Assessing the biodiversity impacts of policies related to REDD+

Key considerations for mapping and land use change modeling, illustrative examples from Brazil

REDD pac

UNEP

UNEP World Conservation Monitoring Centre
219 Huntingdon Road
Cambridge, CB3 0DL
United Kingdom
Tel: +44 (0) 1223 277314
Fax: +44 (0) 1223 277136
Email: info@unep-wcmc.org
Website: www.unep-wcmc.org

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DISCLAIMER

CONTRIBUTORS

Rebecca Mant, Tania Salvaterra, Lera Miles and Valerie Kapos
UNEP World Conservation Monitoring Centre
219 Huntingdon Road, Cambridge, CB3 0DL, UK
E-mail: info@unep-wcmc.org

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Executive summary

Climate change and biodiversity loss are two of the key global challenges facing people and ecosystems. Deforestation and forest degradation represent significant contributions to anthropogenic CO_2 emissions and therefore climate change, with land-use change estimated to provide a net contribution of around 10% of global emissions. Land use change can also cause loss and fragmentation of natural habitats and remains the main driver of biodiversity loss. Two main sets of policies address these issues: (1) those related to the United Nations Framework Convention on Climate Change (UNFCCC) decisions on reducing emissions from deforestation and forest degradation plus conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (REDD+), and (2) those linked to the implementation of the United Nations Convention on Biological Diversity (CBD).

Policies for achieving REDD+ objectives have the potential to deliver multiple benefits, through secruing biodiversity and ecosystem services (e.g. water regulation and provision of forest products) and direct social benefits (e.g., improvement of livelihoods). However, if the UNFCCC-agreed Cancún safeguards are not addressed and respected, there is a risk that REDD+ policies could also lead to negative impacts (e.g., geographic displacement, 'leakage', of deforestation). Parties to the CBD have agreed a Strategic Plan for Biodiversity 2011-2020, which includes a set of 20 Aichi Biodiversity Targets intended to .

Mapping and land use modelling can support assessments of the potential biodiversity impacts of REDD+ policy options and their relationship to the CBD objectives. The REDD-PAC project, a collaborative project, involving the International Institute of Applied Systems Analysis (IIASA), UNEP-WCMC, the Brazilian National Institute for Space Research (INPE) and the Central African Forestry Commission (COMIFAC), aims to support the identification of REDD+ policies that are economically efficient, socially fair and that can safeguard and enhance ecosystem values and help meet the goals of the CBD. The project includes land-use change modeling focusing on Brazil and the Congo Basin, as well as, mapping and spatial analysis to support planning for REDD+ that delivers multiple benefits in five additional countries (China, Peru, the Philippines, Uganda and Viet Nam).

The REDD-PAC project has produced this report to:

1) Serve as a reference document for individuals and organizations undertaking or commissioning assessments of the biodiversity impacts of policies related to REDD+. It sets out the main issues that need to be considered in using mapping and/or modeling to assess impacts and support planning related to REDD+. It is illustrated with options for the REDD-PAC project's analyses in Brazil.

2) Stimulate and support discussions on the exact methods to be used for the biodiversity assessment within the REDD-PAC project in Brazil.

The first main consideration for undertaking analyses of the potential impacts of future REDD+ policies on biodiversity is to understand the national context, both in terms forest and biodiversity-related policy, as well as the wider policy context including agricultural and development policies (section 2).

Fires along the Rio Xingu by NASA's Earth Observatory. *Licensed under a Creative Commons Attribution-2.0 Generic* licence *(CC BY-NC 2.0)*. Accessed 26th August 2014. https://flic.kr/p/azf9PR

Policies and measures may already be in place to reduce deforestation, for example in Brazil, the Forest Code and PPCDAm have already helped in reducing deforestation.

Similarily, parties to the CBD are committed to producing national biodiversity strategies and action plans (NBSAPs) and many have drafted national biodiversity targets for 2020 building on the CBD's Aichi Biodiversity Targets. For example, Brazil's targets set in 2013 include reducing the rate of loss of native habitats by at least 50% in relation to 2009's rate (Goal 5); increasing the coverage of a *System of Conservation Units (SNUC)* to at least 30% of the Amazon and 17% of each of the other terrestrial biomes (Goal 11); and increasing the resilience of ecosystems and the contribution of biodiversity to carbon stocks through conservation and recovery actions, including through the recovery of at least 15% of degraded ecosystems (Goal 15).

Once the national context is understood, it is necessary to decide what type of analysis to undertake. The role of mapping and models (section 3) depends on the type of assessment needed. Mapping (section 3.1) can provide an assessment of the distribution of selected indicators and the spatial relationship between them. As such, maps can support spatial planning through providing an indication of the potential for achieving specific benefits in different areas and identifying potential trade-offs. Maps can be most powerful when they combine information on several factors on one map. For example in relation to REDD+, overlaying information on areas with potential for emissions reductions and priority areas for protecting biodiversity can highlight the areas that are most important for both (Map 4). Greatest benefits in terms of emissions reductions will be achieved by protecting areas of high carbon which are under threat. Mapping areas of past deforestation can provide an indication of the current deforestation front but future deforestation may occur elsewhere. Land-use change models (section 3.2) can be used to project future land use change pressures in different locations. For example, the model used in the REDD-PAC project, GLOBIOM, includes a detailed representation of the major land–based production sectors and provides spatially-explicit land use outputs.

Regardless of which mapping and modelling approaches are used, it is important to define key issues and assumptions that may affect the assessment (section 4). These include land cover and land use definitions and classifications, land use designations, and specific dynamics of interest in the national context. Which land cover and land use categories are used and how they are defined (section 4.2) can significantly affect the conclusions drawn from a map. Forest definitions, for example, can vary from a strict focus on dense forest to broader criteria that may include woody savannahs; the definition used could alter conclusion on which locations should be subject to new forest policies.

Protected areas (section 4.3) are a land-use designation of particular relevance, as they are a tool for biodiversity conservation and for protecting land from conversion that leads to greenhouse gas emissions. However, globally, the land uses formally permitted within protected areas vary, as does the effectiveness of protected areas in conforming to those rules, and both may influence the role an

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area can play in protecting biodiversity and reducing emissions. Therefore, assumptions on land use within, and effectiveness of, protected areas greatly influence the conclusions drawn from both mapping and land use change modelling.

Regeneration (section 4.4) can also be an important component of land-use change policies, for example in the Atlantic Forest in Brazil, and therefore careful consideration needs to be given to the rules used to model the dynamics of vegetation recovery. A good model should track which and has been abandoned and include reaslistic time frames and conditions for its reversion to natural vegetation.

A further, aspect of assessing the potential biodiversity impacts of policy options is deciding which aspects of biodiversity need to be considered (section 5). One approach is to assess the changes that occur in areas highlighted as priorities for biodiversity conservation, such as those indetified by the Ministry of the Environment (MMA) in Brazil. A related approach is to assess impacts in relation to individual species ranges and habitat requirements, usually focusing on species of particular concern. Impact on species can be assessed by projecting total number of species extinctions or changes in species' threat categories. An alternative approach is to assess 'combined species habitat change' based on assessing both the proportion of habitat that is been lost for individual species and the number of species that lose habitat in each area. This is the approach planned for the REDD-PAC project in Brazil.

The final component necessary assess the potential biodiversity impacts of REDD+ policies is to decide what range of future global scenarios and policy options (section 6) will be considered. Ther implementation of REDD+ and biodiversity-related policies will take place in the context of ongoing economic development, which may follow any of several tragectories that will impact on the policies' outcomes. Therefore, an assessment of likely biodiversity impacts ideally needs to include several general development scenarios being considered (and associated parameters such as population and economic growth), as well as the different specific REDD+ and biodiversity-related policies that could be implemented. Although, REDD+ refers to five specific activities related to climate change mitigation actions within the forest sector (reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks), there are multiple ways of undertaking each of these activities depending on the national priorities and circumstances. These can range from implementing new laws and regulations and increasing the enforcement of existing ones (command and control measures) to providing payments for maintaining ecosystem services (incentive-based measures). Across the range of actions, many can potentially also be implemented in ways which create greater or fewer biodiversity benefits. Assessing the biodiversity impacts of different policy options through mapping and modelling can help in selecting policies which enhance benefits.

1. Introduction

Land is used for multiple human activities, such as agriculture and forestry. Land use choices have a wide range of effects on carbon storage, maintenance of ecosystems and biodiversity. Multiple different policy objectives, at both national and international levels, are linked to land use and can significantly influence the impacts of land-use plans on both people and ecosystems. Climate change and biodiversity loss are currently two of the key global challenges people and ecosystems face. Deforestation and forest degradation represent significant contributions to anthropogenic CO_2 emissions and therefore climate change, with land-use change estimated to provide a net contribution of around 10% of global emissions. (IPCC 2013). The conversion of natural ecosystems (for example, into agricultural land or development areas) can also cause loss and fragmentation of natural habitats and remains the main driver of biodiversity loss. Therefore, this report focuses on the two main sets of policies addressing these issues: (1) those related to the United Nations Framework Convention on Climate Change (UNFCCC) decisions on reducing emissions from deforestation and forest degradation plus conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (REDD+) and (2) those linked to the implementation of the United Nations Convention on Biological Diversity (CBD).

Policies to achieve REDD+ objectives have the potential to deliver multiple benefits, both in terms of protecting biodiversity and ecosystem services (e.g. water regulation, soil erosion prevention and provision of forest products) and direct social benefits, such as improvement of livelihoods. However, depending on how REDD+ policies are implemented they could also lead to negative impacts. In particular, geographic displacement (leakage) might increase conversion pressure on low-carbon forests and other ecosystems, including those valuable for biodiversity conservation (e.g. Cerrado in Brazil). Additionally, a primary focus on carbon benefits, including enhancement of carbon stocks, could lead to the planting of monoculture plantations which generally host little biodiversity. In response to these concerns, the UNFCCC agreed a set of safeguards (the Cancún safeguards), to help ensure REDD+ policies safeguard and enhance biodiversity and other ecosystem values and are implemented without causing social or environmental harm (UNFCCC/CP/2010/7/Add.1).

Parties to the CBD, have agreed a Strategic Plan for Biodiversity 2011-2020, which includes a set of Aichi Biodiversity Targets. These were developed to address global objectives on biodiversity and ecosystem service conservation, and are to be implemented at the national level through strategies and action plans for biodiversity (NBSAPs).

The REDD-PAC project is a collaborative project between the International Institute of Applied Systems Analysis (IIASA), UNEP-WCMC, the Brazilian National Institute for Space Research (INPE) and the Central African Forestry Commission (COMIFAC). It aims to support the development of policy options for achieving REDD+ goals and evaluate their impacts on biodiversity using land use change models, focusing on Brazil and the Congo Basin. This information will then support the identification of REDD+ policies that are economically efficient, socially fair, safeguard and enhance ecosystem values, and help meet the goals of the Convention on Biological Diversity. Additionally, mapping and spatial analysis to support planning for multiple benefits within REDD+ has been undertaken in five additional countries (China, Peru, the Philippines, Uganda and Viet Nam).

This report is a deliverable of the REDD-PAC project and has two main purposes:

1. To serve as a reference document for individuals and organizations planning to undertake or commission assessments of the biodiversity impacts of policies related to REDD+. The report aims to set out the main issues that need to be considered in using mapping and/or modeling to assess impacts and support planning related to REDD+. Options for the REDD-PAC project's analyses in Brazil are used to illustrate the report's main points.

2. To stimulate and support discussions on the exact methods to be used for the biodiversity assessment within the REDD-PAC project in Brazil. The report highlights the biodiversity assessments currently planned within the REDD-PAC project.

The report highlights how mapping and land-use modelling can help understand the potential impacts on biodiversity, ecosystems services (and thus CBD objectives) of policy options for achieving REDD+ objectives. It illustrates how such information can identify potential synergies and trade-offs, inform complex decisions, reduce uncertainty and support planning. The key issues to consider which are presented include: the national context (section 2), the benefits of using maps and models (section 3), the assumptions within assessments (section 4), aspects of biodiversity which can be assessed (section 5) and the development of scenarios (section 6).

2. Importance of the national context

Different countries have different policy objectives related to REDD+ and biodiversity, depending on the national context. It is therefore important to consider national objectives and their context when carrying out assessments that can support policy making. National forest policy, biodiversity policy and other relevant land-use related policies need to be considered. Development objectives and agricultural policies are amongst those that can also significantly affect land use and land availability for achieving REDD+ and biodiversity objectives.

