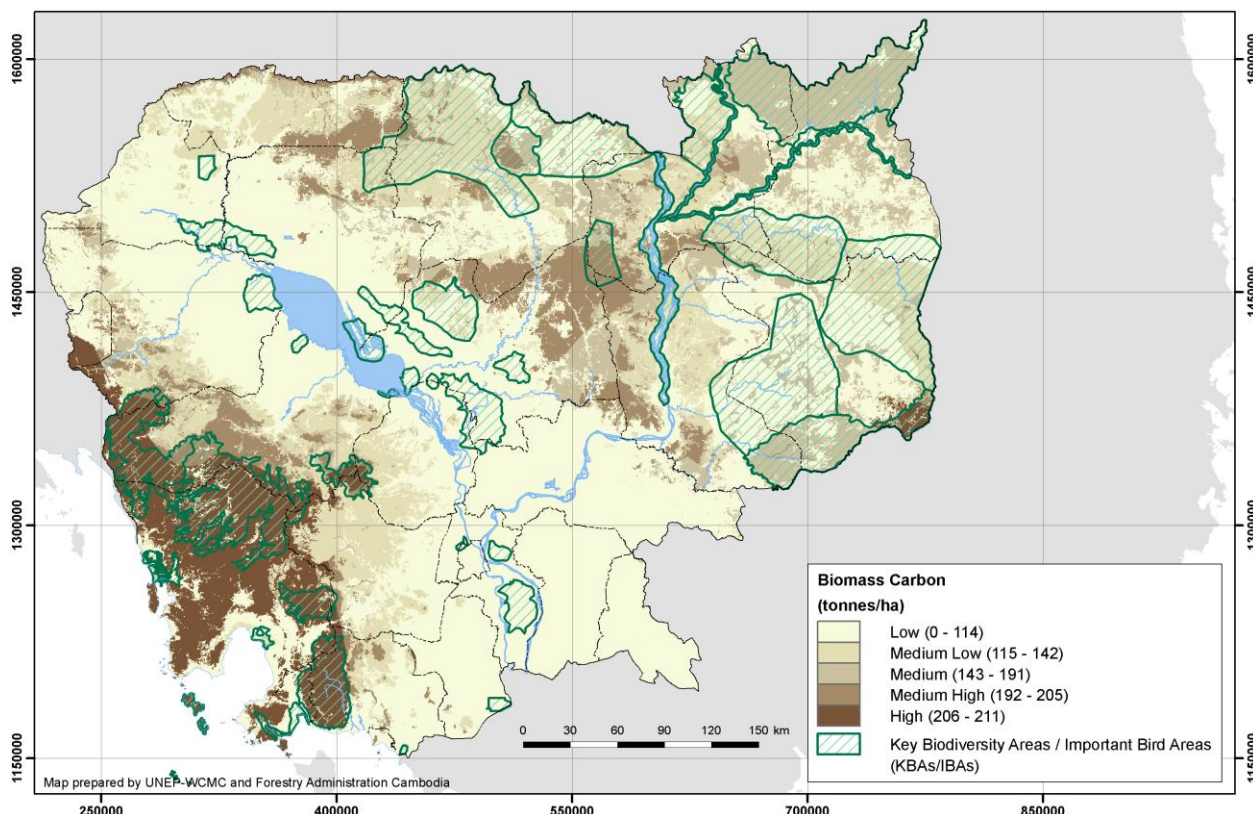
There are a total of 46 IBAs and KBAs covering 46 707km<sup>2</sup> of land across Cambodia (26% of the country by area). They are located mainly in the North-eastern and South-western regions of the country (Map 3). Additionally, there are some clusters of IBAs/KBAs in the vicinity of the Tonle Sap Lake, and along various river courses throughout the country.

Overlaying the IBAs/KBAs and the carbon data shows that almost one third (0.92 Gt) of Cambodia's terrestrial carbon stock falls within IBAs/KBAs. Twenty five percent of the 0.92 Gt is in areas of high carbon density, whereas more than 40% in areas of medium or medium-high carbon density (Figure 2). Eight percent of the terrestrial carbon stocks falling within IBAs/KBAs are in areas of low carbon density.

