Mapping potential biodiversity benefits from REDD+

The Democratic Republic of the Congo

UN-REDD PROGRAMME

FAO UNDP UNEP

République Démocratique du Congo
Ministère de l'Environnement,
Conservation de la Nature et Tourisme

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The UN-REDD Programme is the United Nations collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD+) in developing countries. The Programme was launched in 2008 and builds on the convening role and technical expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP).

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Executive summary

The maintenance and careful management of forest carbon stocks can make an important contribution to global climate change mitigation. However, pressures on forests continue to be high, particularly in forest-rich developing nations. The United Nations Framework Convention on Climate Change (UNFCCC) is addressing this issue through the development of REDD+, a mechanism incentivising the reduction of emissions from deforestation and forest degradation, as well as the conservation of forest carbon stocks, sustainable management of forests and the enhancement of forest carbon stocks.

In addition to its potential to benefit the climate, REDD+ has potential to benefit biodiversity and ecosystem services, i.e. it can realise multiple benefits. However, there is also a need to avoid any risk of environmental harms from REDD+, for example when plantations of non-native species are used to enhance carbon stocks in areas of importance for biodiversity.

Many developing countries have started preparing for REDD+, including by setting goals for multiple benefits. These goals will need to be informed by the Cancun safeguards that address a number of social and environmental issues; but in planning for multiple benefits from REDD+, countries will also need to identify and balance preferred options according to their context-specific priorities and needs. Spatial analyses of the relation between biomass carbon stocks, biodiversity, land use designations and pressures on forests can help to understand potential benefits and risks from REDD+, and thus to evaluate possible REDD+ actions and identify preferred options. Here we present selected results of spatial analyses to explore biodiversity benefits and risks from REDD+ in the Democratic Republic of the Congo (DRC).

Our results confirm that there is great potential to realise benefits for biodiversity from REDD+ in the DRC. Areas that store large amounts of biomass carbon overlap with the occurrence ranges of great apes and Important Bird Areas. Effective and sustainable management of existing land designations, such as protected areas, forest and mining concessions, will be important to reduce environmental harm and secure the valuable assets they contain. The locations of recent forest cover loss show the link between forest roads and deforestation, and help identify where continued deforestation is more likely to happen. These spatial analyses will help ensure that REDD+ implementation realises multiple benefits. They can do so by: supporting the application of national-level social and environmental standards; informing the development of REDD+ scenarios; and by communicating the potential for multiple benefits from REDD+. Going forward it will be possible to build on the analyses by using improved data on carbon stocks in the DRC and by incorporating spatial data on forest ecosystem services.

Introduction

An estimated 15 per cent of all anthropogenic greenhouse gas (GHG) emissions are caused by deforestation and forest degradation, including peatland emissions (van der Werf *et al.* 2009). The maintenance and careful management of forest carbon stocks can therefore make an important contribution to global climate change mitigation. However, pressure on forests continues to be high, particularly in forest-rich developing nations. The United Nations Framework Convention on Climate Change (UNFCCC) is planning to address this issue through REDD+, a mechanism incentivising five key activities:

1) reducing deforestation,
2) reducing forest degradation,
3) conservation of forest carbon,
4) sustainable management of forest, and
5) enhancement of forest carbon stocks (Figure 1).

The aim is for REDD+ to significantly reduce

emissions and increase removals of carbon dioxide whilst promoting the sustainable development of the nations involved.

When forests that would have been lost or degraded are retained, restored or better managed through REDD+, they deliver benefits beyond carbon. The term 'multiple benefits' covers both the global climate change mitigation benefits from REDD+ and any additional social or ecosystem-based benefits. Social benefits arising directly from REDD+ implementation may include jobs, clarification of land tenure, improved livelihoods resulting from carbon credit payments or enhanced participation in decision-making under stronger governance. Ecosystem-based benefits may include forest biodiversity conservation and ecosystem services[1], such as water regulation, soil conservation and the provision of timber, food and other non-timber forest products.

There is a risk of environmental harms, as well as an opportunity for multiple benefits, from REDD+. These harms can include adverse impacts on areas not targeted by REDD+ activities, for example arising from displacement of land-use change, and direct impacts of REDD+ activities such as the development of planted forests in areas of importance for biodiversity. The decisions from the 16th Conference of the Parties to the UNFCCC (Cancun Agreements) include safeguards for REDD+, which countries are asked to promote and support. These are designed to reduce risks and increase the opportunity for multiple benefits.

Many developing countries have started preparing for REDD+. Such national preparation processes can include, among others, the development of methods and tools for measuring greenhouse gas emissions and forest carbon flows, stakeholder consultations, and assessments of drivers of deforestation and forest degradation. Many countries are also setting goals for realising multiple benefits from REDD+.

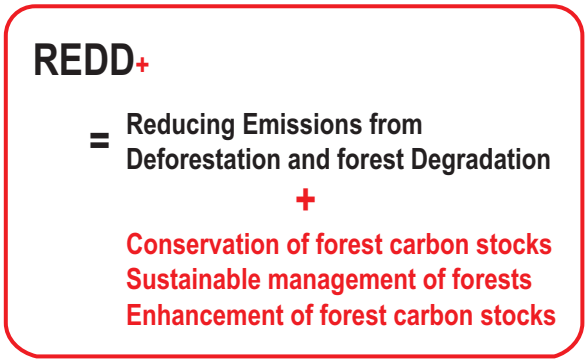


Figure 1: REDD+ activities

In planning for multiple benefits from REDD+, countries will need to identify preferred options according to their context-specific priorities and needs. They may need to balance different options against each other, and consider that prioritising one option may adversely affect another option. The likely cost of implementing REDD+ in different locations may further influence the selection of preferred options. Increasing awareness of the complexity of this decision-making process has led to the development of guidance and tools to assist countries in this. They include interactive online tools that can help in understanding potential benefits and risks, guidance documents, e.g. on methods for assessing and monitoring change in benefits from REDD+, as well as examples and tools for spatial analyses of multiple benefits from REDD+.

This report presents spatial analyses as a contribution to preparing for biodiversity benefits from REDD+ in the Democratic Republic of the Congo (DRC).

[1] Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fibre; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling (Millennium Ecosystem Assessment 2005).

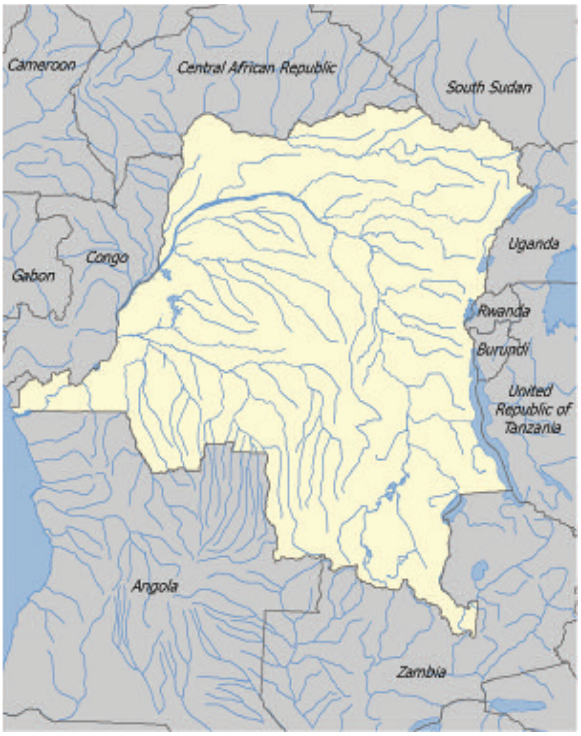
REDD+ and the UN-REDD Programme in the DRC

REDD+ presents an opportunity to address the issue of deforestation and forest degradation in the DRC, while at the same time supporting sustainable development of the country.

The UN-REDD Programme, i.e. the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries, assists countries to prepare for REDD+. The DRC was one of the first nine countries to receive financial support from the UN-REDD Programme for its REDD readiness activities. The country's REDD+ strategy has two main aims: reducing emissions from deforestation and forest degradation, and reducing poverty in line with the DRC's Poverty Reduction Strategy (Ministry of Environment, Nature Conservation and Tourism 2010).

To make it possible to achieve these aims, the DRC's Readiness Plan for REDD includes activities addressing the country's governance system, economy, socio-cultural context and its environment. It also recognises the importance of understanding and addressing the synergies and trade-offs between REDD+ and both ecosystem services and biodiversity conservation in the DRC.

Forests in the DRC



Map 1: Location of the Democratic Republic of the Congo in Sub-Saharan Africa

The Democratic Republic of the Congo, covering more than 2.3 million square kilometres of land, is the second largest nation in Africa. The country is located in the heart of Sub-Saharan Africa and is bordered by the Central African Republic and South Sudan to the north, Uganda, Rwanda, Burundi and Tanzania to the east, Zambia and Angola to the south, and the Republic of Congo and the Atlantic Ocean to the west (Map 1). With more than 150 million hectares of forest, the DRC has the sixth largest forest area in the world (FAO 2010; FAO 2011b; World Resources Institute and Ministère de l'Environnement, Conservation de la Nature et Tourisme de la République Démocratique du Congo 2010). Currently, the DRC's annual deforestation rate is relatively low (an estimated 0.2 per cent of forest was lost per year between 2000 and 2010, FAO 2011a). Reasons for this low rate include the collapse of the DRC's timber industry during the civil war (Draulans and Van Krunkelsven 2011) and poorly developed and war-damaged infrastructure (Foster and Benitez 2010). However, despite the relatively low deforestation rate, the absolute area of forest lost each year is large at an estimated 311 000 hectares per year, the seventh highest annual forest area loss globally (FAO 2011a).