When considering the forest policy context, the history of forest use and change, including the main drivers of deforestation and uses of the forest, can help in appreciating the reasons for policy formulation and the potential success of policy implementation. A wide range of laws and regulations can be relevant to forest policy, covering forest use, deforestation, timber extraction, REDD+ strategy and forest conservation areas. Countries may also have specific policies for safeguarding social and environmental benefits from forests. For REDD+, this can include having developed a national approach to implementing the Cancún safeguards, which may involve a national definition of natural forest.

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National biodiversity policies and regulations will depend on the biodiversity priorities and characteristics of the country, including whether there are particular regions or areas that are important for biodiversity conservation or ecosystem services. The National Biodiversity Strategy and Action Plan (NBSAP) sets out a country's main biodiversity policies and aims. Laws and regulations developed to address these aims may cover protected areas, threatened species and ecosystem services.

The actual impact of laws on deforestation and biodiversity depends as much on the level of enforcement and effectiveness, as it does on the ambitions. Hence, it is useful to seek information on this as part of understanding the national context. It can take substantial resources to be able to effectively implement policies, laws and regulations which are not always available to countries. To illustrate these issues, some key aspects of the Brazilian national context are set out below.

2.1 Forest policy

The Brazilian Amazonian rainforest occupies an area of 4,100,000 km^2, where 720,000 km^2 have been deforested since the 1970s (INPE 2010). Of the areas identified as deforested, 63% are used for cattle raising, 4.9% are used for cash crops, but more than 20% has been abandoned and is now re-growing as secondary vegetation which suggests that there is huge potential for setting aside part of the abandoned area as a carbon sink (Aguiar et al. 2012).

The main legal instrument for forest conservation on private lands in Brazil is the Forest Code, a new version of which was established in 2012. First created in 1965, the current code requires farmers to retain 80% of the area of their properties as native vegetation in the Amazon, 35% in Cerrado areas within the *Legal Amazon* and 20% in other biomes. The forest code identifies both Areas of Permanent Protection (APPs) and Legal Reserves (RL). The recent revisions to the code introduce new mechanisms such as the Environmental Reserve Quota (Portuguese acronym, CRA), a tradable legal title to areas with intact or regenerating native vegetation in excess of the forest code requirements. The new code also reduced some requirements for reforestation and restoration, especially for small properties.

Enforcement of the Forest Code is a key challenge, which Brazil is tackling with increasing effectiveness. High deforestation rates persisted during the 1990s and early 2000s and it was only after the government implemented the Action Plan for Prevention and Control of Deforestation in the Amazon (PPCDAm) in 2004 that illegal deforestation decreased. The PPCDAm programme integrates satellite monitoring of forest cover, land-use planning and land titling, inspection and enforcement, promotion of sustainable use of natural resources, and promotion of protected area expansion and legal recognition of indigenous territories. In 2008, reacting to a spike in deforestation, the government also brought about restrictions on bank credit: in municipalities with critical rates of deforestation, rural credit provision was limited to farmers that could prove their compliance with environmental regulations.

This increase in enforcement contributed to reduced deforestation rates, from 27,000 km^2 in 2004 to 6,500 km^2 in 2011 (INPE 2010). Assunção et al. *(2012)* estimated that *"approximately half of the deforestation that was avoided in the Amazon in the 2005 through 2009 period can be attributed to conservation policies introduced in the second half of the 2000s".* However, it is important to recognise that consumers and action in the private market have also contributed to reduced deforestation rates. For example, Greenpeace and ABIOVE (Brazilian Association for Vegetable Oil) have signed an agreement annually since 2006 (the "Soy Moratorium") in which ABIOVE member companies pledged not to trade soy originated from deforested areas within Amazonia. More recently, there has been increasing market pressure to certify timber and beef products. Variations in national and international prices of soybeans and meat have also affected deforestation.

The Brazilian government has a continuing commitment to reducing deforestation and included ambitious deforestation reduction goals in the National Law on Climate Change, enacted in 2009. This law sets a target of 80% reduction in deforestation in Amazonia for the period 2006-2020 against the average rate of deforestation for the period 1995-2006 as a baseline (Figure 1).

Besides the Forest Code and PPCDAm, future forest cover in Brazil is likely to be directly affected by the action plan for prevention and control of deforestation and forest fires in the Cerrado (PPCerrado) and Payment for Ecosystem Services in the Atlantic Forest. The Action Plan for Prevention and Control of Deforestation and Forest Fires in the Cerrado (PPCerrado) was launched in 2010, with the main goal of reducing greenhouse gas (GHG) emissions from deforestation in the biome by 40% by 2020. The policy aims for an expansion of protected areas and legal recognition of indigenous land in the Cerrado. The programme also includes several actions focusing on reforestation and recovery of degraded land, including, degraded pasture, legal reserve, and permanent preservation areas. Special credit will also be available for large commercial reforestation projects.

Payments for Ecosystem Services (Portuguese acronym PSA) projects have been developed in Brazil

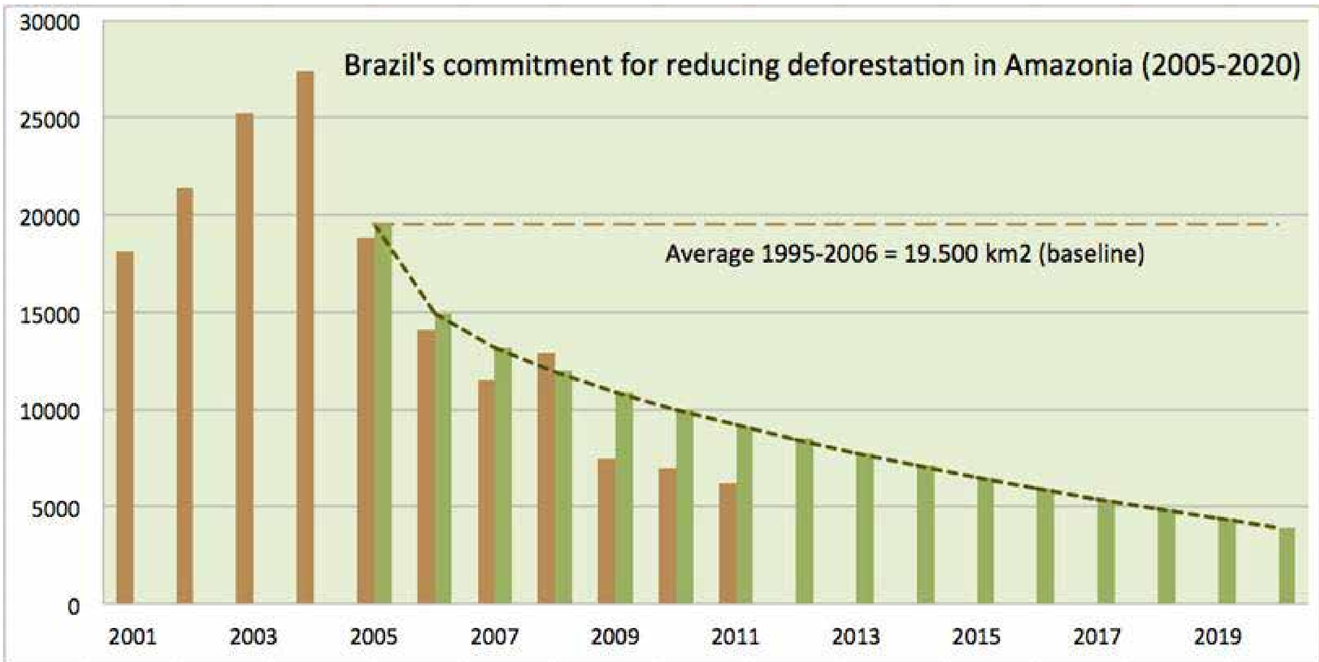

Figure 1: Brazil's projected reduction in deforestation (green bars) and actual rates (brown bars) measured in km^2 per year (data from G. Carmara).

since 2006 as incentives for the conservation of ecosystem services. According to a report released by the MMA (Becker and Seehusen 2011), PSA initiatives developed in the Atlantic Forest are mainly related to carbon (33 projects identified, ranging from recovery of degraded areas to promoting sustainable practices), water resources (29 projects) and biodiversity (5 projects).

2.2 Biodiversity policy

Brazil is one of the most biodiversity rich countries in the world. While deforestation and conversion of natural landscapes represent major threats to wildlife, Brazil has also become a world leader in biodiversity conservation efforts.

The Brazilian National Congress ratified the CBD through a national decree in 1994 which was later turned into a law on biodiversity, soon after the convention first came into force. Together with existing laws relevant to biodiversity conservation, including the Forest Code and the Wildlife Act, this helped to establish the framework for the National Biodiversity Strategy. Subsequently, additional laws and strategies have been set up including the National System of Conservation Units (SNUC, 2000), the Forest Concessions Law (2006), the Agro-Ecological Zoning for Ethanol Production (2009), the National Strategy on Invasive Alien Species (2009), and the National Policy on Climate Change (2009), among others.

Within its national legislation the Brazilian government

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distinguishes between six terrestrial biomes which occur within Brazil: Amazon, Cerrado, Pantanal, Caatinga, Pampas and Atlantic Forest. Although, the establishment of protected areas is the main strategy for biodiversity conservation in all biomes, there is large variation amoung biomes in the total area under protection (Table 1).

Table 1: Coverage of protected areas in the six Brazilian biomes (Biomes data: National dataset of 2005 provided by Ministerio do Meio Ambiente (MMA); Protected Areas data: IUCN and UNEP-WCMC (2014), The World Database on Protected Areas (WDPA) [May, 2014]. Cambridge, UK: UNEP- WCMC).

Biome	**Protected area coverage (% of biome)** – including public forests, indigenous land and conservation units.
Amazonia	47%
Caatinga	8%
Cerrado	12%
Mata Atlantica	8%
Pantanal	4%
Pampa	3%

In 2013, the country released national biodiversity targets for 2020, which build on the CBD's Aichi Biodiversity Targets (MMA 2013). These were developed through an initiative called "Dialogues on Biodiversity: Building the Brazilian Strategy for 2020". The targets include reducing the rate of loss of native habitats by at least 50% in relation to 2009 rates (Goal 5); increasing the coverage of *National System of Conservation Units (SNUC)* to at least 30% of the Amazon and 17% of each of the other terrestrial biomes (Goal 11); significantly reducing the risk of extinction of threatened species (Goal 12) and increasing the resilience of ecosystems and the contribution of biodiversity to carbon stocks through conservation and recovery actions, including through the recovery of at least 15% of degraded ecosystems (Goal 15).

The federal government has also supported the development of state level policies and implementation plans, including the use of ecological and economic zoning, or Zoneamento Ecológico-Econômico (ZEE). The ZEE is defined as a "political and technical instrument for planning, whose objective is the optimization of land use and public policies [and to] establish a canvas for environmental protection in order to maintain hydrological resources, soil resources and biodiversity conservation". States are at varying points in the implementation of the plans, and the exact rules that apply to different categories of land use designated through the ZEE also vary among states. All the States in the *Legal Amazon* have

conducted their ZEE, but most States outside of this region have not.

Separately from the ZEE process, a national process has been undertaken to identify "Priority Areas for the Conservation, Sustainable Use, and Sharing of Benefits from the Brazilian Biodiversity". These priority areas were identified through a consultative process within each biome. A first map of priority areas was released by MMA in 2004 and then updated in 2007. A further revision to the areas is currently underway.

2.3 Other policy

Brazil is a rapidly developing country. As recognised by the Ministry of Environment's 4th national report to the CBD (Brazil Ministry of the Environment, 2010), a range of industries and activities related to development have the potential to affect biodiversity (including extractive industries, agriculture and timber). In particular, plans for agricultural development and infrastructure development are likely to significantly influence rates and location of deforestation and land-use change more widely. Created in 2010, the Low Carbon Agriculture plan (Portuguese acronym is ABC) is aimed at fostering the adoption of modern technologies, allowing more soil recovery, a productivity gain, and the reduction of GHG emissions. The ABC plan is intended to reach rural producers individually or through their cooperatives, and aims to recover degraded pasture land, encourage adoption of an integrated system of pasture-crop-forest, increase the use of direct planting systems, incentivize biological nitrogen fixation in soy production, and increase the plantation of commercial forests. Substantial plans for infrastructure development include Brazil's Plan for Energy Expansion, which calls for the construction of 30 large hydroelectric dams in the *Legal Amazon* region during the 2011-2020 period, which will flood large areas of forest. To understand the climate mitigation impacts of this construction, the GHG emission reduction gains of these new facilities need to be offset against emissions of CO_2 and methane from decay of flooded forest (Fearnside and Pueyo 2012).