Analysis of the protection status of carbon stocks falling within IBAs/KBAs shows that almost 0.6 Gt of carbon within IBAs and KBAs is either in a Protected Area or a Protected Forest area (Figure 3). This means that approximately 64% of the carbon within IBAs/KBAs is under some type of protection status.



Photo: Sarus Crane (© Eleanor Briggs)



Map 3: Biomass carbon and Important Bird Areas/Key Biodiversity Areas (Data on IBAs/KBAs from BirdLife International and Conservation International 2010)

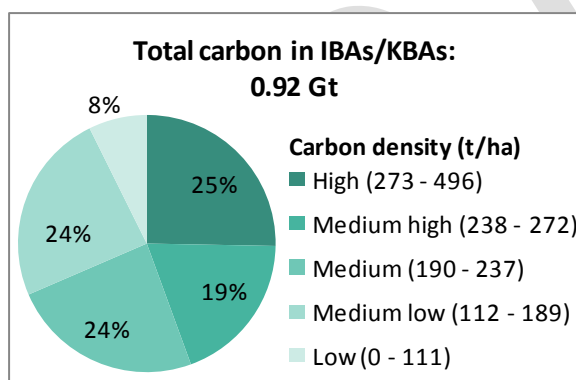


Figure 2: Distribution of total carbon within IBAs/KBAs across density classes

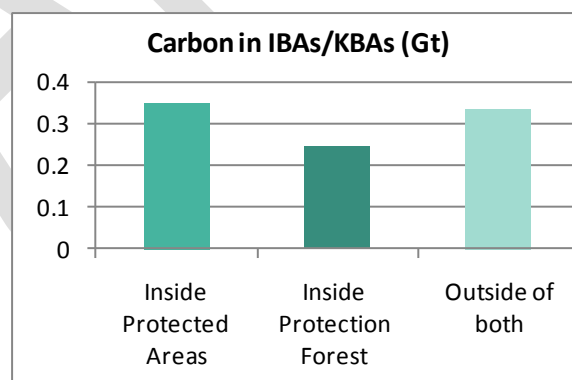


Figure 3: Protection status of carbon stocks within IBAs/KBAs

## Carbon, Protected Areas and Protection Forests

Protected Areas are nationally, and in some cases, internationally recognised areas that are managed to achieve long term conservation of nature, in line with the area’s ecosystem services and cultural values (Dudley 2008). In Cambodia, Protected Areas were established by the 1993 Royal Decree on Creation and Determination of Nature Reserves and the 2001