The forests of the DRC cover more than 60 per cent of its national territory and represent nearly half of Africa's rainforests; they are the second largest block of tropical forest in the world (Eba'a Atyi and Bayol 2009; Seyler *et al.* 2010). Eleven different forest types can be distinguished: swamp forest, tropical lowland rainforest, tropical submontane rainforest (between

500 and 1 500 metres of altitude), three types of afromontane forest, Zambezian dry forest (*Muhulu*), Zambezian woodland (*Miombo*), Sudanese woodland, coastal sclerophyllous forest and mangroves (Ministère de l'Environnement, Conservation de la Nature et Tourisme 2009).

According to the country's Forest Code of 2002, the forest is owned by the state (République Démocratique du Congo 2002). Three main categories of forest areas are distinguished:

1) permanent production forests;
2) protected forests; and
3) classified forests.

Permanent production forests include forest areas that were under concession or otherwise used for timber production before the Forest Code came into force. In these forests, industrial logging concessionaires are required to apply sustainable management practices. Protected forests can include small-scale farming areas and community forests, but concession contracts of less than 25 years can also be granted for these areas. Classified forests are established with the main aim of environmental protection and include nature reserves, forests located in national parks and hunting areas, among others (Eba'a Atyi and Bayol 2009).

A preliminary analysis identified four major drivers of deforestation and forest degradation in the DRC: farming and fire wood harvesting around urban zones, where human population density is high and still increasing; commercial logging and related road infrastructures and settlements; mining and related road infrastructures and settlements; and informal logging in easily accessible areas (Ministry of Environment, Nature Conservation and Tourism 2010). Through their impacts on forests, these activities are also having major impacts on the country's biodiversity.

Biodiversity in the DRC

Due to its species richness and high level of endemism, the DRC is considered one of the world's seventeen megadiverse countries (Mittermeier *et al*. 1999). It contains four different floristic regions:

1) a mountainous forest region with a number of big lakes in the east of the country;
2) a narrow band of woody and herbaceous savannah in the north;
3) the Guinea-Congolean forest massif covering the central basin; and
4) a band of woody savannah that connects the Guinea-Congolese region with the Zambezian zone south of the equator
(Ministère de l'Environnement, Conservation de la Nature et Tourisme 2009).

The mountain forest in the east is part of the Albertine Rift Valley that belongs to the Eastern Afromontane Biodiversity Hotspot, which is famed for harbouring the largest numbers of endemic bird species, mammal species and amphibian species across the African continent (Conservation International 2011). Among the iconic mammal species occurring in the DRC are okapi and white rhinoceros, the Endangered bonobo and common chimpanzee and the two Endangered subspecies of the eastern gorilla (mountain gorilla and eastern lowland gorilla). Despite the large number of species known to occur

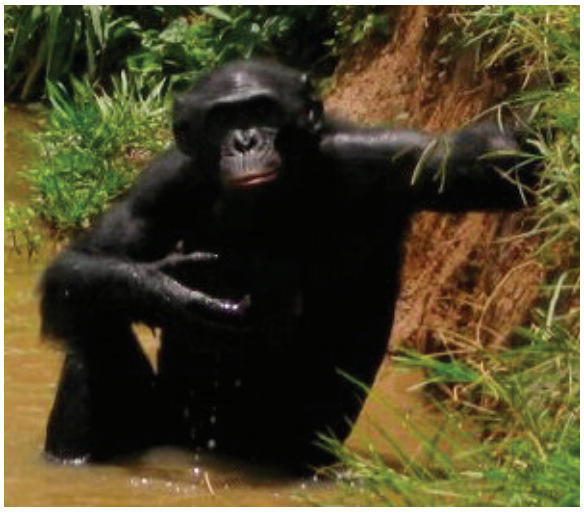


Table 1: Number of known and threatened species of the DRC by taxonomic group

Taxonomic group	No. of known species[1]	No. of threatened species[2]
Reptiles	352	4
Amphibians	168	14
Birds	1 086	32
Mammals	421	30
Aquatic vertebrates	1 606	5
Vascular plants	>10 000	83

[1]IUCN 2011; [2]Ministère de l'Énvironnement Conservation de la Nature et Tourisme 2009

in the DRC (Table 1), taxonomic inventories for the country are still far from complete (Ministère de l'Environnement, Conservation de la Nature et Tourisme 2009), especially for invertebrates.

The government of the Democratic Republic of the Congo is committed to conserving the country's rich biodiversity; however, threats to biodiversity persist, including deforestation and habitat degradation, illegal logging, poaching and the introduction of invasive species. Conservation efforts have also been seriously affected by the First and Second Congo Wars (1996, 1998), and today's continuing armed conflict in some parts of the country renders conservation activities in these areas both difficult and dangerous (Ministère de l'Environnement, Conservation de la Nature et Tourisme 2009).

Spatial analyses as a tool to explore the synergies and trade-offs of REDD+ for biodiversity

In the results-based phase of REDD+, payments will be linked to contributions to climate change mitigation made by forest based actions: Reduced deforestation and forest degradation can help reduce carbon dioxide emissions, sustainable management of forest and conservation of forest carbon stocks can help avoid such emissions, and enhancement of forest carbon stocks can help remove them. When considering the synergies and trade-offs between REDD+ and biodiversity, it is helpful as a first step to understand the spatial relationship between carbon stocks and areas of biodiversity importance. This requires an overview of the spatial distribution of carbon stocks. Field plot data of forest carbon in different vegetation types and from different locations in the DRC would be most appropriate to use in the generation of such an overview. However, in the absence of such data, best available regional and global data were used to generate a preliminary biomass carbon map for the DRC (see Annex I for method and Annex II for more detail on the limitations of the data). This preliminary map was then overlaid with spatial data on biodiversity and conservation priorities, protected areas, forest and mining concessions, recent forest cover loss, roads, and conflicts in order to:

- help illustrate where REDD+ could secure biodiversity benefits in addition to maintaining carbon stocks;
- present the distribution of carbon stocks in relation to existing land use designations (such as protected areas) that may affect planning and options for REDD+; and
- highlight where areas of importance for ecosystem-based multiple benefits may be under pressure, e.g. from deforestation.

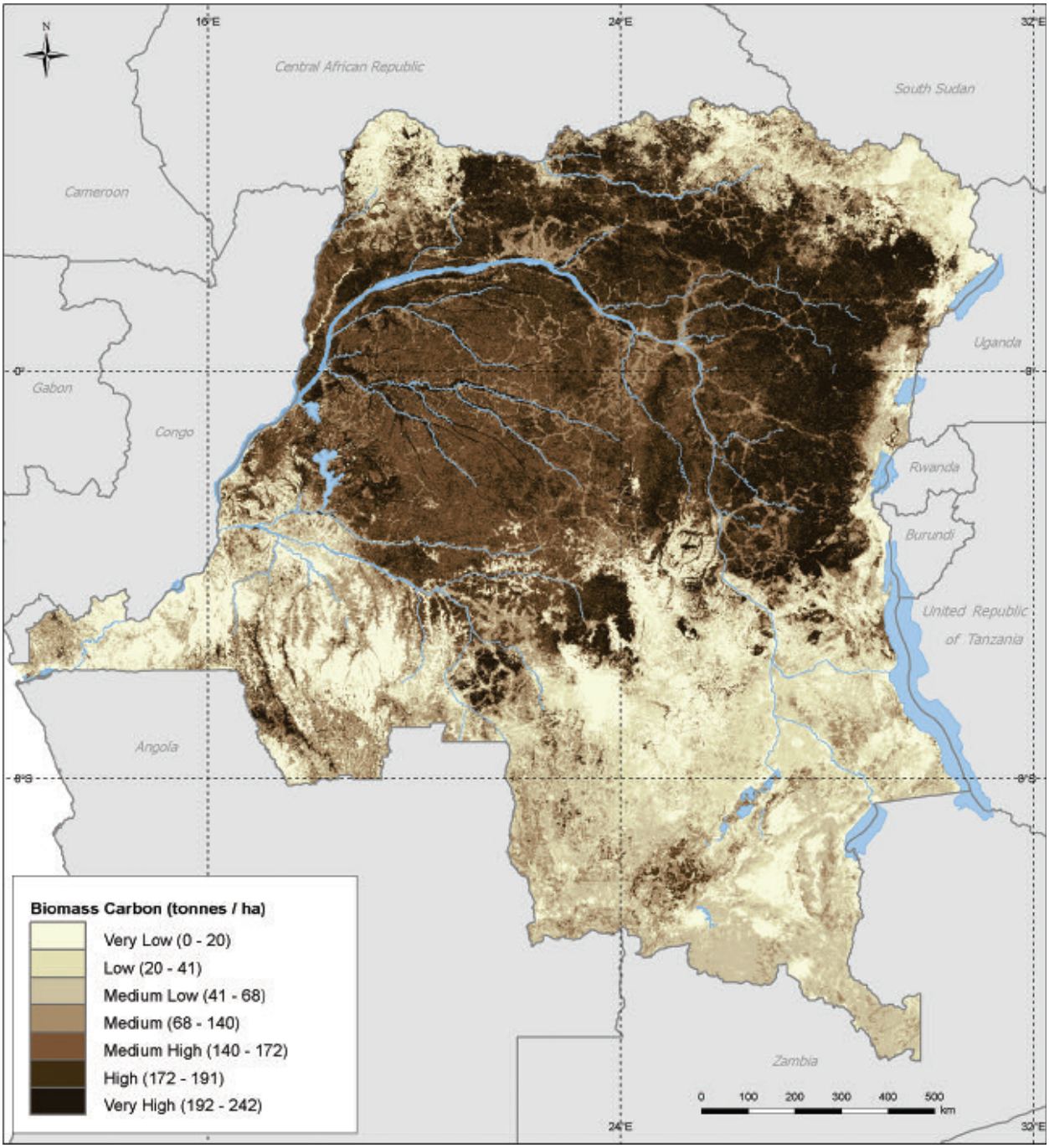
Results of this work can help the DRC to include consideration of, and goals for, multiple benefits in its planning and preparation for REDD+. As field plot data on carbon stocks in the DRC and spatial information on other ecosystem services becomes available, repeating the analyses could provide further support to spatial planning and preparation processes at national scale.