Mata Atlântica: Serra da Gandarela - Atlantic forest by frederico Pereira. Licensed under a Creative Commons Attribution-ShareAlike 2.0 Generic (CC BY-SA 2.0). Accessed 15 July 2014. https://flic.kr/p/jwexQt

3. The role of maps and models in assessing policy impacts

Mapping, spatial analysis and modelling can all be used to support assessments of the biodiversity impacts of REDD+ related policies. The first part of this chapter presents a range of potential mapping approaches and illustrates them using examples from Brazil. Here we use the concept of spatial indicators – maps that give a clear picture of the status or change in the topic of interest. To map and analyse any selected indicator, relevant spatial information is needed. Hence, the high quality and availability of spatial data within Brazil makes it an excellent country with which to illustrate the potential for this sort of mapping.

Models can also be used to support assessments of the biodiversity impacts of REDD+ related policies. In particular, land use change models can be useful, as how policies affect land use and related land cover will have large impacts on biodiversity. There are a range of different types of land use change models with different advantages and disadvantages for their use in assessing impacts on biodiversity. The second section of this chapter presents what the different types of models can provide. It then gives more detail on the specific example of the land use change model being used within the REDD-PAC project in Brazil.

3.1 Mapping

Mapping and spatial analysis can support policy development, including through spatial planning, identifying potential trade-offs and providing an indication of the potential for achieving specific benefits in different areas. They can provide an assessment of the distribution of selected indicators and the spatial relationships amongst them. The types of information which can be mapped range from current observations to historical data and future projections; across a broad range of different types of indicators, such as those related to the ecosystem services an area may provide (e.g. biomass carbon storage, soil erosion, biodiversity) and socio-economic information (such as population density, crop production, infrastructure).

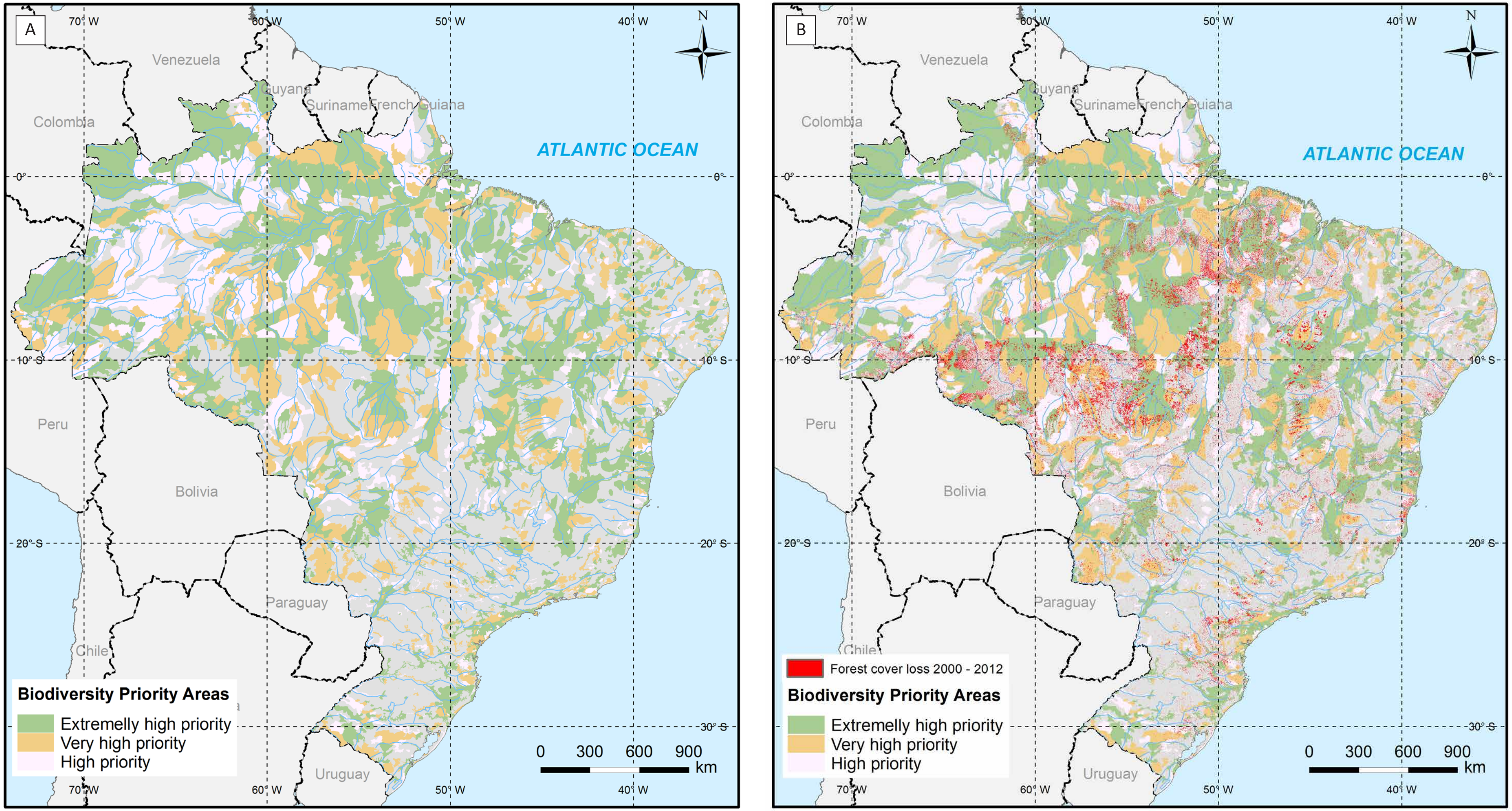
Maps of single indicators can be useful for communications and engagement. For example, a map can simply show the location of biodiversity priority areas, illustrated for Brazil in Map 1A. Overlaying information for more than one indicator on a single map provides a visual representation of the relationship between them; for example, presenting both biodiversity priority areas and recent deforestation within Brazil, Map 1B, shows where areas of high biodiversity importance are at risk from advances in the deforestaion front - and therefore where actions to reduce deforestation could readily deliver biodiversity benefits. From such data it is also possible to do simple spatial analyses, for example calculating the amount of recent deforestation both inside and outside biodiversity priority areas, and the level of deforestation in different types of priority area.

Overlaying several different indicators at the same time can enable more complex evaluations to be made. For example, mapping the potential contribution of an area to climate change mitigation against indicators of the potential of the area for conserving biodiversity and the potential costs of undertaking mitigation actions help to highlight where multiple benefits can be achieved by reducing deforestation most cost effectively. However, the utility of any given analysis depends on the availability of data and relevant indicators in relation to the questions of political concern (section 4).

The identification of areas important for the conservation of biodiversity and ecosystem services depends on which aspects of biodiversity are prioritized, as is discussed in more detail in section 5. If individual ecosystem types are the main focus, then maps of such biomes can be useful (Map 2A); alternatively, if the priority is specific groups of species, maps of their distributions may be most relevant (Map 2B). Where national processes have already developed biodiversity priority maps, these may be most relevant (Map 1A).

The importance of an area for reducing emissions from deforestation depends on both the carbon stored within the area and the likelihood of that area being deforested or degraded, as well as the cost of mitigation actions. A range of maps of biomass carbon and soil carbon stocks in Brazil exist (Map 3). Identifying which areas are at risk of deforestation and forest degradation is more complex. Past deforestation may provide some guide to where deforestation may occur in the immediate future (Map 4). A map-based analysis of where the maximum benefits for reducing carbon emissions and protecting biodiversity could be achieved, the overlap between them and the potential trade-off between the two objectives, can thus be developed using

Map 1: Biodiversity Priority Areas and deforestation within Brazil – Map (A) shows areas identified as priority for biodiversity (by MMA 2007). Recent deforestation data can be overlaid (B) to reveal areas currently under threat from deforestation, and therefore where actions to reduce deforestation could deliver benefits to biodiversity.