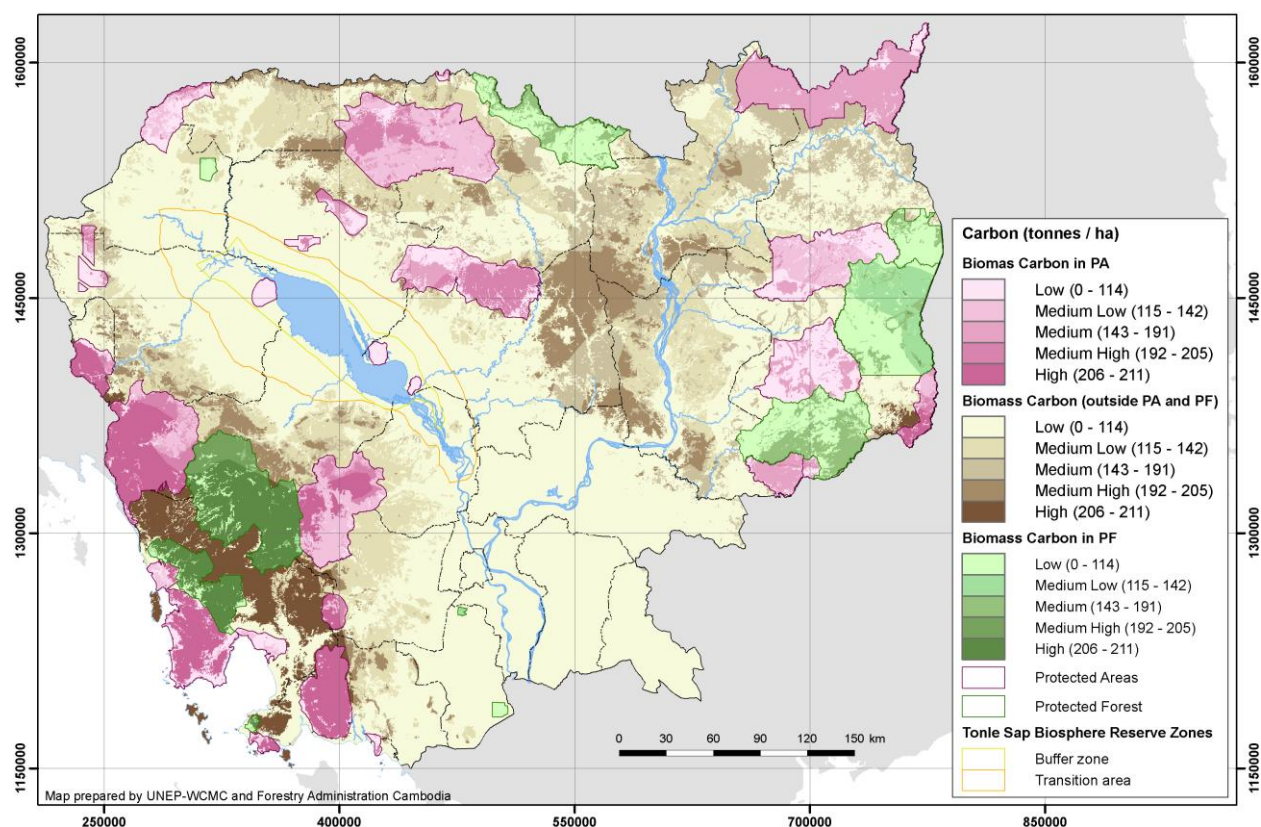
Royal Decree on the Establishment and Management of the Tonle Sap Biosphere Reserve, and are managed by the Ministry of Environment. More recently, the Royal Government of Cambodia has declared a number of Protection Forests under the 2002 Forestry Law, whose primary function is to protect forests’ ecosystems, which serve the

public interests. Unlike Protected Areas, however, Protection Forests are managed by the Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries. There are currently 27 Protected Areas and 10 Protection Forests in Cambodia, representing about 24% of the country's total land area.

A new spatially explicit dataset for Protected Areas and Protection Forests was developed by combining current records held in the World Database on Protected Areas (WDPA) (IUCN and UNEP-WCMC 2010) with more recent records from the Forestry Administration and Ministry

of Environment. Further updates to the layer were provided through expert input (Tom Clements, pers. comm.). The new layer was then overlaid with the carbon density map to calculate how much carbon is currently stored in Protected Areas and Protection Forests (Map 4).

About 21% of Cambodia's total carbon stock (0.62 Gt) is stored in its Protected Areas. An additional 11% (0.33 Gt) is stored within Protection Forests. Of the carbon in Protected Areas and Protection Forests, almost one third (0.31 Gt) is found in high carbon density areas.



**Map 4: Biomass carbon, Protected Areas and Protection Forests (Data on Protected Areas and Protection Forests from IUCN and UNEP-WCMC 2010, with amendments from the Forestry Administration Cambodia)**

## Carbon and other land management categories

Land management, or the use and development of land resources, comes in many forms and can include practices as varied as habitat conservation, agriculture and farming, and timber production. Understanding how carbon

density is distributed under different land management categories is useful, as the type of land management category can indicate whether carbon is likely to be protected or be exposed to pressure. Also, since land



management is fundamentally tied to the use of natural resources (including services provided by ecosystems), considering types of land management category may also indicate what ecosystem services are being provided in a given area. As progress on climate mitigation measures moves forward, an understanding of carbon distribution relative to land management categories will also prove crucial, as the appropriateness of different measures

will at least partly depend on the land management categories they fall under.

For Cambodia, the following land management categories were considered: protected areas, protected forests, community forestry areas, forest concessions, community fisheries areas, fishing lots (fisheries areas managed by concessionaires), and economic land concessions.

### Carbon, community forestry areas, and forest concessions

Community forestry areas are places where state forest has been allocated for the purposes of a management agreement between the state and a local community living within or nearby the forest area. The community is given responsibility for management and harvest of forest products, and in return receives social and ecosystem service benefits arising alongside the management of forest resources. In Cambodia, community forestry areas can only be located in production forests, and are regulated by the Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries.