Results

The carbon stocks of the DRC

According to the preliminary biomass carbon map generated, the total carbon stored in the above- and below-ground biomass of the DRC amounts to 24.5 gigatonnes (Gt). More than half of this biomass carbon is concentrated in only 28 per cent of the national area, mainly coinciding with the dense forest in the Congo Basin and the submontane and afromontane forests (Map 2).

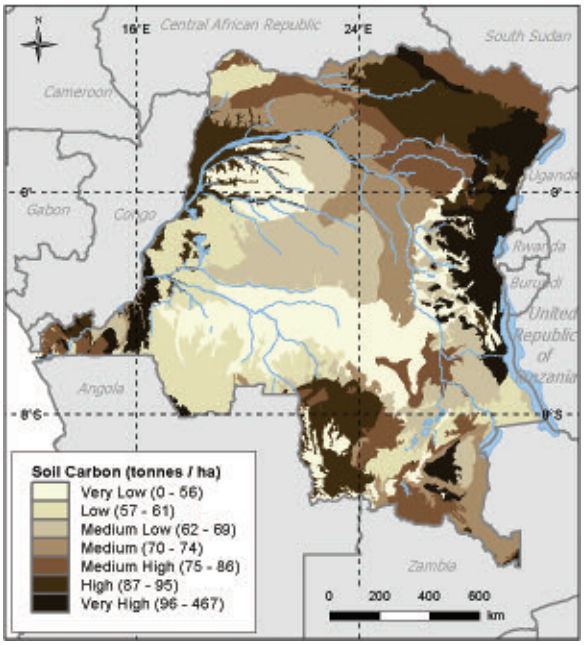
In addition to the carbon stored in the roots and shoots of live vegetation, there is a pool of carbon in the soil. Roughly two thirds of this is soil



Map 2: Preliminary biomass carbon map for the Democratic Republic of the Congo (data sources: Baccini *et al.* 2008, FAO 2001, FAO 2006, Gibbs and Brown 2007, Ruesch and Gibbs 2008, see Annex I for technical detail)

organic carbon, i.e. organic matter resulting from decomposition of leaves, wood and roots. The remainder is soil inorganic carbon, i.e. mineralised forms of carbon. Globally, the soil carbon pool is estimated to be 3.3 times the atmospheric carbon pool and 4.5 times the biotic carbon pool (Lal 2004). Land use change, certain agricultural practices and erosion can lead to a loss of carbon from the soil. Managing soil for its carbon stocks as a contribution to climate change mitigation is therefore gaining increasing attention in international climate negotiations (Lal 2010).

Data on soil carbon pools is very limited. According to a global dataset on soil organic carbon (Scharlemann *et al.* in prep., Map 3, see Annex III for further detail), the DRC's soil organic carbon stock amounts to over 18 gigatonnes. The maximum values for soil carbon density (467 tonnes/ha) by far exceed the maximum values for biomass carbon density (242 tonnes/ha). These figures emphasise the importance of managing soil carbon for climate change mitigation, and of identifying potential losses when planning avoided emissions in particular. However, due to the coarseness of and uncertainties in the available data on soil carbon, the remainder of this report will focus solely on biomass carbon.



Map 3: Soil organic carbon to 1m depth in the DRC
(data source Scharlemann *et al.* in prep., see Annex III for technical detail)

Biomass carbon and biodiversity in the DRC

Biodiversity is distributed unevenly across space and, because of its complexity, is difficult to capture in a single indicator. The following spatial datasets were used to examine biodiversity in the context of REDD+:

- range of occurrence of eastern gorilla, common chimpanzee and bonobo (Caldecott and Miles 2005);
- Important Bird Areas (BirdLife International 2011a);
- the Congo Basin Forest Partnership (CBFP) Landscapes (CARPE 2009; Yanggen *et al.* 2010).

The DRC is a signatory to the Kinshasa Declaration on Great Apes and has thus agreed to undertake all necessary efforts to ensure the long-term future of the species of great apes within its boundaries (UNEP *et al.* 2005). While all three of the great ape species included in the analyses are endangered, bonobo and eastern lowland gorilla are also endemic to the country. Data were only available for the 'ranges of occurrence' of the eastern gorilla, common chimpanzee and bonobo; these are the areas within which the species can occur, but there may have been substantial population declines in some parts of them, for example due to outbreaks of the Ebola virus and to the impacts of armed conflict (especially in the case of the eastern gorilla, Nellemann *et al.* 2010). Therefore, the 'areas of occupancy', i.e. the areas where the species are actually found, are likely to be much smaller than their ranges of occurrence.

Important Bird Areas (IBAs) provide information on an additional taxonomic group. They are key sites for the conservation of birds because of their importance for globally threatened bird species, restricted-range or biome-restricted ones, or for migratory or congregatory bird species (BirdLife International 2011b). The CBFP Landscapes are priority areas for conservation based on their

taxonomic importance, their overall integrity, and the resilience of ecological processes represented. They were identified through a region wide evaluation conducted by more than 160 biological and socioeconomic experts from around the world. While neither IBAs nor CBFP Landscapes have been officially recognised or adopted by the DRC government, many IBAs overlap with nationally protected areas and several of CBFP's landscapes are recognized by international agreements promoting cooperation on environmental monitoring and law enforcement (e.g. COMIFAC 2010).

The ranges of occurrence of the three great apes jointly cover almost the entire forest area of the country (Map 4) and include more than 70 per cent of its biomass carbon. The largest amount of biomass carbon is within the occurrence range of the common chimpanzee (almost 11 Gt, Figure 2), which also covers the largest area. IBAs (Map 4) and CBFP Landscapes (Map 5) overlap with all three species' occurrence ranges in different places. On 780 000 hectares of land, the eastern gorilla co-occurs with the common chimpanzee inside land that is also considered important for birds (IBAs). These areas are potentially of major importance for biodiversity conservation because of their importance for different taxonomic groups. The area is part of the Maiko Tayna Kahuzi-Biega CBFP landscape (Map 5).

The CBFP Landscapes cover almost all of the occurrence range of the eastern gorilla, about 17 million and 18 million hectares of the occurrence ranges of common chimpanzee and bonobo, and more than 60 per cent of the area of IBAs (Map 5), and include over 25 per cent of the country's biomass carbon stocks (Figure 2).

Including biodiversity in REDD+ planning in the DRC

In considering how and where to implement REDD+ activities, in ways that avoid significant social and environmental risks, and help realise multiple benefits, additional spatial information will be valuable. This includes information about