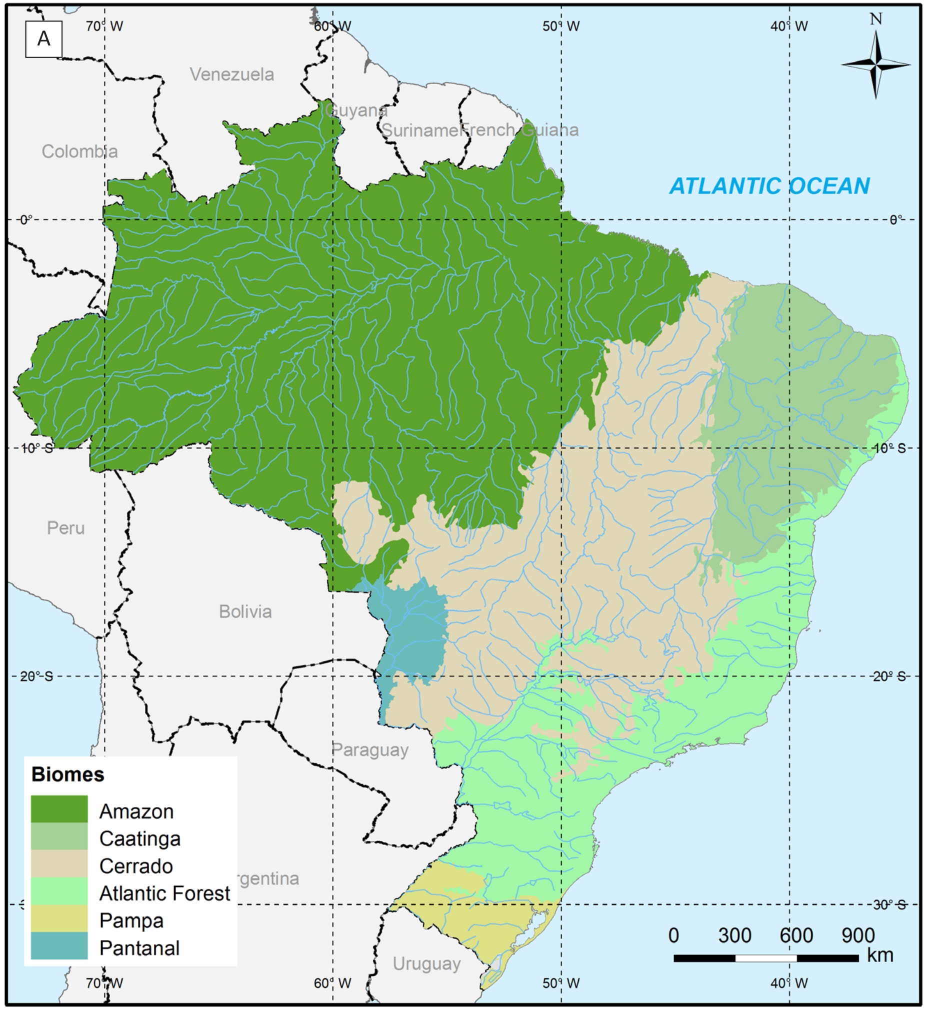


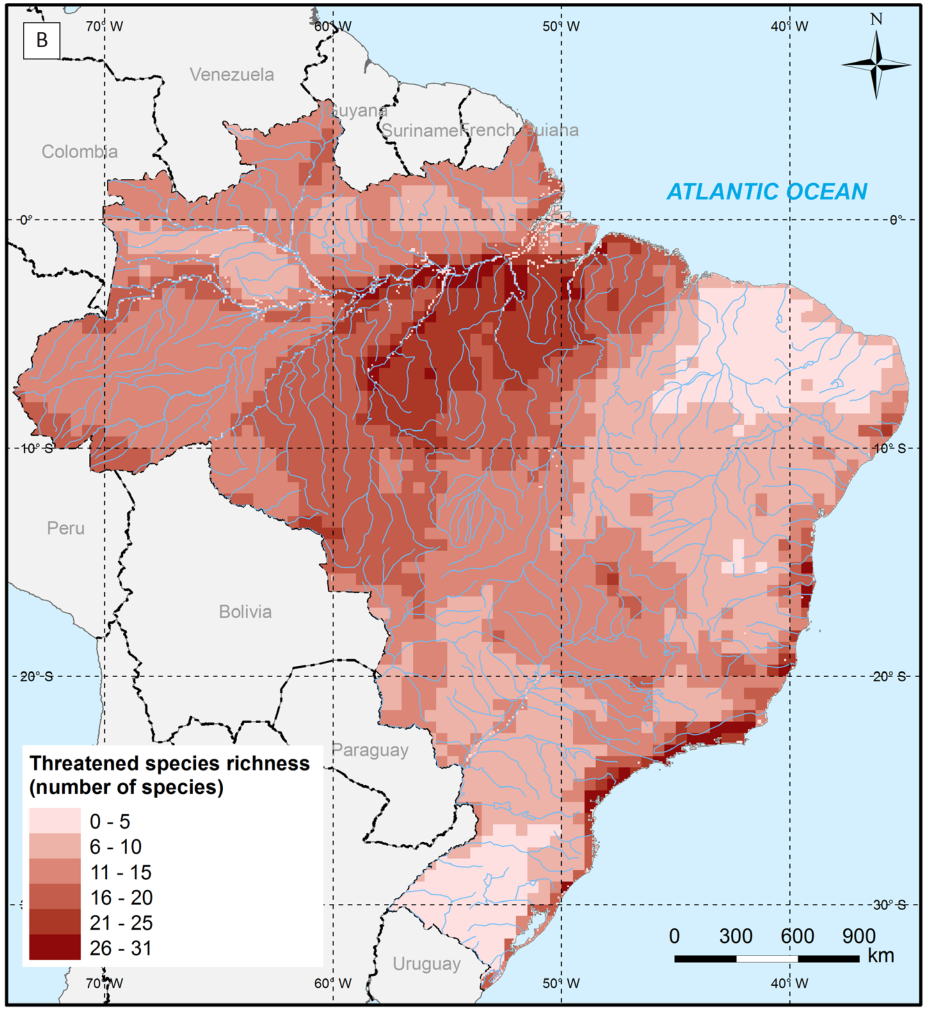
Data sources:

Biodiversity Priority Areas: National dataset of 2007 provided by Ministerio do Meio Ambiente (MMA). Data available online from http://mapas.mma.gov.br/i3geo/datadownload.htm#

Forest cover loss 2000 – 2012: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850–53. Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest

Map 2: Brazilian biomes and species richness of threatened mammals, amphibians and birds - The distribution of different biomes (A) and endangered species (B) within Brazil, can be used to identify areas important for conservation based on specific ecosystem types or on a specific group of species.





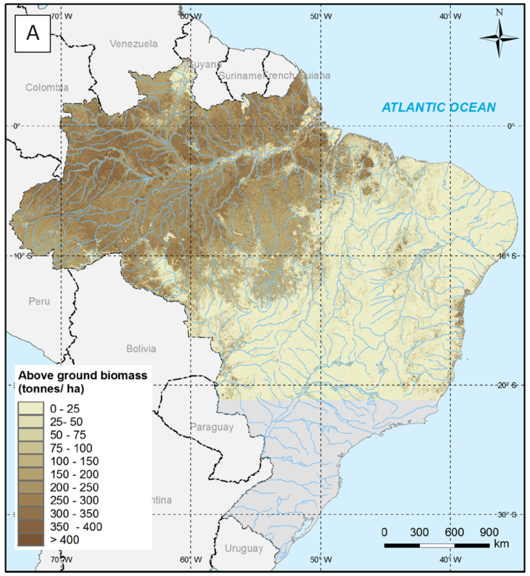
Data sources:

Brazilian Biomes: National dataset of 2005 provided by Ministerio do Meio Ambiente (MMA). Data available online from http://mapas.mma.gov.br/i3geo/datadownload.htm#

Species richness: IUCN (2013) Based on mammal, bird and reptile species classified as threat status 'Critically Endangered', 'Endangered', and 'Vulnerable' by the IUCN Red List of Threatened Species (2013) Version 2012.2 http://www.iucnredlist.org

Map 3: Carbon stocks: The carbon stored in a location impacts the emissions released during conversion of that area. Different datasets are available for carbon stocks including data on above ground biomass carbon based on data from (A) Saatchi et al. (2007), (B) Saatchi et al. (2011), (C) Baccini et al. (2012) and (D) Reush and Gibbs (20008) and soil organic carbon (E). The sources of biomass carbon show similar broad-scale patterns but significant variations in certain locations. The data on soil organic carbon shows a different pattern but is at much coarser resolution.

Saatchi 2007: above ground biomass (Amazon

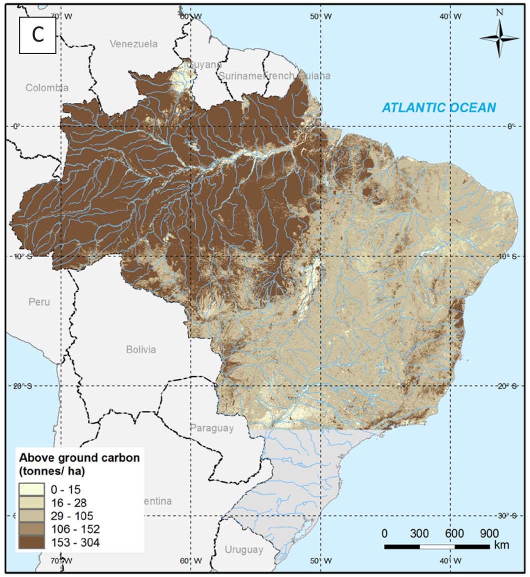


Data source: Saatchi S., Houghton, R.A., dos Santos Alval'a, R.C., Soares, J.V., Yu, Y. 2007. Distribution of aboveground live biomass in the Amazon basin. Global Change Biology. 13(4):816-837

Saatchi 2011: above ground carbon

Data source: Saatchi S., Harris, N.L., Brown, S., Lefsky M., Mitchard E.T., Salas, W., Zutta, B.R., Buermann, W., Lewis, S.L., Hagen, S., Petrova, S., White L., Silman, M., Morel, A. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. Proceedings of the National Academy of Sciences USA. 108(24):9899-904

Baccini: above ground carbon (500m resolution) (pantropical region only)

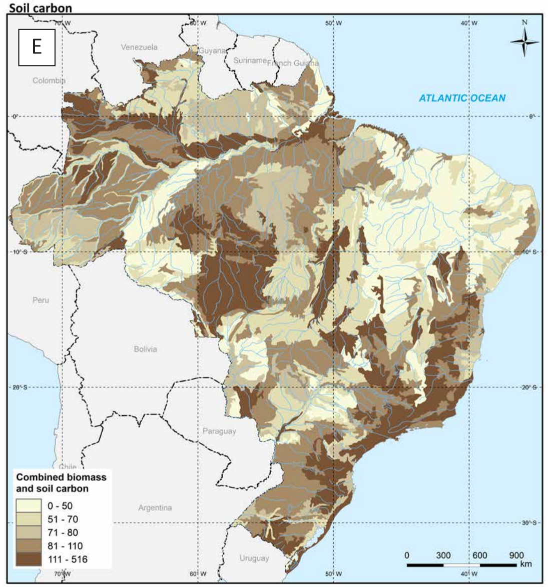


Data source: Baccini, A, Goetz, S. J., Walker, W. S., Laporte, N. T., Sun, M., Sulla-Menashe, D., Hackler,, J., Beck, P. S. A., Dubayah, R., Friedl, M. A., Samanta. S. and Houghton, R. A. 2012. Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change. 2:182-185

Ruesch and Gibbs: above and below ground biomass carbon

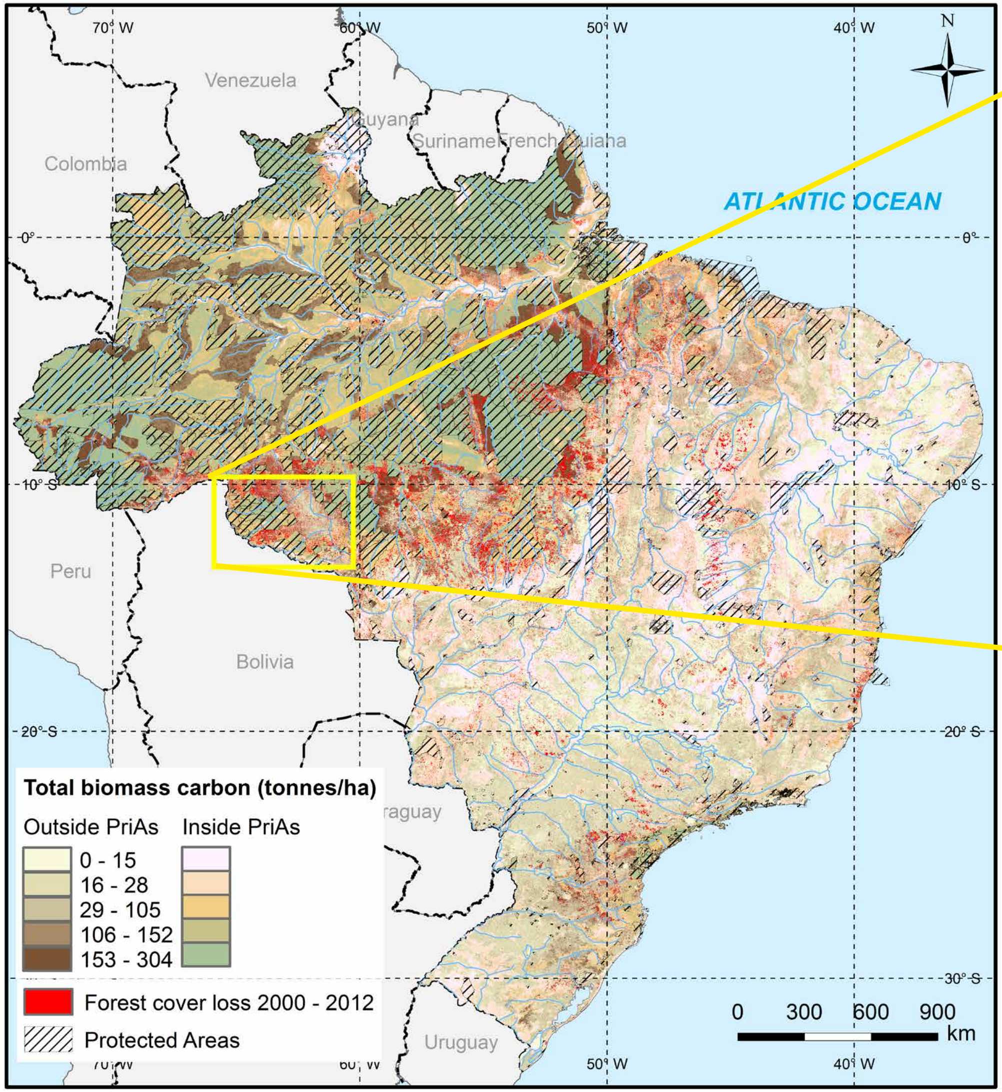
Data source: Ruesch, Aaron, and Holly K. Gibbs. 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Available online from the Carbon Dioxide Information Analysis Center [http://cdiac.ornl.gov], Oak Ridge National Laboratory, Oak Ridge, Tennessee.

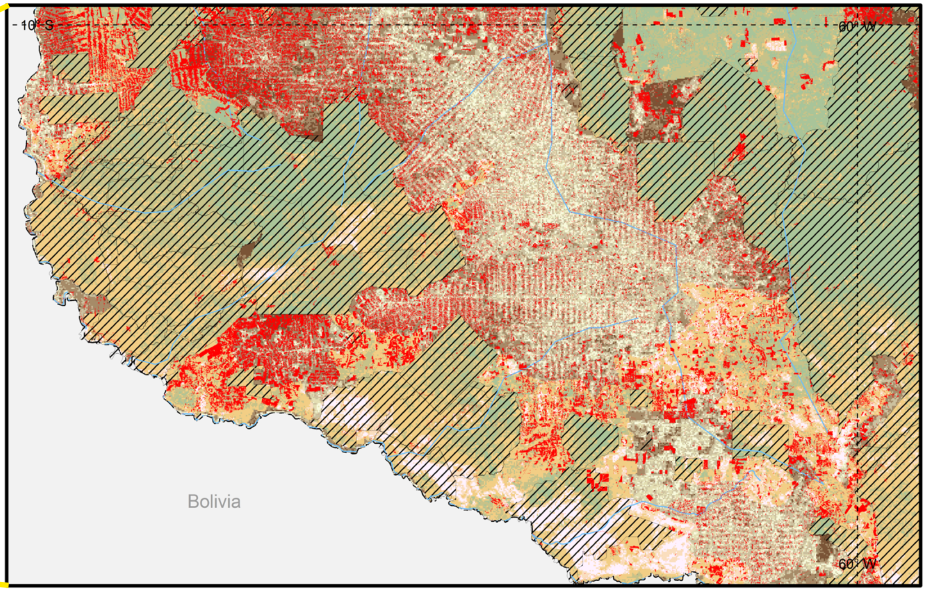
Soil carbon



Data source: Hiederer, R. and M. Köchy (2011) Global Soil Organic Carbon Estimates and the Harmonized World Soil Database. EUR 25225 EN. Publications Office of the European Union.79pp

Map 4: Areas important for carbon and biodiversity in relation to deforestation. Carbon stocks inside the MMA priority areas (PriAs) are highlighted in shades of green and those outside in shades of brown. Protected areas (black hashes) have protected may biodiversity priority areas which are high in carbon from deforestation (red). However, closer examination (insert) also shows that deforestation has occured in priority areas, especially those of lower carbon outside protected areas.