The Community Forestry scheme is considered a key part of efforts to reduce rates of forest loss in Cambodia. Presently, there are more than 400 community forests, covering about 3 646 km<sup>2</sup> (2% of total land area). The country's National Forest Programme has set a goal of approving a further 20 000 km<sup>2</sup> of community forests in the near future. This will significantly increase the amount of land area designated under community forestry management.

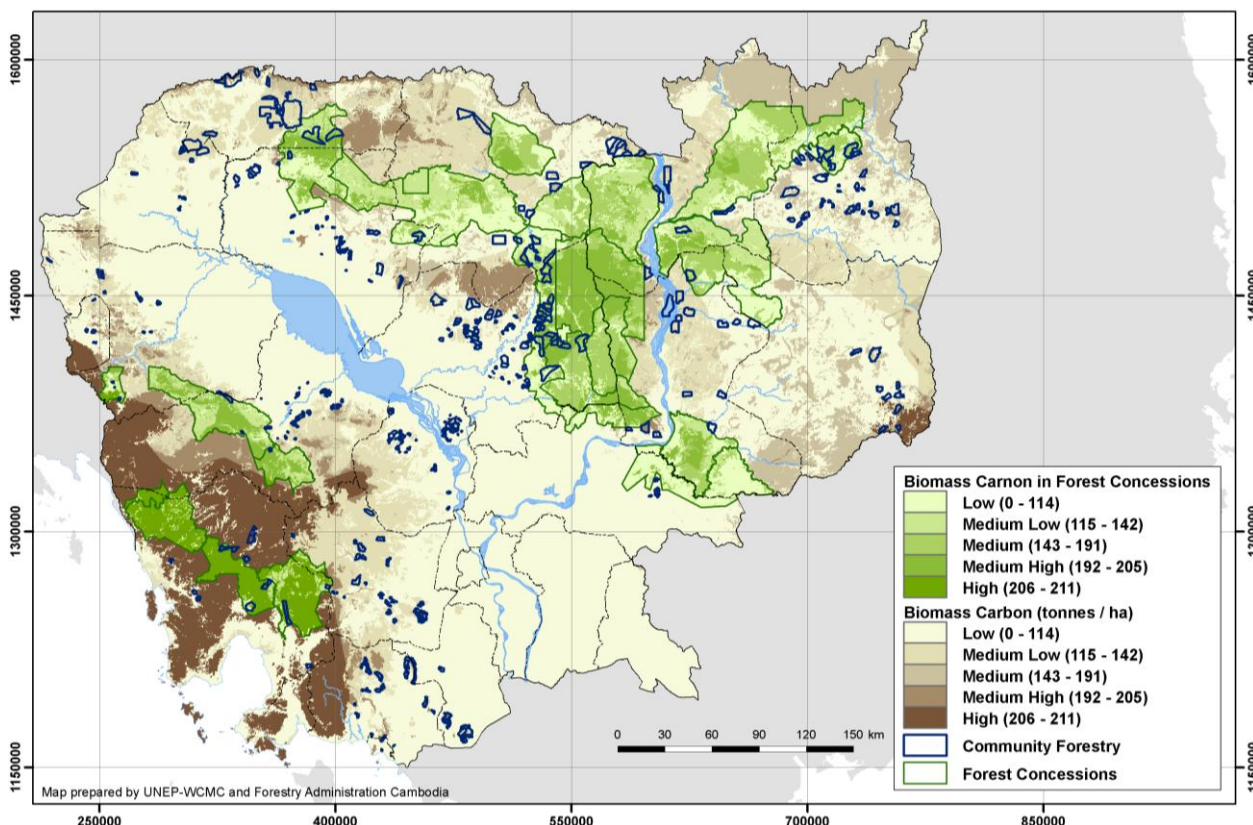
Forestry concessions, on the other hand are leased to other third parties such as private and state timber companies for the purposes of sustainable management and harvest of forest products and by-products. In Cambodia, forest concessions, according to the received data,

cover 34 391 km<sup>2</sup>, which is about 19% of Cambodia's total land area. It should be noted, however, that following the 2002 Forestry Law which declared a logging moratorium, activity within forest concessions has been suspended, with all concessions currently under state review.