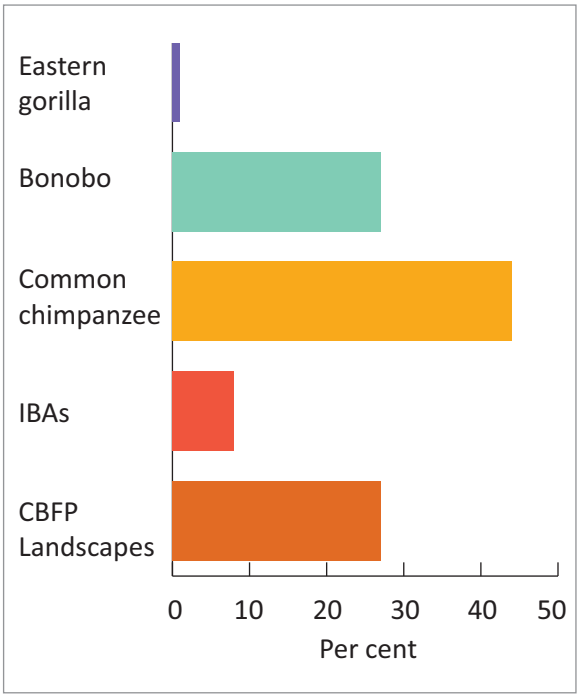


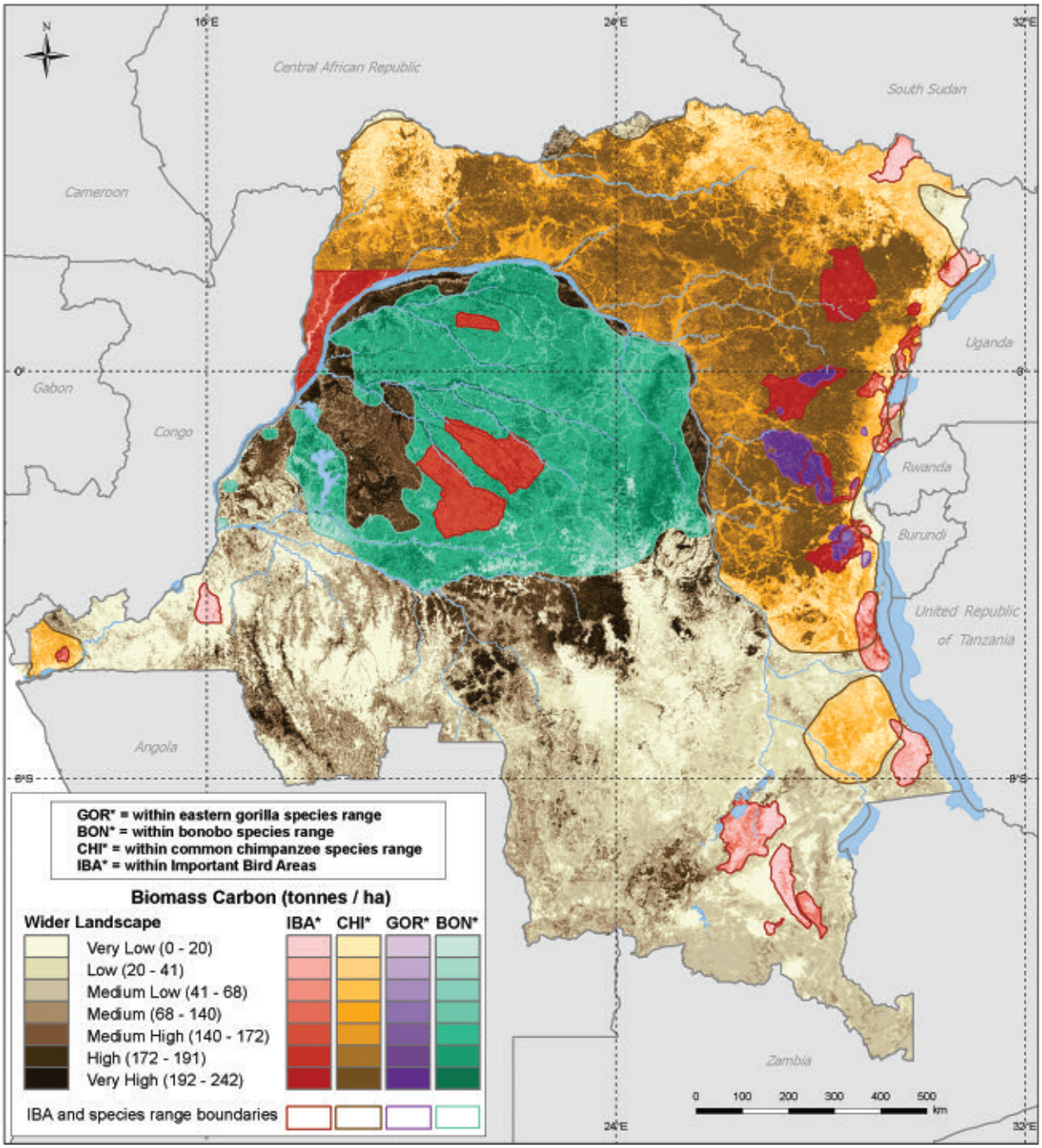
Figure 2: Percentage of biomass carbon inside the range of occurrence of eastern gorilla, bonobo and common chimpanzee, IBAs and CBFP Landscapes

official designations for land use, the location of recent deforestation, and the location of activities and infrastructure that may be driving deforestation and degradation.

Land use designations

In addition to the broad categories of forest defined by the Forest Code, there are a number of land use designations relevant for REDD+ planning in DRC. Mapped data were available for protected areas, forest concessions and areas under active mineral exploitation and exploration.

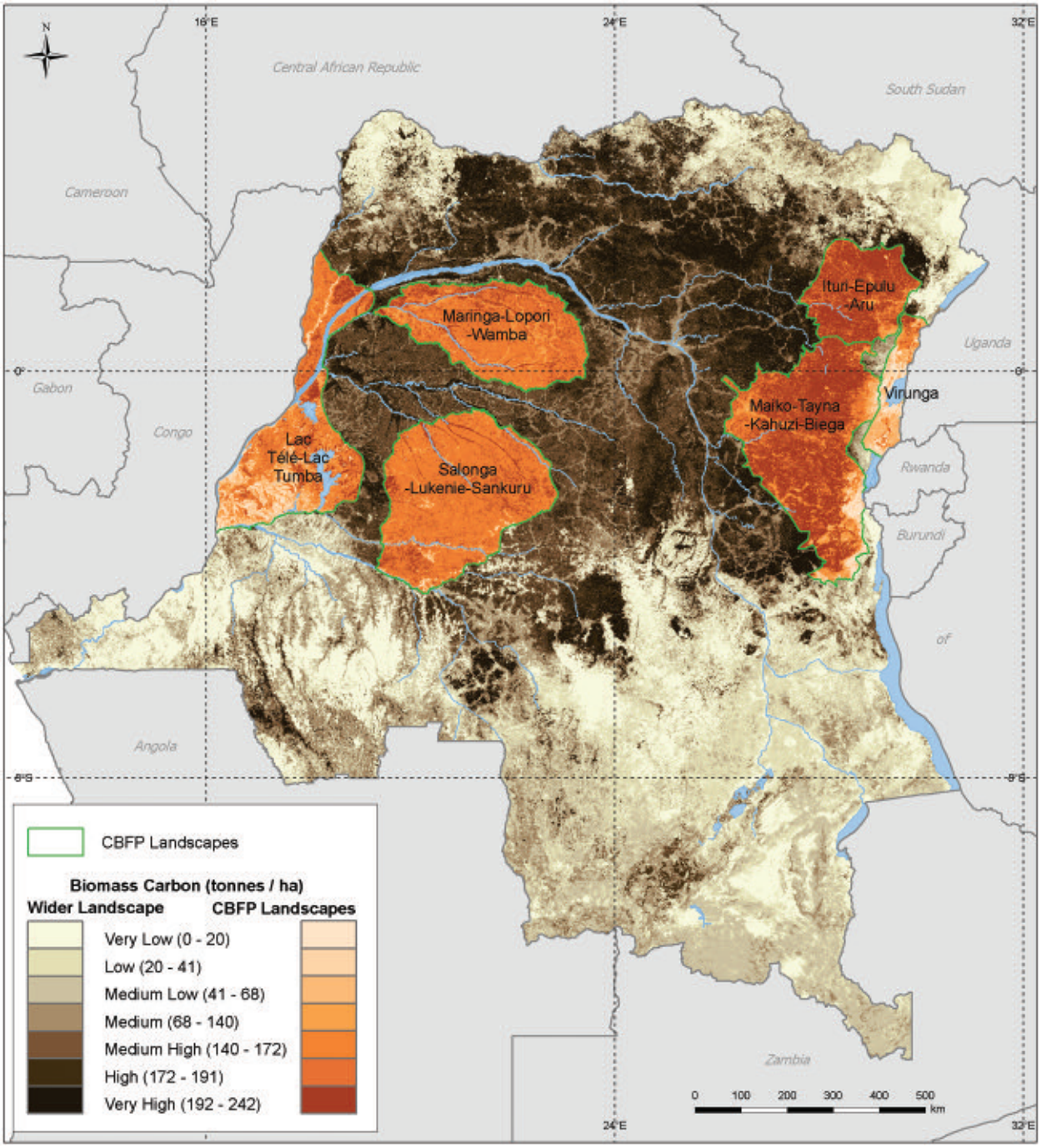
The designation of land as protected areas (and the management that may go with it) may help reduce deforestation and degradation, although it cannot be assumed that there will be no deforestation in protected areas (Campbell *et al.* 2008). By 2009, a total of 40 protected areas had been officially designated while another 17 had been proposed (ICCN *et al.* 2009, Map 6). The designated protected areas cover about 10 per cent of the area of the country and contain 2.8 Gt of biomass carbon (i.e. 12 per cent of the total,



Map 4: Biomass carbon, occurrence range of eastern gorilla, common chimpanzee and bonobo and Important Bird Areas (data sources: Caldecott and Miles 2005, BirdLife International 2011)

Figure 3). The proposed protected areas cover an additional 3 per cent of the country's total area and store 0.7 Gt of biomass carbon.

That a piece of land is a forest concession may be an indication that forest degradation or even deforestation is likely to occur there. On the other hand, if they are managed in appropriate ways, forest concessions may be an important tool for reducing or even avoiding degradation through sustainable management of forest. Forest titles have been issued for a total of 80 forest concessions (DIAF and WRI 2011), which in total cover 6 per cent of the area of the DRC. They are mainly located in the



Map 5: Biomass carbon and CBFP Landscapes within the DRC (data source: CARPE 2009)

west of the country and along the Congo River, which facilitates the transport of the timber out of the forest. A total of 2.4 Gt of biomass carbon (i.e. 10 per cent of the total, Figure 3) is estimated to be stored in the forest concessions of the country. Their effect will depend on the rules relating to the concessions and how they are managed in practice. Effects on biodiversity will also depend on management approaches. Protected areas and forest concessions are shown in Map 6.