Data sources:

Biodiversity Priority Areas: National dataset of 2007 provided by Ministerio do Meio Ambiente (MMA). Data available online from http://mapas.mma.gov.br/i3geo/datadownload.htm#

Protected Areas: IUCN and UNEP-WCMC (2014), The World Database on Protected Areas (WDPA) [May, 2014]. Cambridge, UK: UNEP- WCMC. Data available online from http://www.protectedplanet.net/termsandconditions

Forest cover loss 2000 – 2012: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850–53. Data available online from: http://earthenginepartners.appspot.com/science-2013-global-forest

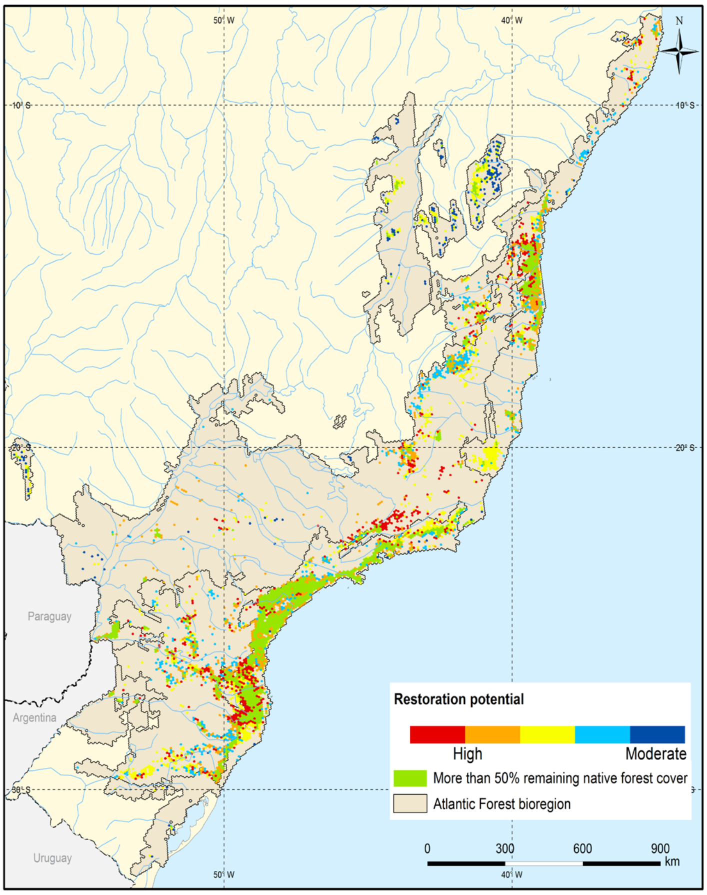
Above ground biomass (1km resolution): Saatchi S., Harris NL, Brown S., Lefsky M., Mitchard ET., Salas W., Zutta BR., Buermann W., Lewis SL., Hagen S., Petrova S., White L., Silman M., Morel A. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. Proceedings of the National Academy of Sciences USA. Jun 14; 108 (24):9899-904

Soil carbon: Hiederer, R. and M. Köchy (2011) Global Soil Organic Carbon Estimates and the Harmonized World Soil Database. EUR 25225 EN. Publications Office of the European Union.79pp

maps of carbon, past deforestation and biodiversity. However, the past will not always project the future so more sophisticated models are important for longer term projections (section 3.2).

Activities to reduce forest-related emissions do not only include actions to reduce deforestation, but actions to increase the sustainability of forest management and enhance forest carbon stocks. Different maps can be useful for planning for each of these different activities. In terms of reforestation or restoration of forest carbon stocks, maps of the location of past deforested or degraded areas compared to areas required for agriculture or other land-uses can highlight the potential importance of restoration and regeneration. They can illustrate how much deforestation and degradation has previously occurred and also whether these affected areas are no longer needed for production. For example within Brazil, restoration of deforested land is required within the Forest code and is a particularly important issue within the Atlantic forest where only a small percentage of original forest remains. In addition to sequestering carbon and so reducing the overall net emissions, restoration, as with reducing deforestation, can also help protect and restore the biodiversity in that area, supporting conservation objectives (especially in terms of Aichi Biodiversity Target 15). Therefore, understanding restoration potential of areas in relation to areas important for biodiversity and potential carbon sequestration can support achieving multiple objectives. For example, within Brazil MMA funded work to identify priority areas for restoration taking into account locations of remaining habitat fragments and the need to increase connectivity (Map 5). However, it takes a long time for ecosystems to fully recover and biodiversity is spatially variable so the biodiversity and carbon impact of a loss of primary habitat in one area cannot simply be offset by restoring another area elsewhere. The approach to restoration also has significant influence on the speed and quality of the results (Miles et al. 2010). Therefore, the most appropriate restoration measure varies between locations (see section 4.4).

Map 5: Areas identified as having restoration potential within the Atlantic Forest biome, Brazil.



Data source: Cunha, A.A. and Guedes, F. B. 2013. Mapeamentos para conservação e recuperação da biodiversidade na Mata Atlântica: em busca de uma estratégia espacial integradora para orientar ações aplicadas. Ministério do Meio Ambiente (MMA), Secretaria de Biodiversidade e Florestas. Brasília, DF. 216p

Maps can also support planning for sustainable management of forests for timber production. This is likely to be of most relevance for areas which are currently or already planned to be used for timber production and where the management strategy could be improved. Information on the location of timber concessions or volumes of industrial timber production from different areas is often easily accessible but determining the sustainability of management plans, and the potential to reduce carbon emissions, requires much more in-depth work. Additionally, identifying areas of informal or illegal timber harvesting can be challenging. Ensuring the sustainability of timber production in those harvesting areas that contain high levels of biodiversity can also help to achieve conservation objectives.

In terms of planning for REDD+, mapping can be most useful in understanding where potential multiple benefits are located and so where activities could be conducted to achieve multiple objectives; for example planning new protected areas that will protect the current location of a range of ecosystem services.

3.2 What can models provide?

Models can support mapping and evaluations as they offer ways to estimate what is likely to occur where directly observed data are not available. This can range in complexity from interpolating the value of a parameter (such as biomass carbon) in locations between observation sites (such as to produce wall-to-wall carbon maps), to projecting the potential land use in different areas in the future (for example 2050). However, in order to build plausible models, a detailed understanding of the system being modelled is needed and this can often require significant amounts of data for that system.

One of the main ways in which biodiversity is impacted by land use policy is through land use

change. Habitat destruction is currently one of largest threats to species. Many species require specific land covers and associated flora and fauna (such as tropical forests) for survival, for example for food and nesting requirements. Therefore, understanding the potential impacts of policies on biodiversity requires an understanding of their impacts on land use, and on the drivers of land-use change. This in turn requires evaluation of future land-use change under different scenarios. Strategies that address expected land use change (including deforestation) over the next 30 to 50 years, not just current areas at risk, are more likely to have sustainable results. Land-use change models and the logic used to develop them are particularly useful for providing these projections of what may occur in the future and also, depending on the type of model used, for exploring the potential for drivers of land-use change to be displaced into new areas by any particular policy option modelled.

Land-use change models vary in their complexity. Most consider land-use change to be a function of a selection of socio-economic and biophysical variables or 'driving forces', which control what change occurs (Verburg et al. 2004). Most existing land-use models can be categorised into empirical-statistical "geographic" models or economic models.

"Geographic" land use models involve the allocation of land to specific land-uses based on the suitability of land for different land use types and location. They are capable of capturing supply side constraints based on land resources and spatial determination of land use, however, they cannot address the interplay between supply, demand and trade (Heistermann et al. 2006). Examples of these empirical statistical geographic land use models have been used in Brazil, including for assessing deforestation. For example the LandSHIFT model has been used to assess deforestation related to biofuel expansion (Lapola et al. 2010). The DINAMICO EGO (Environment for Geoprocessing Objects) model, which has been used for a number of studies within Brazil and in support of REDD+ projects, is a cellular automata model developed by the remote sensing laboratory at the Federal University of Minas Gerais in Brazil. It uses a 'weights of evidence' method to generate a map of change potential based on a number of explanatory variables and past trends that involve expert knowledge (Soares-Filho et al. 2006). The key assumption underlying several of these models is that observed spatial relations between land use types and potential explanatory factors represent currently active processes and remain valid in the future. For example, the IDRISI land change modeller (Lin et al. 2013) works by reviewing historical changes between land-cover maps of two time periods alongside maps of driver variables (e.g. distance to roads or accessibility to forest) to create a layer of the likelihood that a land use will transition in the future, based on past trends. It has been applied to assess priority areas for implementation of REDD+ policies (e.g. in Tanzania, Lin et al. 2013).

Economic models use supply and demand of land-intensive commodities as a basis for allocation of land. A key assumption of economic models is that people will seek to maximise financial gains. Most are based on land-rent theories that assume that any parcel of available land will be allocated to the use earning the highest rent. Global economic models are often equilibrium models that explain land allocation by evaluating the potential demand and supply of products within the land-intensive sectors (such as agriculture and forestry), and maximising both the demand and supply under exogenously defined constraints (Heisterrmann et al. 2006). Most will model the total area of specific land-use types within defined regions but unlike geographic models, do not produce detailed maps.

It is possible to combine the two approaches to quantify demand and supply and allocation of land use based on geographic analysis. In combining economic and geographical information they overcome some of the limitations associated with purely geographical and purely economic land use models. An example of such a model is GLOBIOM (Havlik et al. 2011) which includes a detailed representation of the major land–based production sectors and provides spatially-explicit land use outputs. This model is being used within the REDD-PAC project and is explained in more detail below.

Once a model has been used to project land use change, it is then possible to use the modelled land use change to assess the likely impacts on biodiversity (see section 5). There are multiple different methods for undertaking such assessments which can provide different results. For instance, Soares-Filho et al. (2006) and Bird et al. (2012) both used projections of forest change in Amazonia from the DINAMICA-EGO model described above. Soares-Filho et al. (2006) then estimated that one quarter of (382 mammalian) species assessed will lose significantly high levels of suitable habitat. In contrast, Bird et al. (2012) found that the number of threatened species (of 814 Amazonian birds) is projected to increase from 3% to 8–11%. The robustness of these assessments depends on a large part on the quality of the land use change estimates, which in turn depend on the quality of information which goes into them and the assumptions which they entail (section 4).