Overlay results show that community forests currently store 0.07 Gt of carbon, which represents approximately 2.4% of Cambodia's total carbon stock. Of this, approximately 13% (0.01 Gt) is found in high carbon density areas. By contrast, forest concessions store 0.72 Gt of carbon, which accounts for 24% of Cambodia's total carbon stock. Of the 0.72 Gt, approximately 6% (0.17 Gt) is found in high carbon density areas.



Photo: Children in Pu Char village, Mondulkiri  
(© Edward Pollard / Wildlife Conservation Society)



Map 5: Community forestry areas, forest concessions and biomass carbon (Data on Forest Concessions and Community Forestry areas from the Forestry Administration Cambodia)

### Carbon, fishing lots and community fisheries areas

In Cambodia, fishing lots are areas of the freshwater fisheries domain which supply fish production, leased to a third party (the lot concessionaire) and regulated by the Fisheries Administration of the Ministry of Agriculture, Forestry and Fisheries. Community fisheries areas, on the other hand, are areas of the fisheries domain of the state which have been handed over to local community management under an agreement between the Fisheries Administration and the communities living inside or around the domain. Fishing lots and community fisheries areas in Cambodia cover a combined area of 12 434km<sup>2</sup> (7% of total land area). They are mostly situated in the floodplains along Tonle Sap Lake and in the Southeast region along the Mekong River.

Fishing lots and community fisheries areas hold 0.08 and 0.02 Gt of carbon respectively. Together, this represents approximately 3.4% of the total carbon within Cambodia. None of the carbon in fishing lots was in areas of high carbon density (see Figure 4 for fishing lots).

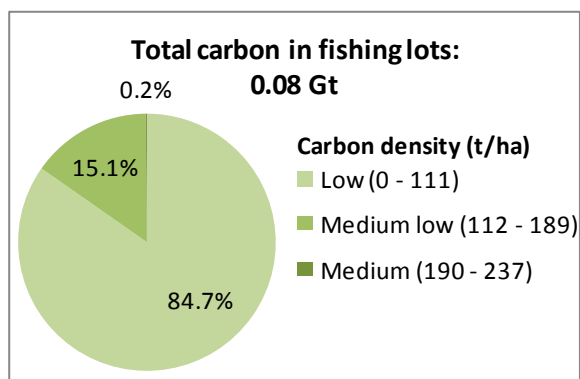


Figure 4: Distribution of total carbon within fishing lots across carbon density classes.

## Economic land concessions

Economic land concessions are blocks of land designated by the state and leased to third parties (concessionaires) for the purposes of agri-industrial development. According to the data received, Cambodia has over 160 economic land concessions, located mostly in the Northeast and Southwest regions, covering an area of 17 770 km<sup>2</sup> (10% of total land area).

Carbon overlay results show that 0.31 Gt of carbon is stored within economic land concessions, representing 10.5% of total carbon within Cambodia. Of this 0.31 Gt, 8% is found within areas of high carbon density (Figure 5).

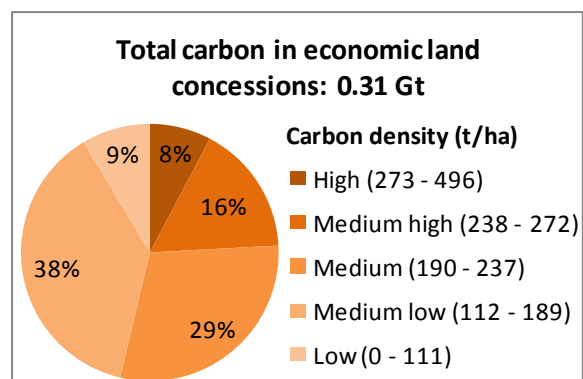


Figure 5: Variation in the density of carbon found within economic land concessions

## Comparison of results for different land management categories

Carbon storage varies greatly according to the land management category under consideration (Figure 6). For example, forest concessions store the most carbon (0.72 Gt), which is more than 30 times the amount of carbon stored in community fisheries areas (0.02 Gt), the land management category with the least carbon. This is not surprising, as forest concessions also cover the most area of all land management categories.