Designated or proposed protected areas cover *ca.* 17 per cent of the range of bonobos and common chimpanzees and about half of the range of eastern

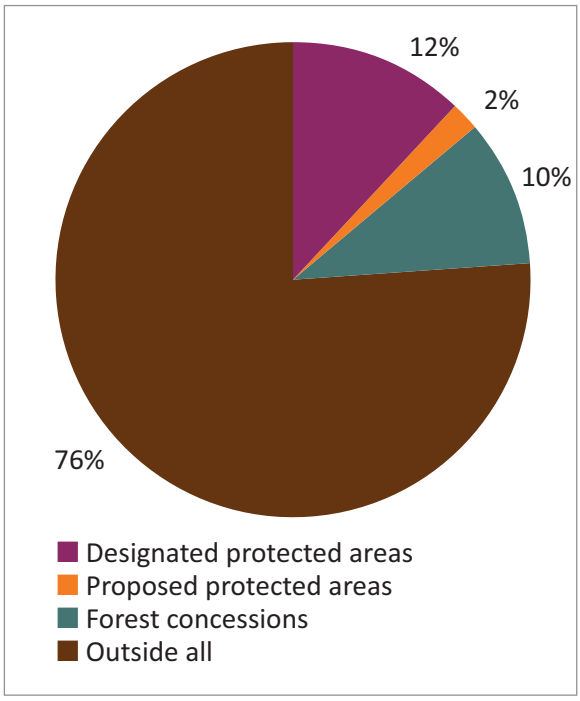


Figure 3: Percentage biomass carbon inside and outside of the DRC's protected areas and forest concessions

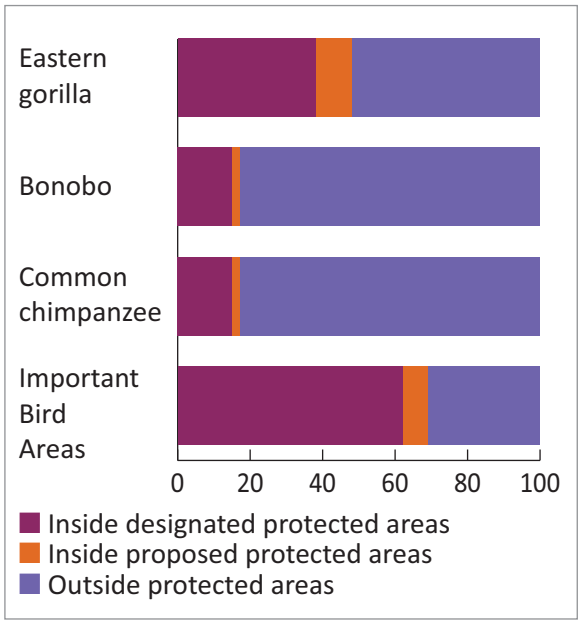


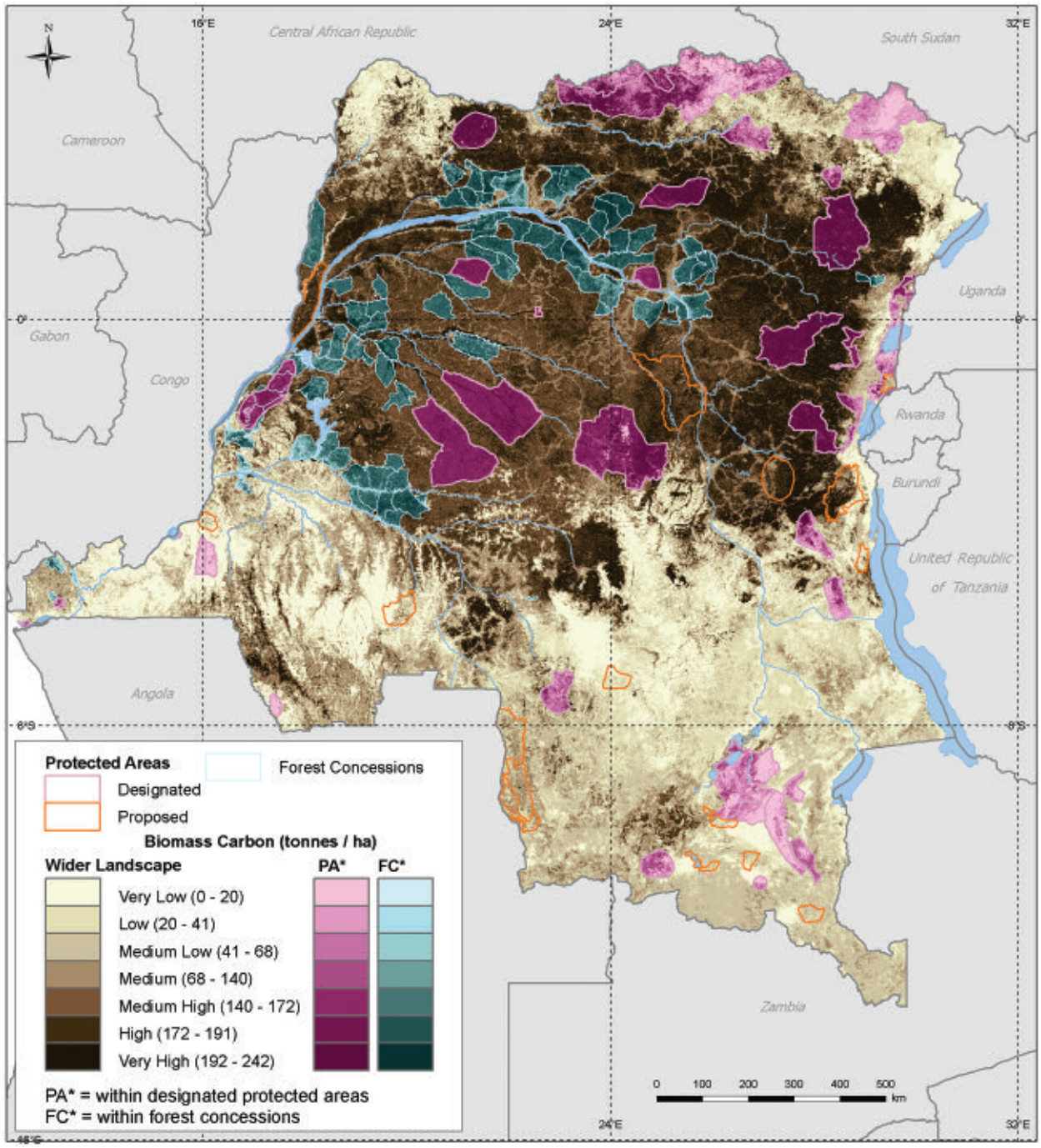
Figure 4: Percentage of the area of eastern gorilla, bonobo and common chimpanzee ranges of occurrence and IBAs within designated and proposed protected areas and outside both

gorillas in DRC. The vast majority (92 per cent) of the area where eastern gorillas co-occur with common chimpanzees in Important Bird Areas is within designated (71 per cent) and proposed (21 per cent) protected areas. However, more than 50 per cent of the range of occurrence of the eastern gorilla and more than 80 per cent of the occurrence ranges of common chimpanzee and bonobo are outside of the designated protected areas (Figure 4). About 21 per cent of the CBFP Landscapes within the DRC are inside designated, and an additional 3 per cent inside proposed, protected areas. While there are no forest concessions in the range of occurrence of the eastern gorilla, 16 per cent of the distribution range of the bonobo and 6 per cent of that of the common chimpanzee are inside forest concessions. Management for REDD+ in areas of biodiversity importance that are not currently within protected areas can bring significant biodiversity benefits if it is based on appropriate strategies (Secretariat of the Convention on Biological Diversity 2009).

Mining activities can impact on carbon stocks and biodiversity, for several reasons, including infrastructure development to improve access to areas designated for mining (see section on drivers of deforestation), and bushmeat hunting to supply miners and their families (Nellemann *et al.* 2010; Redmond 2001). Nevertheless, appropriate management may reduce the loss of carbon and of biodiversity. The DRC is very rich in mineral resources; its untapped mineral reserves are estimated to be worth US$24 trillion (UNEP 2011). Currently, the area designated for active mineral exploitation amounts to about 4.8 million hectares (i.e. 2 per cent of the terrestrial area of the country, Map 7, Cadastre Minier de la RD Congo 2011). However, an additional *ca.* 57 million hectares (i.e. 25 per cent of the terrestrial area of the country) are designated for exploration of their mineral resources. There is significant overlap between areas designated for mineral exploitation and the occurrence range of the eastern gorilla, as well as between areas designated for exploration and the occurrence range of the common chimpanzee. In addition, some parts of the areas designated for mineral exploration are within protected areas.