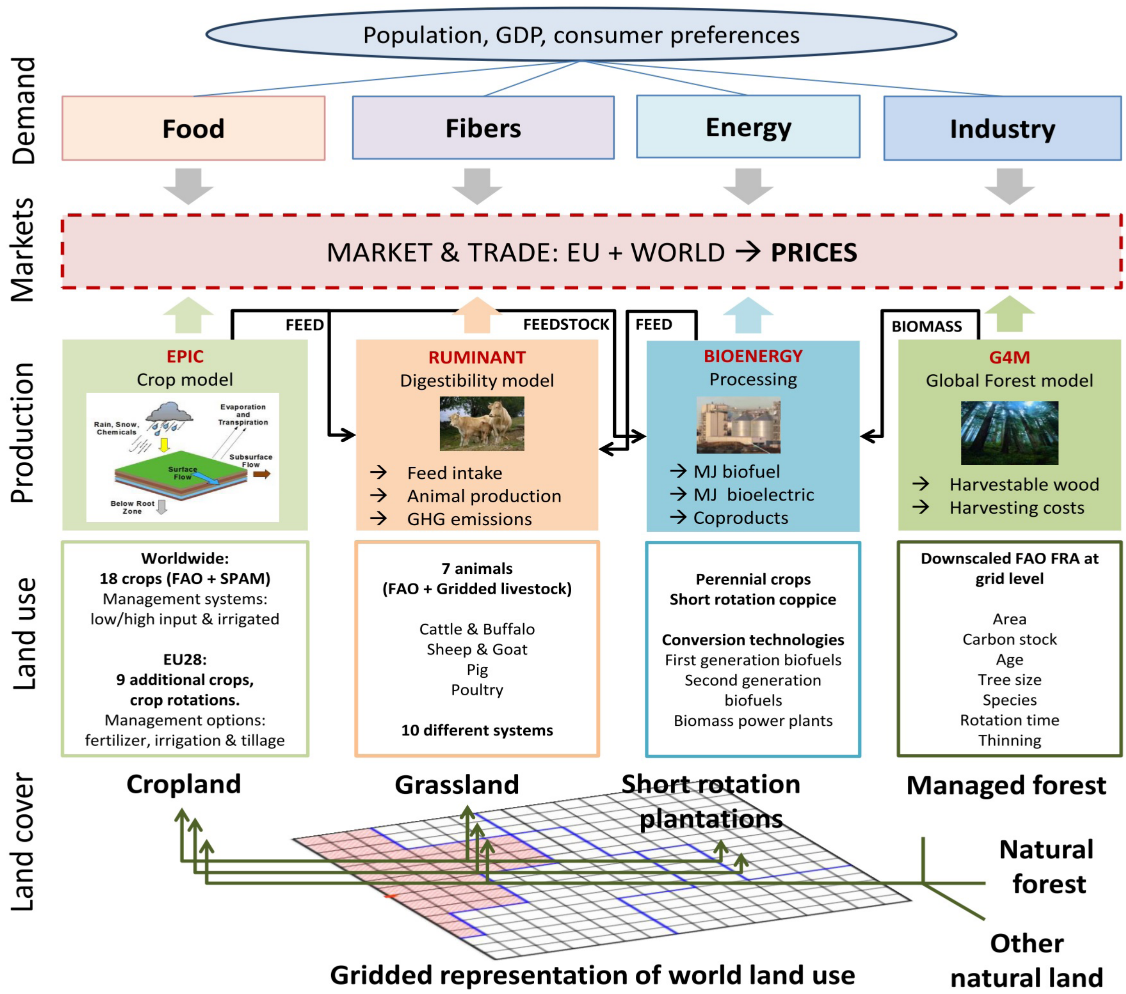
3.2.1 Modelling in the REDD-PAC project

In the REDD-PAC project the global land-use model (GLOBIOM) developed by IIASA will be used, and refined, to support analyses of the land use and biodiversity impacts of REDD+ policy options. INPE, IPEA and IIASA are working jointly to refine and regionalize GLOBIOM tools, data and approaches for Brazil. GLOBIOM is a recursive dynamic partial equilibrium model, designed to aid policy analysis of land-use competition among the major land-based production sectors, particularly agriculture, forestry, and bioenergy (Figure 2). It provides a detailed representation of each sector, accounting for 18 crops, a range of livestock production activities, major forestry commodities, and multiple bioenergy transformation pathways. The crops considered represent 86% of the harvested area in Brazil (IBGE-PAM).

GLOBIOM-Brazil is run on a 50x50 km grid and includes 6 broad land use and associated land-cover categories (see section 4.2), with the crop production category being subsequently subdivided. It is an optimization model that selects the land use and processing activities which maximise both consumers' utility of products and producers' profits, within biophysical constraints (Havlík et al. 2011). It draws from a global database on soil types, climate, topography, land cover, and crop management. An important characteristic of the GLOBIOM model is that international trade flows are computed internally within the model which enables one region to react to future changes in the other regions and vice-versa (Mosnier et al. 2012).

The main output of GLOBIOM includes the proportion of different land uses in each grid cell. The estimated land-use changes are then used to estimate GHG emissions and biodiversity impacts. GHG emissions and sinks related to land-use change are calculated as the difference between the above- and below-ground living biomass carbon content of the initial land-cover class and that of the new class. By default, carbon for forest biomass is taken from Kindermann et al. (2008), and carbon in grasslands and in other natural vegetation is taken from Ruesch and Gibbs (2008). However, Saatchi et al. (2011) and Baccini et al. (2012) biomass maps are systematically used for sensitivity analysis (see Map 3). The methods for assessing the biodiversity impacts from land-use change are explained in more detail in the folowing sections.

Figure 2: Schematic of the GLOBIOM model



4. Defining key issues and assumptions in both mapping and modelling to support decision making

In undertaking assessments to support understanding of the biodiversity impacts of policy options there is a need to first specify the key issues of concern and define the assumptions being made within the assessment. For policy-relevance, there is a need not only to understand the broad policy context and the types of assessments which are feasible, but also to specifically define the key issues which will be addressed in any given assessment. In most assessment approaches it is necessary to simplify and make assumptions about how the world operates. Issues which are particularly relevant for biodiversity assessments including what land uses and land-use changes can occur, how protected areas operate and how natural regeneration occurs.

4.1 National priorities

For use in policy development, the assessment needs to address the needs and priorities of the relevant policy-makers. Focusing assessments on national targets (such as Brazil's national biodiversity targets for 2020) and national priorities (such as Brazil's biodiversity priority areas) can help to ensure the relevance of assessments. However, written reports on national priorities can quickly become outdated and are unlikely to specify all concerns and exact requirements of policy makers. Therefore, there is a need for engagement with national stakeholders and this document forms part of that process for the REDD-PAC work within Brazil.

4.2 Land cover and land use categories

Land cover forms complex patterns which occur along a range of largely continuous gradients such as the level of tree cover and the density of cultivated vegetation. However, in order to map and model land cover it is generally necessary to categorise the land into discrete classes. Even with deceptively simple requirements, such as mapping the distribution of forests, there can be significant challenges. Across the world, different definitions of forests are used, ranging from focusing on dense forest to being broader and including woody savannahs. The challenge gets even greater when trying to map natural forests (which the Cancún safeguards protect, see section 2). Defining natural forest is only possible when a forest definition has already been settled upon. Various definitions of 'naturalness' are available, and factors can include whether the forests is largely composed of native species and whether the forests has been formed through natural regeneration rather than planting.

Assessments of policy impacts need to consider both the land cover and the land use, and the categorisations used for each. Land cover, the vegetation growing in a location, is very closely related to, but distinct from, land use, the ways in which humans use the land. Depending on the categorisations applied, many uses, such as cultivation of specific crops can give rise to a single broad land cover, and conversely quite distinct types of (for example) forest vegetation could be lumped into a single land use. One broad category of land use can have very different implications for biodiversity depending on how it is implemented. For example, timber extraction by conventional logging has more impact on the forest than reduced-impact selective logging (Putz et al. 2008). It can also be important to recognise that local communities can benefit from services from largely undisturbed and un-managed areas. For example in Brazil, non-timber forest products can be a significant source of food security (Menton 2003) and income for families in the Amazon biome (Morsello et al. 2012).

Recognizing and specifying how a classification has been made, both in terms of land use and land cover is very important for understanding what an analysis shows and ensuring that the analysis is relevant to the policy question of interest. For example, in order to identify areas that are important for both national policies on reducing deforestation and protecting forest-dependent species, it is necessary to know what the national forest definition is, and how that relates to the actual habitat requirements of the species of interest, and to the definition applied within the input data and model. Species may have more precise requirements, such as for undisturbed natural forests rather than managed forests or plantations, or particular forest ecosystem types such as tropical dry forest.

If these different types of use are grouped into one category (e.g. of crop production or timber production) within an assessment, the large-scale impacts of changes from natural vegetation to productive areas can be assessed but the differential impacts between more specific types of use cannot. However, the inclusion of more land categories within a model makes it more computationally demanding to run; and requires more information on their distribution and characteristics. Therefore, there is a limit to the number of categories which can be included in any one model and what categories are included will depend on the type of model. If the

Table 2: Land transitions currently included within the GLOBIOM-Brazil model.

		Land use in second time period						
		Pristine forest*	Managed forest	Cropland	Pasture	Short-rotation tree plantations	Non-productive land	Recovering forest
Land Use in first time period	Pristine Forest*	-	Y	Y	Y	Y	N	N
	Managed forest	N	-	N	N	N	N	N
	Cropland	N	N	-	Not yet	Y	Y	Y
	Pasture	N	N	Y	-	Y	Y	Y
	Short-rotation tree plantations	N	N	Not yet	Not yet	-	Y	Not yet
	Non-productive land	N	N	Y	Y	Y	-	Y
	Recovering forest	N	N	N	N	N	N	-

**Includes woody savannahs to dense humid forest*

main focus and driver of a model is economic, then the most critical factor in determining the land use projections is that these economic decisions are as accurately captured as possible. For example, the economics of converting an area to cropland may not be significantly affected by the previous vegetation cover (for example *Estepe*, *Savana* or abandoned pasture). Distinguishing between these categories would not then significantly affect the projected future land use changes. However, these categories may be relevant to results in terms of biodiversity impacts. Savannah or steppe vegetation types have different biodiversity associated with them, and both are likely to harbour significantly higher levels of biodiversity than abandoned pasture. One solution can be to cross reference the areas where an economic model projects land use change with more refined initial land cover maps.

An example of the land use categories in an economic model are those used within the REDD-PAC project: two categories of forested land (unmanaged forest and managed forest), cropland, short-rotation tree plantations, pasture, and "other natural vegetation" (including unused grasslands) (Table 2). Within these broad categories the model also specifies different intensities of crop production and crop types. Forested land includes one category of use (managed forest), which is assumed to be under sustainable timber production, such that it remains under forest cover.

4.3 Protected areas

Protected areas are a land-use designation of particular relevance to assessments of biodiversity impacts. Protected areas are a tool for biodiversity conservation and for protecting land from conversion that leads to GHG emissions. However, globally, protected areas have very varying levels of effectiveness in meeting these goals. Assumptions about the land uses that are formally permitted within a protected area, and the effectiveness of protected areas in conforming to those rules, can be important in both mapping and land use change modelling.

Maps can be used to evaluate the percentage of areas of interest (for example, biomes, areas particularly high in carbon, species ranges) which are protected. Mapping can also be used to assess the amount of conversion happening within protected areas, and thus help identify their effectiveness. For example, comparison of data on deforestation and the location of protected areas in Brazil show that although they are generally effective at halting deforestation, over 2700 ha of protected areas were deforested between 2000 and 2012 (see Map 6). However, in simply comparing the level of conversion within and outside protected areas it is important to note that they are often located in remote areas that may suffer less conversion simply due to their remoteness and difficulty of access (Joppa and Pfaff 2009). A more

Map 6: Overlap between protected areas and past deforestation highlights the role of protected areas in reducing deforestation

Data sources:

Forest cover loss 2000 – 2012: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850–53. Data available online from http://earthenginepartners.appspot.com/science-2013-global-forest

Protected Areas: IUCN and UNEP-WCMC (2014), The World Database on Protected Areas (WDPA) [May, 2014]. Cambridge, UK: UNEP-WCMC. Data available online from http://www.protectedplanet.net/

accurate assessment of protected area effectiveness would involve considering other factors in the analysis and using statistical matching methods to compare the relative levels of conversion or degradation in protected areas and in equivalent un-protected areas (Nelson and Chomitz 2011, Barber et al. 2012, Joppa and Pfaff 2010).

Different types of protected areas may have different regulations on permitted land uses. Even where the rules are the same, the type of protected area may also influence its effectiveness at preventing land conversion. A global analysis of protected areas in forest biomes suggested that multiple-use protected areas were more effective than strict protected areas (Nelson and Chomitz 2011). However, other global studies have show little impact of type of protected area (Nagendra et al. 2008). Additionally, within Brazil, studies in both the Cerrado and Amazon have shown that multiple use protected areas are less effective (Carranza et al. 2013 and Nolte et al. 2013 respectively). Clearly it is not the type of designation *per se*, but differences in factors such as the attitude of the local population and the investment in protection that influences their success in reducing deforestation.

Assumptions about the restrictions protected areas place on land conversion, and their effectiveness, are also very important within land use change modelling. If it is "hard wired" within a model that protected areas prevent all land use change then it is not possible to use the model to assess potential conversion within protected areas. The model output will automatically protect all biodiversity within the protected areas into the future. This has the potential to underestimate pressures on biodiversity and does not allow for the assessment of the impacts of changes in protected area policy on biodiversity or carbon.