There is also a considerable amount of carbon (0.95 Gt) in land management categories that are more likely to conserve or protect carbon than endanger it (Protected Areas and Protected Forest areas). For carbon in land management categories which are more likely to endanger carbon stocks, the picture is less clear. Whether carbon is at risk will highly depend on the management practices adopted under each category.

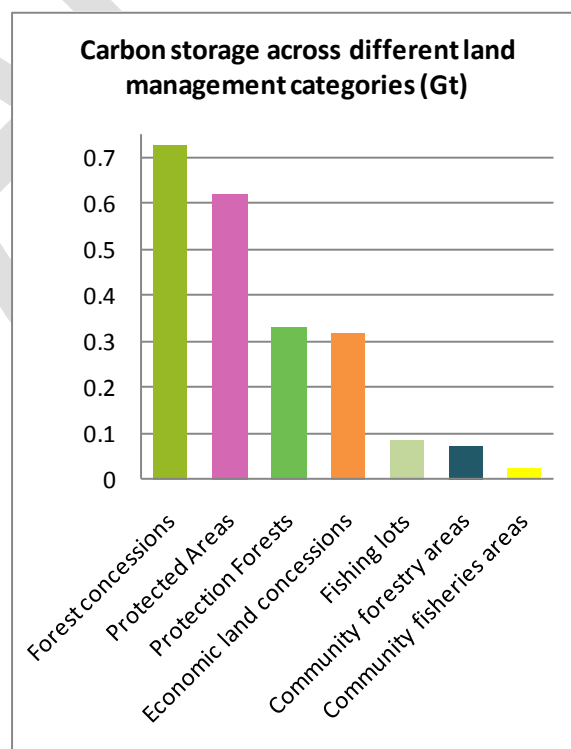


Figure 6: Variation in the storage of carbon across different land management units

## Pressures on carbon

### Forest cover loss

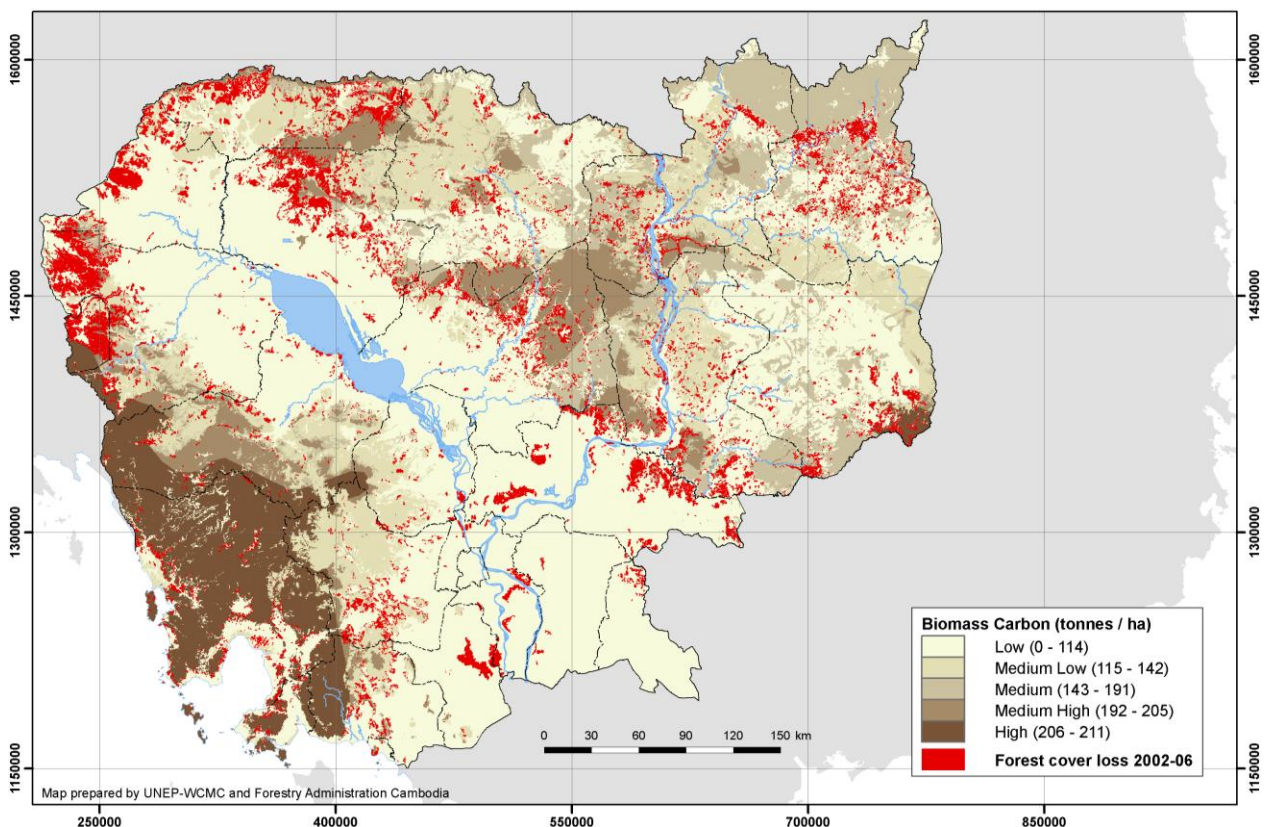
Forest cover loss represents a major challenge for Cambodia (Map 6). Between 2002 and 2006, Cambodia lost approximately 3 735km<sup>2</sup> of forest, reducing the country's total forest cover from 61% to 59% (Forestry Administration 2007). This places the country slightly below its Millennium Development Goal (MDG) target of 60% forest cover.