Location of recent deforestation

Areas where deforestation has occurred recently

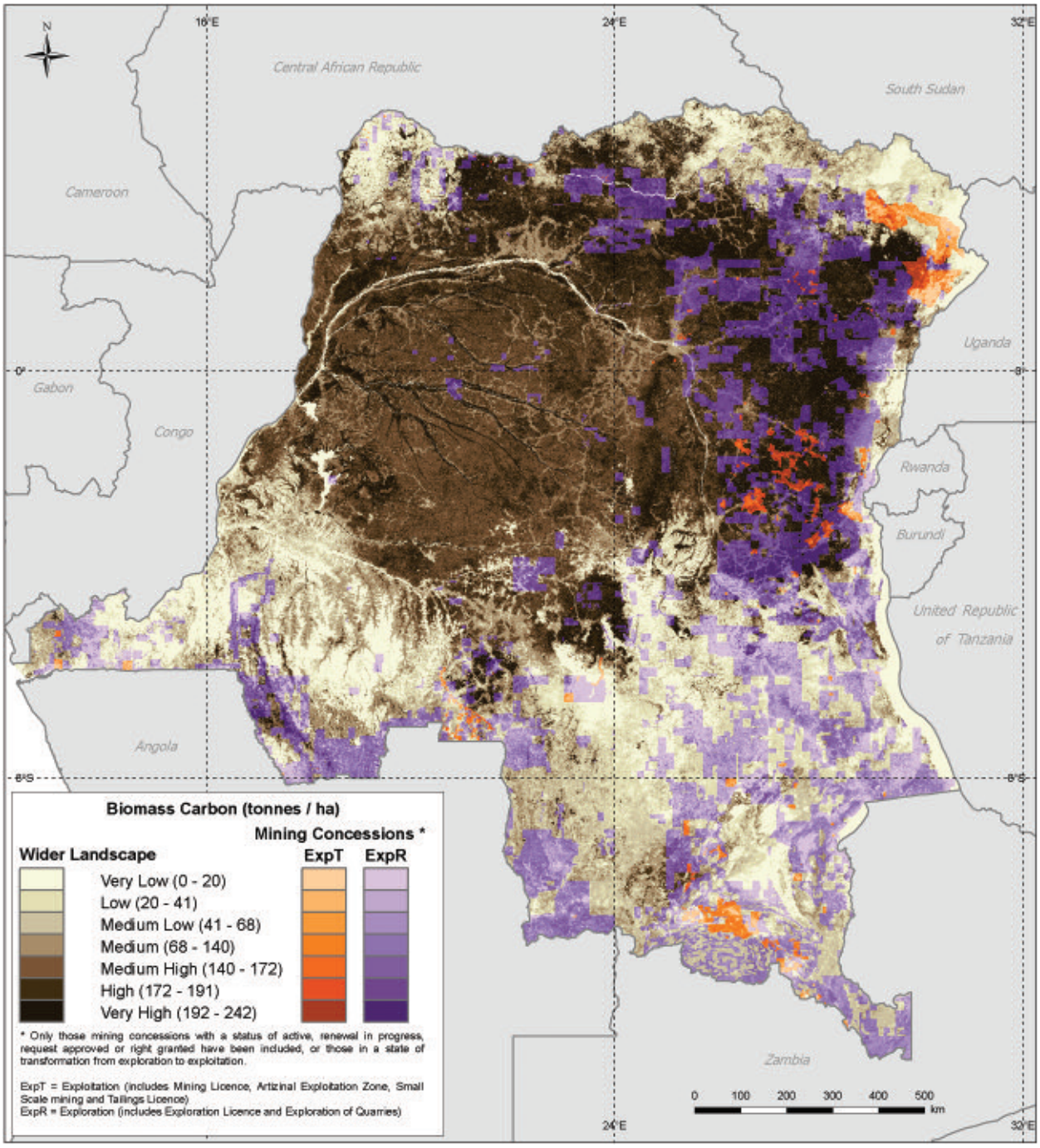


Map 6: Biomass carbon, protected areas and forest concessions in the DRC (data sources: ICCN *et al.* 2009 and DIAF and WRI 2011)

can potentially indicate where deforestation is likely to continue in the near future. According to the latest assessment based on remotely sensed information (Forêts d'Afrique Centrale Évaluées par Télédétection (FACET) 2010), the area affected by forest cover loss in the DRC between 2000 and 2010 amounts to about 3.4 million hectares (Map 8). Some of this forest cover loss has happened close to the boundaries of protected areas, and a small fraction of it is located within designated protected areas. If deforestation is likely to spread from recently deforested areas, a simple estimate of pressure on forest carbon can be made by identifying areas adjacent to those that have recently lost their forest cover. The 240 metres around recent

forest cover loss store almost 13 per cent (3.2 Gt) of the country's biomass carbon. This figure rises to 22 per cent (5.3 Gt) when increasing the buffer around already affected areas to 480 metres[2]. As biodiversity is also potentially at risk in these areas they may be especially important locations in which to focus action to reduce deforestation. However, implementing REDD+ may be particularly

[2] The 240 and 480m belts around areas affected by forest cover loss were generated at the 60m resolution of the original FACET (2010) data by expanding the area around cells affected by forest cover loss by 4 and 8 pixels respectively. To estimate biomass carbon within these belts, FACET data had to be scaled up and calculations were done by looking at the proportion of each analysis cell affected by forest cover loss.

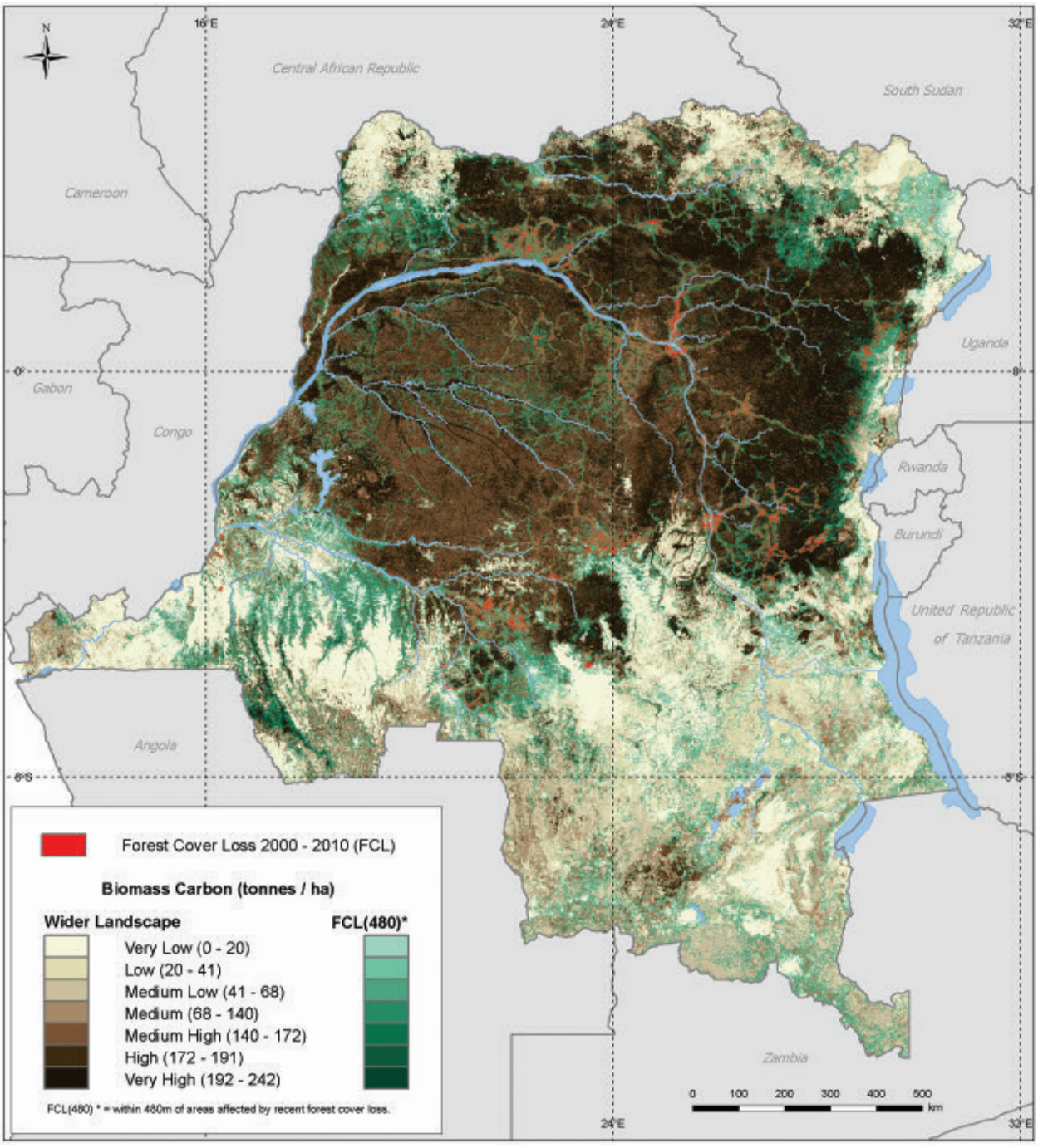


Map 7: Biomass carbon and mining in the DRC (data source: Cadastre Minier de la RD Congo 2011)

costly and challenging in areas where deforestation pressure is highest.

Drivers of deforestation

Land designations for timber exploitation and mining, as discussed above, provide information on some of the key drivers of deforestation identified in a DRC government assessment (Ministry of Environment Nature Conservation and Tourism 2010, see also Biodiversity in the DRC, p5). Roads also play a role in several of the drivers identified by this assessment, and conflicts are known to prompt movements of population and development of new settlements and patterns of