4.4 Regeneration

Within land-use change models, assumptions about what happens when land is abandoned determine the level of regeneration that will occur. It can be complex to model the dynamics of how vegetation will recover, however, a good model should keep track of what land has been abandoned and not assume it instantaneously recovers to natural vegetation.

There are multiple aspects of recovery including biomass, vegetation structure, species richness and diversity. Just considering biomass carbon, estimates of recovery time range from between 25 to 70 years (e.g. Pascarella et al. 2000, Aide et al. 2000, DeWalt et al. 2003). Forest area recovery can vary between different components such as forest structure and species. For example, Piotto et al (2009) observed that within Brazilian Atlantic forest plots forest structure was not restored after 40 years, whereas over half of old-growth species were present. Although, the diversity of species generally increased with the age of secondary forests, the rate of species recovery varied greatly depending on the taxonomic group (Chazdon et al. 2009). For example, Barlow et al. (2007) found that within 14 to 19 years secondary forest in the Brazilian Amazon contained under 50% of primary forest species of trees, lianas and birds but there were 95% of orchid bee species. It can take long time periods for complete recovery, one study in the Brazilian Atlantic forest estimated that it would take secondary forest 100-300 years for species composition to recover (Liebsch et al. 2008).

The recovery of a system will depend on the intrinsic rate of recovery of the particular ecosystem, the land-use history and level of degradation, the land context including proximity to natural vegetation, and whether any active measures are put in place to support recovery (Holl and Aide 2011). The rate of recovery is very variable between ecosystem types (Jone and Schmitz 2009) and along aboitic gradients such as temperature and rainfall including within tropical forest (Holl and Aide 2011). The previous land use can cause degradation of the soil and nutrient availability. The intensity and length of previous land use will significantly impact the rate of recovery, (Hughes et al. 1999, Guariguata and Ostertag 2001). The regeneration of a site will also depend on the proximity to forest fragments. If there are no sources of new seeds newly abandoned land is unlikely to return to forests un-assisted. For example, within the Atlantic Forest in Brazil distance to potential propogules severly limits the possibility of natural regeneration (Rodrigues et al. 2009).

The level of human intervention in encouraging restoration also significantly impacts restoration rates, activities range from leaving an area to naturally regenerate to actively restoring the area including planting and introducing species. The biodiversity impact of active restoration will depend on whether the aim is simply to restore biomass and forest cover (and so include plantations) or whether the faunal and floral biodiversity of natural forest is restored. In the Atlantic Forest sowing seeds and/or plant seedlings to promote environmental conditions favorable for the invasion of other species is one of the most common restoration strategies (Rodrigues et al. 2009). However, there can be a significant cost involved with assisting regeneration.

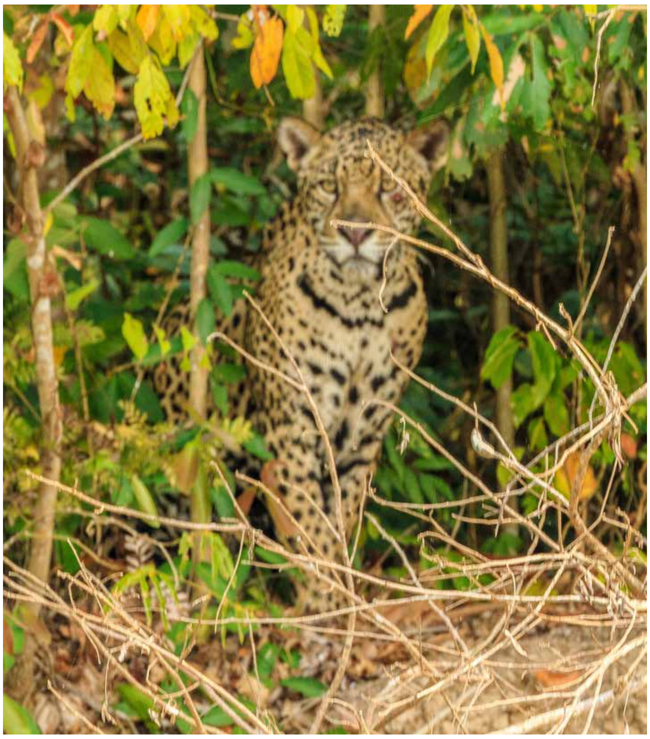
5. Approaches for assessing biodiversity impact

When carrying out assessments of the biodiversity impacts of policy options, many different elements to biodiversity can be considered, and different approaches of greater or lesser complexity are available. The simplest method for assessing biodiversity impacts is to assess the changes which occur in areas highlighted as priority areas for biodiversity. As a sole approach, it has the disadvantage of excluding from consideration the impacts outside those areas. An alternative, but similar, approach is to assess impacts in relation to individual species ranges and habitat requirements. In carrying out such assessments it is important to identify which species are of particular concern and how the impact on species will be evaluated. As a final alternative, biodiversity models could be employed, simulating the impact on species or communities.

Policy makers may also be particularly interested in the services that biodiversity and ecosystems provide to humans. There are a range of potential ecosystem services, and the different services can require different assessment approaches.

5.1 Priority areas

There are multiple components to biodiversity (including diversity in ecosystems, diversity in species and diversity in genetics), and each of these is distributed differently across space. Certain areas within a country can be of higher conservation priority for one or more of these components.



Therefore, which aspects of biodiversity are considered most important will impact which areas are of highest conservation value overall. In several countries, including Brazil, official national processes have identified the areas which are most important for biodiversity according to national priorities. Where this has not yet happened, it is possible to use areas identified by civil society, nationally and/or internationally. For example, Key Biodiversity Areas have been identified globally through in-country consultations that apply criteria developed by IUCN and BirdLife International (Eken et al. 2004).

As discussed in section 3, spatial overlay of those areas identified as biodiversity priorities with other information relevant to REDD+ policies can support policy development and planning. Including spatially-explicit modelled land use change under different policy scenarios within the assessment can help to highlight the areas which are under greatest threat in different scenarios and the overall relative impact of different scenarios across all priority areas.

In carrying out such an assessment of modelled land use change, three points are especially relevant. First, many areas which have been identified as national priorities for biodiversity may already be under protection. Therefore, how protected areas are dealt with within the model will likely influence the distribution of land use change projected within the priority areas, as discussed in section 4.3.

Second, is which land use changes to include within the assessment. The focus of REDD+ policy assessments is often the occurrence of deforestation within forested protected areas. However, there is a risk that policies to reduce agriculture or cattle ranch expansion within forested areas may displace these pressures to non-forested areas. Land-use change modelling that includes the areas outside forests enables an estimate of the impact of this displacement. Therefore different impact assessments may be needed depending on location. For example in Brazil, deforestation may be most relevant in Amazonia, but conversion of other natural vegetation more relevant in the Cerrado or Pantanal. The conversions of interest are also likely to depend on the specific definitions of land cover and land use within the model (see section 4.2).

Third, the resolution of the model results should be considered. If the spatial resolution of the information on land use change and biodiversity priority areas are not the same, it can be necessary to make assumptions in relating the two. For example within the REDD-PAC project the land-use change model runs in 50x50km

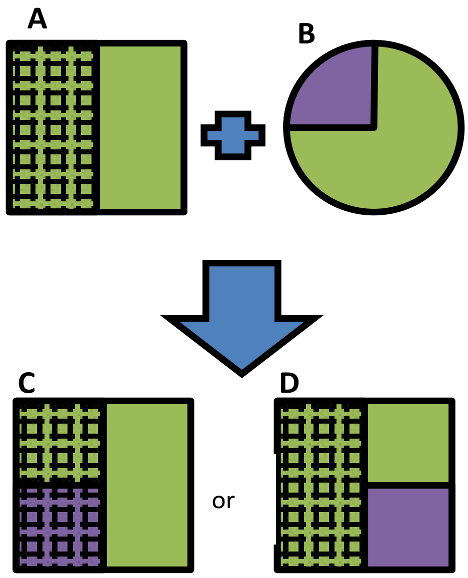


Figure 3: Options for allocating land use change within a gridcell 50% covered by a biodiversity priority area (black hatching) and completely covered by forest (green) at the start (A), and projected to lose 25% of its forest cover (purple) (B). The impact of deforestation will vary depending on whether this deforestation is assumed to be more likely to occur within (C) or outside (D) the biodiversity priority area, or anywhere in between.

grids and the model projects proportion of each land-cover category within each gridcell at each time step. If a gridcell that is 50% covered by a biodiversity priority area and completely covered by forest at the start (Figure 3A), and is projected to lose its forest cover by 25% (B), an assumption has to be made about whether this deforestation is more likely to occur within (C) or outside (D) the biodiversity priority area. Exploring the difference in impact depending on what assumption is being made can highlight the potential that restricting conversion within priority areas can have without impacting production.

5.2 Species

When assessing impacts of land-cover change on species ranges, the factors to be considered include what species are of particular interest (all, protected, threatened species, birds, mammals, etc.) and what data are available on the species ranges and their ecological requirements. The species richness of different groups can show different patterns and so the selection of which species are of particular interest can influence the conclusions of assessments (Map 7).

Assessing impacts in relation to all species would allow a complete assessment of the overall biodiversity impact. However, it is not possible to get accurate data on the location or habitat requirements of all species, not least as there are many species yet to be discovered (Pimm et al. 2010). The IUCN Red List process has assessed all known species of mammals, birds and amphibians and has compiled distribution data for most as part of an effort to identify the species which are most threatened with extinction (available at www.iuncredlist.org).

The location of threatened species is particularly relevant to reducing the threat of species extinctions, as per the objectives of Aichi biodiversity target 12 and the Brazilian national biodiversity target 12. Another way of identifying species of particular national concern is to consider species which are legally protected by national legislation.

The number of species within an area (species richness) offers a relatively crude measure of biodiversity as it does not distinguish between the presence of common and rare species. Locations with many endemic species are especially important for biodiversity. One alternative approach to assessing a location's importance for biodiversity is to combine the number of species present within that location with the proportion of each species range which that location represents (its endemism), to create a "endemism richness" indicator (Kier and Bartholtt 2001, Figure 4).