To understand how carbon density is distributed around areas of recent forest cover loss, a series of 1, 2 and 5km buffers were created around spatial data showing areas of forest cover loss between 2002 and 2006 (Technical Working Group on Forestry & Environment 2007). These buffers were then overlaid with Cambodia's national carbon map. Results show that of the 0.64 Gt of carbon

within 1km of forest cover loss, 17% (0.11 Gt) was in high carbon density areas. The proportion of high density carbon within a 2km buffer remained the same, at 17% of total carbon (1.1 Gt) within the buffer, and rose slightly to 19% of total carbon (1.9 Gt) within a 5km buffer.



Photo: Deforested land (© Edward Pollard / Wildlife Conservation Society)



Map 6: Pressures on biomass carbon: forest cover loss (Data on forest cover loss from Technical Working Group on Forestry & Environment 2007)

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## Conclusions

### Carbon and co-benefits

Whilst there are substantial areas of Cambodia with both high carbon stocks and high biodiversity priority, some areas of importance for biodiversity fall into lower carbon regions. Such information is crucial for guiding decisions on climate change mitigation. In areas where biodiversity importance is high, but carbon density is low, it is less likely that forest carbon management initiatives such as REDD+ will be implemented. On the other hand, where both values are high, carefully chosen actions, such as including more high carbon lands in

Protected Areas, may help to secure biodiversity and ecosystem services as co-benefits from REDD+.

Land management regimes will also need to take account of the carbon values stored within different land management units. Decisions on actions under REDD+ should take account of the many uses and values of these areas, and attempt to secure as many of their co-benefits as possible.

### Outlook

These results represent a first step in exploring the co-benefits of carbon conservation under a REDD+ initiative in Cambodia. Certain issues have been identified that should be addressed in future work on carbon and co-benefits in Cambodia. The national carbon map, for instance, could benefit from further development and improvement, such as incorporating a national scale soil carbon map. Also, while some datasets used in the analyses indicated the nature and provision of ecosystem

services (e.g. fishing lots, community forestry areas), they were not a measure of ecosystem services per se. Future work should involve the integration ecosystem services datasets (e.g. maintenance of watersheds, soil erosion protection, non-timber forest products) if and when these become available. Finally, use of additional datasets which give an indication of other pressures on carbon (e.g. population density, poverty) would also be useful.

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Black-shanked Douc: Courtesy of Rob Tizzard



The benefits of actions to maintain and enhance carbon stocks for climate change mitigation can be increased by taking into account the distribution not only of carbon, but of other ecosystem services, such as biodiversity. Here, we map the distribution of carbon stocks in relation to that of biodiversity in Cambodia. Other relevant factors, such as protected area distribution and land management units are also related to carbon and biodiversity distributions. A new map of carbon in Cambodia's ecosystems has been produced for this analysis.



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Federal Ministry for the  
Environment, Nature Conservation  
and Nuclear Safety



Federal Agency  
for Nature  
Conservation