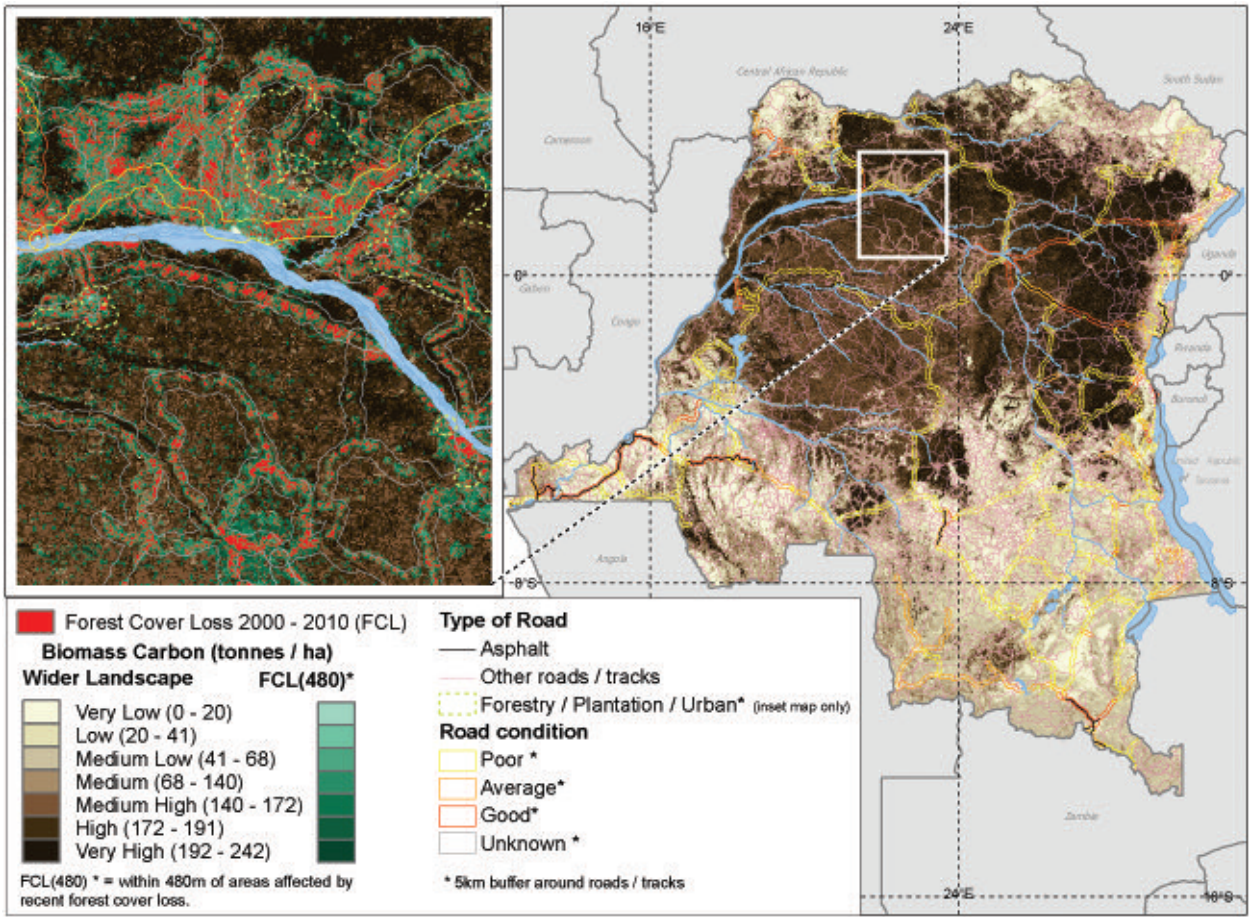


Map 8: Forest cover loss between 2000 and 2010 (red) and areas within 480m of areas affected by forest cover loss (green) (Forêts d'Afrique Centrale Évaluées par Télédétection (FACET) 2010)

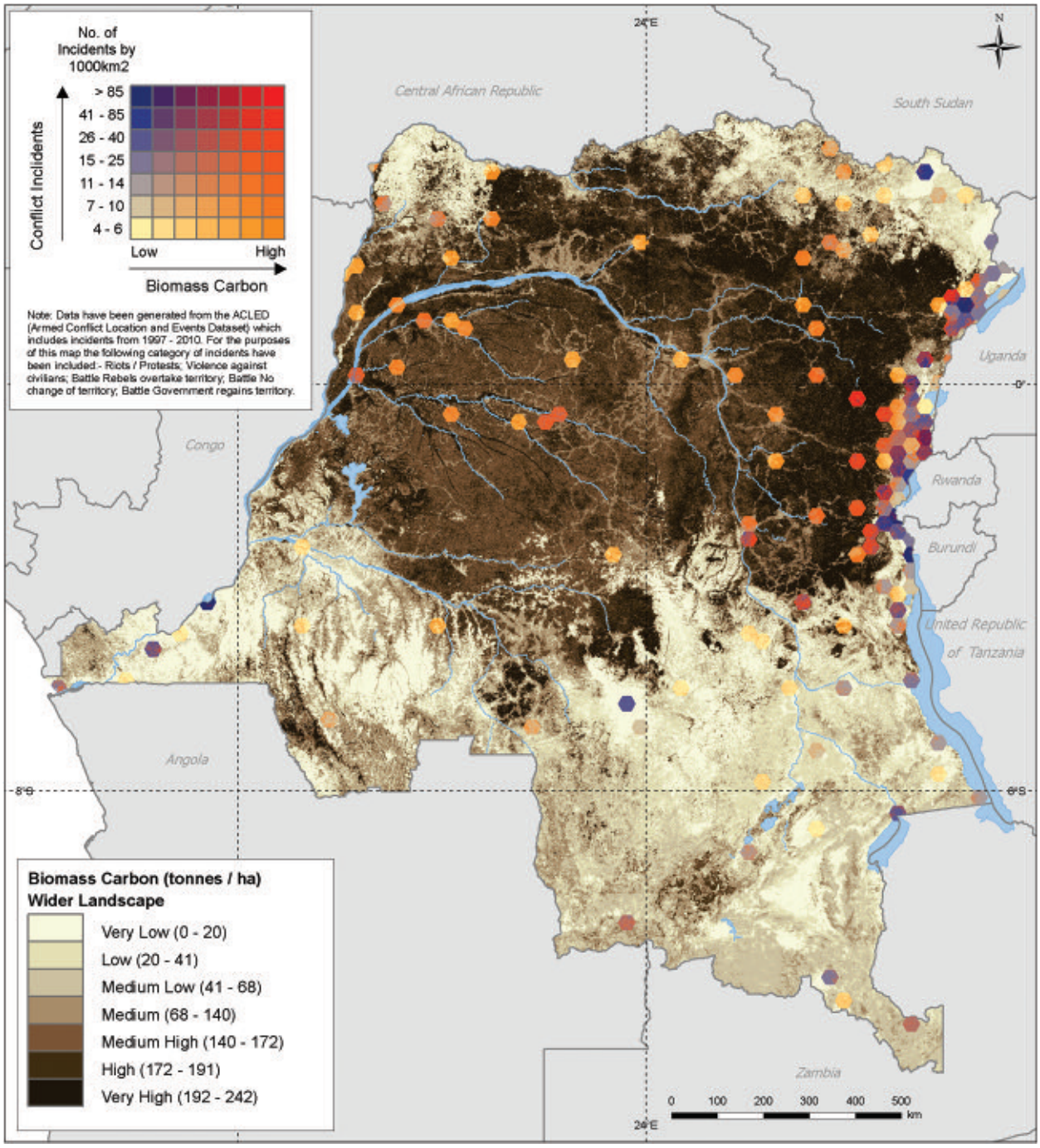
resource use that also contribute to deforestation (UNEP 2011).

Of the DRC's road network of about 152 400 km more than 70 per cent is damaged or destroyed (African Development Fund 2004). Road access is directly related to forest cover loss (Map 9). The improvement and expansion of the DRC's road infrastructure will facilitate access to forest areas of economic interest and ease timber extraction and transport. In addition to the direct effects of both road building and deforestation on carbon and biodiversity, these activities also cause edge effects, i.e. physical and biotic changes associated with the often-abrupt verges of roads and linear clearings (Laurance *et al.* 2009). Edge effects can reduce the potential of adjacent forest areas to realise ecosystem-based multiple benefits, such as biodiversity (Broadbent *et al.* 2008; Laurance *et al.* 2009).

The link between unsustainable natural resource use and the continuing conflicts between armed groups of different origin and the DRC's military has been recognised at the highest political level (UNEP 2011) and is also of importance in the context of deforestation and forest degradation in the DRC. These conflicts are most serious in the country's east (Map 10, data from Raleigh *et al.*



Map 9: Road system by road type and condition. Inset shows the link between road access and forest cover loss (data sources: Cellule Infrastructures 2007; Forêts d'Afrique Centrale Évaluées par Télédétection (FACET) 2010; World Resources Institute and Ministère de l'Environnement, Conservation de la Nature et Tourisme de la République Démocratique du Congo 2010).



Map 10: Biomass carbon and incidences of violence between 1997 and 2010 in the DRC (data source: Raleigh *et al.* 2010)

2010). Natural resources, including mainly minerals, but also high-value timber, charcoal, and bushmeat contribute considerably to financing, sustaining and perpetuating armed groups involved in the conflicts (Nellemann *et al.* 2010; UN Group of Experts on the Democratic Republic of the Congo 2010; UNEP 2011). The internal displacement they cause, affecting more than 1.7 million people by January 2011, has led to environmental degradation (mainly deforestation or fuelwood and charcoal), resource scarcity and competition (UNEP 2011; UNHCR 2011).

Conclusions and next steps

The DRC has great potential to realise biodiversity benefits from REDD+: the occurrence ranges of eastern gorilla, common chimpanzee and bonobo, as well as Important Bird Areas all overlap with areas that store important amounts of biomass carbon. Continued conservation efforts in the CBFP Landscapes can contribute to maintaining these valuable assets as the CBFP Landscapes include large parts of the areas of importance for both carbon and biodiversity.

Both protected areas and forest concessions store important amounts of biomass carbon and cover large areas of importance for biodiversity. While currently the area designated for active mineral exploitation is limited, mineral exploration is taking place in large parts of the country, suggesting that mining activities are likely to increase in the future. In all three land designations included in the analyses, effective and sustainable management will be important in order to successfully secure the valuable assets they contain, including carbon, biodiversity and other ecosystem services. Options for REDD+ implementation will have to be developed in line with the objectives of these and other existing land-use designations, as well as for areas outside such designations.

The location of areas of recent forest cover loss can indicate where further deforestation is likely to occur, or most difficult to halt. It can also help identify where implications for biodiversity may be most serious and where current management of certain land designations may not be effective. Overall, the information can thus help prioritise areas where reducing deforestation is most appropriate. In order to address deforestation and forest degradation, however, it is important to also look at the drivers of these processes. Improved road access to currently poorly connected parts of the country, many of which store large amounts of carbon and are rich in biodiversity, may increase the potential for economic exploitation of these sites, for example for their mineral resources. Continuing conflicts also contribute to driving unsustainable resource use, including minerals and timber. Implementing a robust REDD+ mechanism that realises multiple benefits and reduces environmental and social risks may be particularly challenging in those parts of the country that are difficult to influence due to these conflicts and their consequences. Maintaining efforts to end these conflicts will be important if REDD+ is to be implemented in the affected areas.

The data used for this work was the best available data at the time of production. However, limitations apply to several of the datasets (see Annex II and III), and some may be subject to regular updates (e.g. forest and mining concessions). For national-level decision-making, it may be useful to update the analyses, i.e. integrate more recent, more suitable and additional datasets relating to both values associated with and pressures on forest carbon (e.g. population density, infrastructure, other ecosystem services). These spatial analyses can be useful in a number of further activities to ensure that REDD+ implementation will realise multiple benefits in the DRC, for example:

- in a comparison of scenarios for business-as-usual development *versus* REDD+ implementation in the DRC, they can help assess the difference that could be made by REDD+ to the conservation of the DRC's forests and biodiversity;
- taking into account the multiple benefits associated with REDD+ can be useful in comparing the costs of different REDD+ strategies with the carbon and non-carbon benefits to be gained;
- by improving the understanding of the potential benefits and risks to people and the environment of implementing REDD+, the analyses can help in the adaptation and specification of social and environmental safeguards for application in the DRC's national context. The UN-REDD Programme's Social and Environmental Principles and Criteria (UN-REDD SEPC) may be useful here. Furthermore, repeating the analyses as more recent data becomes available can help report about the effectiveness of the safeguards implemented.

Annex I
Generation of the preliminary biomass carbon map for the DRC

Several data sources were brought together to generate a preliminary biomass carbon map for the DRC, comprising carbon stored in above- and below-ground live biomass. The above-ground biomass was derived from a dataset for tropical Africa, based on remotely-sensed MODIS NBAR data from 2000-2003 at a resolution of 1 km (Baccini *et al.* 2008). Each 1 km by 1 km pixel in this map contains a value for biomass density in tonnes per hectare (t/ha). Ecosystem-specific root-to-shoot ratios (FAO 2006) were applied to these values to add below-ground biomass, using FAO ecological zones to distinguish between ecosystems (FAO 2001). The carbon mass of the resulting total was estimated as half the biomass (Gibbs and Brown 2007). The dataset provided by Baccini *et al.* (2008) did not cover areas with less than 9 tonnes of above-ground biomass per hectare. A National Land Cover map (Vancutsem *et al.* 2009) was overlaid with these areas and the following categories were assigned a value of 4 tonnes of carbon per ha, based on the values from a global biomass carbon map (Ruesch and Gibbs 2008):

- agriculture: permanently cropped area with rainfed broadleaved tree crops (plantations) or rainfed herbaceous crops or bare soils;
- broadleaved deciduous woodland: savanna woodland;
- broadleaved deciduous woodland: tree savanna;
- broadleaved deciduous woodland: woodland (*miombo*).

A few remaining scattered pixels were assigned the value of their nearest neighbour while ensuring that areas of water remained 0. This resulted in the preliminary map of biomass carbon (Map 2).

The shading of the map was produced using the GIS "quantile classification" method. This method allocates the same number of pixels to each class. The variable deciding the class breaks was carbon density. Depending on the number of classes to be generated, in this case seven, the method allocates the pixels with the lowest carbon density to the lowest class until one seventh of all pixels are in that class. The next pixel with a slightly higher carbon density than the previous is then allocated to the next class, and so on. Collaboration partners assessed different ways to classify and shade the map, for example, using a different number of classes, and agreed to the shading that is shown in the report.

Annex II
Limitations of the preliminary biomass carbon map for the DRC

The preliminary biomass carbon map generated has a number of limitations, for example regarding the age and resolution of the underlying data, the way the data has been processed and interpreted and the lack of field plot data to verify the final dataset.

Baccini *et al.* (2008) used MODIS Nadir bidirectional reflectance distribution function adjusted reflectances (NBAR) data from the years 2000 to 2003 to generate a biomass dataset. However, in the ten years since 2000, an estimated 3.4 million hectares of recent forest cover were lost (Forêts d'Afrique Centrale Évaluées par Télédétection (FACET) 2010), a development that is not reflected in Baccini *et al.* (2008). Forest degradation may have occurred as well since the year 2000, but can be more difficult to track from remotely sensed data. It is therefore uncertain how well forest degradation from 2000 to 2003 is reflected in Baccini *et al.* (2008), and how much more forest degradation has occurred since then.

The resolution of the dataset generated by Baccini *et al.* (2008) is currently limited to 1km by 1km. For use of the resulting map at national and sub-national scale this resolution may not be sufficient.

In addition, and despite the fact that techniques for the collection and interpretation of remotely sensed data are improving rapidly, errors can still

occur in the generation and interpretation of remotely sensed data. Baccini *et al.* (2008) predicted above-ground biomass using a regression-tree model and latest Light Detection and Ranging (LiDaR) metrics from the Geoscience Laser Altimetry System (GLAS), which are sensitive to vegetation structure, to cross-validate the model results. However, data interpretation needs to take into account a number of influencing factors, which can vary across space, such as altitude of the terrain, and whose omission or inaccurate consideration can result in misinterpretation of the data.

Since completion of the main analyses, two new biomass carbon datasets have become available: Saatchi *et al.* (2011) published their benchmark map of forest carbon stocks in tropical regions across three continents and Baccini *et al*. (2012) published an improved pantropical carbon-density map.

Both the Baccini *et al*. (2008) and the Saatchi *et al*. (2011) datasets are based on remotely sensed data from the early 2000's, while Baccini *et al*. (2012) is based on data from the period 2007-2008. No field plot data from the DRC was used in Baccini *et al*. (2008) or Saatchi *et al*. (2011), while Baccini et al. (2012) used some field plot data from the DRC to characterize above-ground biomass within GLAS footprints. Baccini *et al*. (2012) estimate the above-ground biomass carbon in the DRC at about 22 Gt. This figure is higher than the figure provided by Saatchi *et al*. (2011) of 18.9 Gt above-ground biomass carbon in the DRC and the FAO FRA 2010 estimate of 19.6 Gt (FAO, 2010). According to the preliminary map presented in this report, which is based on Baccini *et al*. (2008), above- and below-ground biomass carbon in the DRC amount to 24.5 Gt. This is in line with Saatchi et al. (2011) whose figure for above- and below-ground biomass carbon was 22-24 Gt for the DRC. Saatchi *et al*. (2011) estimated biomass carbon uncertainty for most of the DRC's forests to be between 35 and 50%. Baccini *et al*. (2008) and (2012) do not include a spatially explicit uncertainty assessment.

A deeper analysis is required to establish which of the datasets that have more recently become available would be most appropriate to use for the DRC. However, due to time and resource constraints this was not possible within the scope of the present piece of work. Having shared the preliminary biomass carbon map based on Baccini *et al*. (2008) with national stakeholders, it was jointly decided to continue using this one for the present analysis.

To improve the preliminary biomass carbon dataset for the DRC, it will be important to update the underlying data, to increase its resolution and to validate any resulting map using field plot data from different sites in the country. National Forest Inventory data would be very helpful to generate a more recent and validated map of biomass carbon in the DRC.

Annex III
Soil carbon data for the DRC

The Harmonized World Soil Database (HWSD, FAO *et al.* 2009) combines existing data on soil properties from best available sub-global sources into a global dataset. The contents of the Harmonized World Soil Database for the DRC are based on soil parameter estimates from the World Soil and Terrain Digital Database (Batjes 2007). Using the HWSD, Scharlemann *et al.* (in prep.) generated a global map of soil organic carbon storage to a depth of 1 metre. The result for the DRC (Map 3) reflects the coarseness of currently available soil carbon stock information in the country. The map was discussed and due to its coarseness and further questions that arose from this discussion it was decided not to combine the preliminary biomass carbon map with the soil carbon map and to exclude soil carbon from the statistical analyses.

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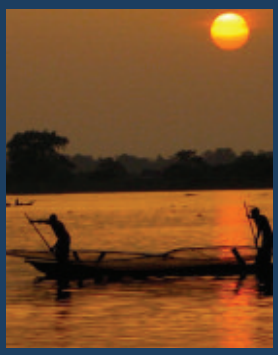
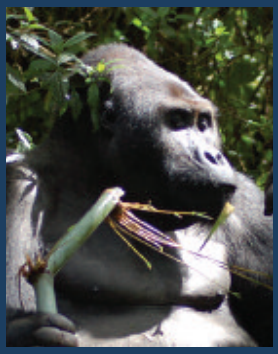


REDD+ aims to incentivise Reducing Emissions from Deforestation and forest Degradation, as well as the conservation of forest carbon stocks, sustainable management of forests and the enhancement of forest carbon stocks. Such activities can potentially provide biodiversity benefits, but there is also a need to avoid any risks of environmental harms from REDD+. Here we present selected results of spatial analyses to explore biodiversity benefits and risks from REDD+ in the Democratic Republic of the Congo.



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Direction des Inventaires et Aménagement Forestiers

OSFAC

UN-REDD PROGRAMME

FAO UNDP UNEP

2011-2020
United Nations Decade on Biodiversity