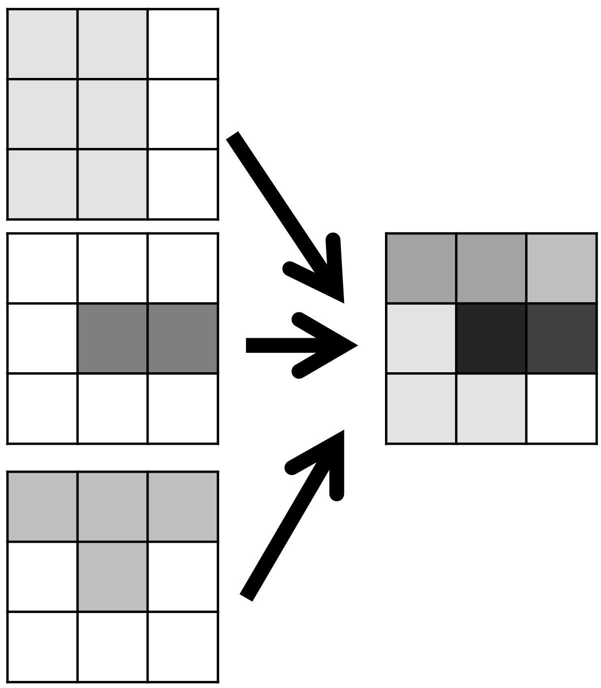
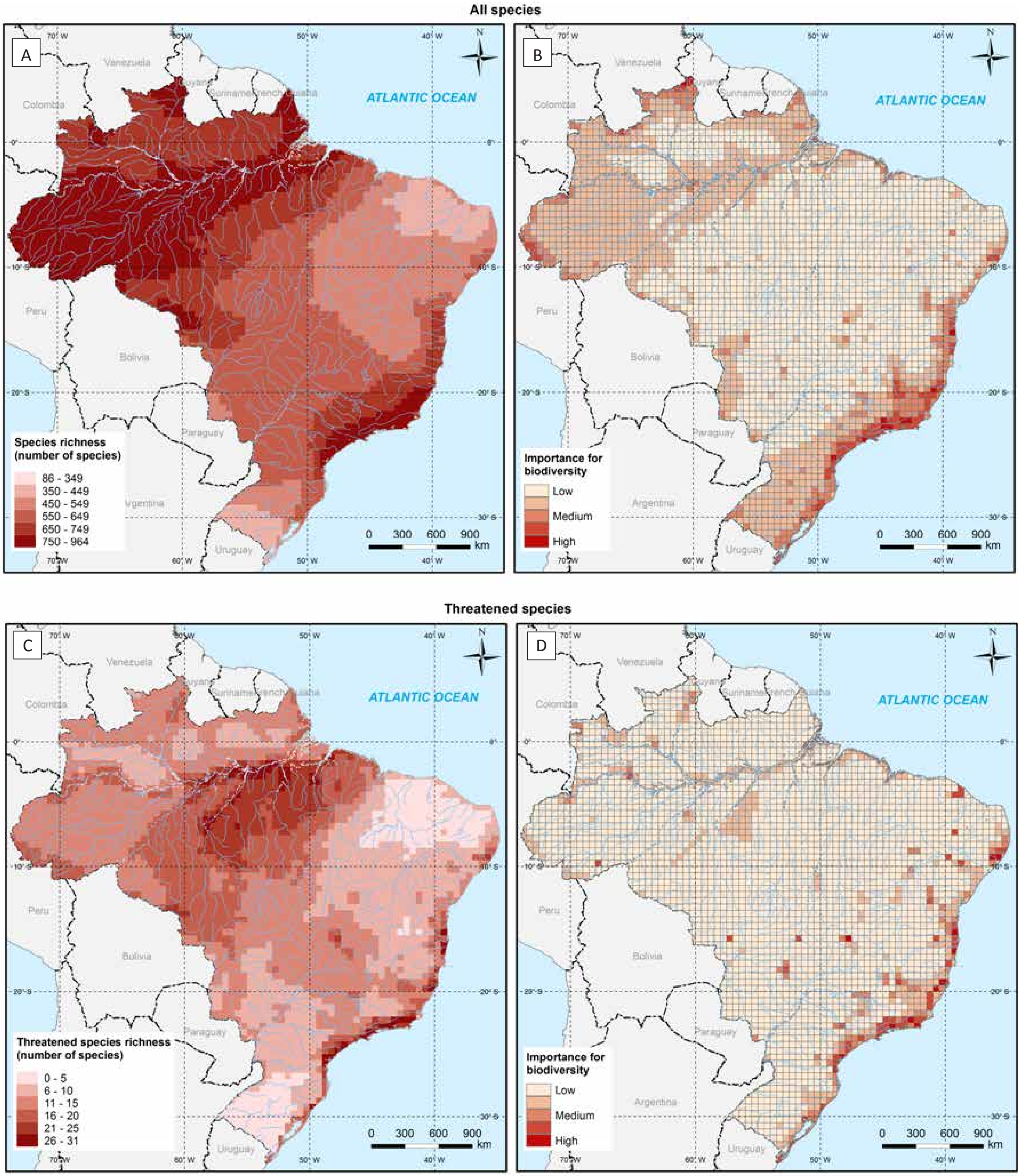


Figure 4: Information on the contribution each cell makes to an individual species range (shade of gray in the first column) can be combined across species (right hand map), such that the indicator is higher where mores species occur and the cell contains a larger proportion of their range.

Map 7: Maps of species richness (A) and the importance of areas in terms of 'endemism richness' (B) of all amphibians, birds and mammals. As well as the richnesss (C) and importance of areas (D) for and threatened amphibians, birds and mammals (D). Data derived from IUCN species range size data and presented at a 50x50km gridcell resolution.



Data sources:
Vertebrates: IUCN. 2013. The IUCN List of Threatened Species. Version 2012.2. http://www.iucnredlist.org

Maps and analysis of current distributions of species can identify locations which are particularly important for biodiversity now, and the potential impact of the distribution of REDD+ activities in relation to these areas. Combining information on the distribution of species and modelled future land use change, can enable an assessment of the impact of that land-use change has on species. As with the biodiversity priority areas a key benefit models can be in assessing the impact of displaced land use on non-forest species.

In order to assess the impact of land use change on individual species, one of the first factors to consider is the habitat requirements of the different species and thus the likely impacts of land use and land cover change. For example, if species are dependent on forests, deforestation will likely lead to the species extinction from that area. Once the species to be assessed and the land-use change of interest have been selected, a range of possible approaches for summarising the impact of changes in land use exist, including:

- Projecting the total number of species extinctions by:
  – Identifying the number of species which lose all of their habitat and so would go extinct. This is likely to result in an underestimate of biodiversity impact as even species which do not lose all of their range are likely to be negatively impacted and go extinct;
  – Estimating likely extinctions based on the species areas relationship, i.e. the assumption that if the area of available habitat decreases fewer species will be able to survive in it;
  – (*e.g. Strassburg et al 2012 calculated extinction of forest dependent mammals and amphibians in REDD-eligible regions under a range of scenarios*).

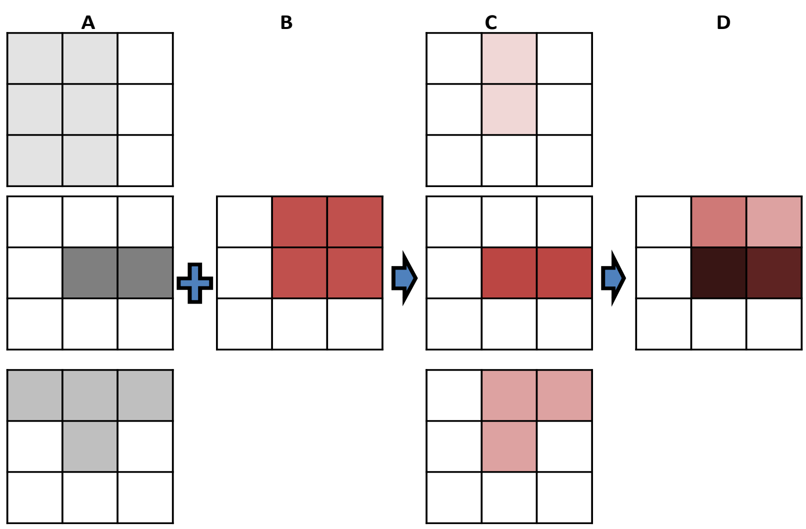
- Projecting the number of species which will change their extinction threat category (e.g. going from vulnerable to endangered):
  – Based on the IUCN Red list criteria including reductions in species range and amount of remaining range (*e.g. Strassburg et al 2012);*
  – *e.g. Bird et al 2012 assessed all forest dependent Amazonian bird species by combining data from a spatially explicit deforestation model with generation length estimates.*

- Identifying species with a large percentage of their habitat lost:
  – *e.g. Soares-Filho et al. (2006) simulated forest change in Amazonia and identified which of 442 species for which they had range data, suffered more than 60% deforestation within their range.*

These assessments provide ways of presenting the total biodiversity impact. However, it can also be useful to identify specific areas where the modelled land use change is likely to have the largest impact on species overall. In order to spatially assess the distribution of impacts, Soares-Filho et al. (2006) overlayed the ranges of species which were projected to lose most their range, to identify areas where most threatened species occurred. This analysis did not highlight the threatened parts of the ranges, or take account of species losing even a little less than the threshold amount of habitat. Bird et al. 2012 overlayed distribution maps for their revised list of threatened species, to identify "crisis areas" (areas of projected deforestation supporting the highest numbers of threatened species) and "refugia" (areas projected to retain forest supporting the highest numbers of threatened species).

Within the REDD-PAC project, we are planning to carry out an alternative biodiversity impact assessment linked to the "endemism richness" indicator described above. In understanding the relative impact of biodiversity loss in different locations it can be important to assess both where loses represent a large proportion of a species habitat (due to the species having a small range) and where loses will impact on a large number of species. Therefore a composite index of "combined species habitat change" will be mapped (Figure 5).

Figure 5: A index of species habitat change can be mapped (D) using the range of species weighted by how widespread they are (A) plus the location of their habitat loss (B) to identify loss of range for individual species (C) and then summing the habitat lost for individual species across all species (D)



5.3 Biodiversity models

Assessments of biodiversity impacts can also use more complex biodiversity models, two examples include, modelling species ranges and modelling changes in species communities. Surveying the entirety of species potential range is often not possible. Therefore models are often used to assess the most likely distribution of species, based on the current (or future projections of) climatic and other environmental variables and the characteristics of the locations where the species are known to occur. For example, ICMBio in Brazil are undertaking such analysis of threatened species, which the REDD-PAC project plans to use. Models can also be used to make assessments of the potential change is species' abundances across an ecosystem due to land use changes. For example, models such as Predicts (Newbold et al. 2014) or GLOBIO (Alkemade, et al. 2009) make estimates of change in species abundance caused by different land uses.

5.4 Ecosystem services

Understanding the impacts of policies on the services which biodiversity and ecosystems provide to people (ecosystem services), can be of great interest to stakeholders. Ecosystem services include regulating services (such as soil erosion control and flood control), provisioning services (such as the supply of food or non-timber forest products) and cultural services. The broad range in ecosystem services means that different

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assessment methods are needed for assessing impacts. Assessing the impacts on biodiversity, which provides a significant component to cultural ecosystem services, are discussed in detail in the previous sections of this report.

In terms of regulating ecosystem services, climate regulation is particularly important for REDD+ policies and requires information on land use change and carbon stocks to assess changes (see section 3). Another example of an important regulating ecosystem service that land use, including forest cover, can have significant impacts on is water flow and filtration which can cause changes to soil erosion, nutrient retention and water yields. Tools such as WaterWorld (Mulligan 2012) and InVEST (Sharp et al 2014) can support evaluation of these ecosystem services. The main input information needed for these models include rainfall, slope and land cover. Other regulating ecosystem services such as pollination can require more detailed information including the amount of habitat for pollinators (such as bees) which different land covers provide.

In terms of provisioning ecosystem services, it is important to understand what natural resources different local populations are using in different locations. Specific wild species can be important for food, medicines, and other non-timber forest products in rural communities (for example in the Amazon biome in Brazil (Menton 2003, Morsello et al 2012)). Assessing the impact of policies on these non-timber forest products can be undertaken in the same way as other species (section 5.2). As with other species they require information on the species distribution which can be difficult to obtain.

6. An uncertain future – the role of scenarios

As discussed above there are a range of different potential policy options for achieving REDD+ and biodiversity objectives. The impact of these different policy options will also depend on future developments in a wide range of other factors which impact on land use and policy implementation. These include population growth, infrastructure development, technology development and changes in diet, as well as policy developments in other sectors. Developing a range of potential scenarios for the future is a way of specifying and dealing with uncertainty in how these factors will develop, and exploring what factors may have the largest influence, by comparing the potential future under different conditions and assumptions. In understanding and developing scenarios it can be useful to divide the uncertainty in the future into two groups:

a. Global scenarios – about uncertainty in global development and policies such as population growth, economic growth, changes in diets and demand,
b. Policy options – about uncertainty in what specific land use and biodiversity policies will be adopted and how they will be implemented.

Specifying a scenario goes from describing a qualitative storyline for how the world is likely to change, to developing quantitative projections of the changes. The "Shared Socio-Economic Pathways" (SSPs) used within the IPCC assessments are an example of a set of global narratives for how the world will develop (sustainability, middle of the road, fragmented world, inequality and conventional development) (O'Neill et al 2012) which have been linked to quantitative projections of: population by age, sex and education; urbanization; and economic development (GDP) (SSP Database, 2012). Policy option scenarios are often implemented within one or more global scenarios. Mapping can be useful for visualising and developing potential scenarios. Maps can be useful for visualising the impacts of different scenarios, alternative futures, in a spatial context. Developing alternative maps of the future distribution of specific factors, such as infrastructure, can support discussions on how that factor, i.e. infrastructure, may impact future land use and so scenario development. Land-use change models are particularly useful for exploring scenarios that have been developed, and related assumptions about the future (such as infrastructure development), and how land use will change under different scenarios and assumptions.

Exploring how biodiversity impacts change under different global scenarios and specific policy options is important both for understanding the confidence attached to any one particular impact projection and for visualising the relative impacts of the different policy options, to enable policy makers to make informed choices and identify ways of making policies more effective. In terms of exploring the impact on biodiversity of policies related to achieving REDD+ objectives, the impact will depend on the global scenario being considered, what specific REDD+ related policies are implemented and the ways that REDD+ policies may be modified due to biodiversity considerations and policies. However, the specific scenarios which can be explored within any given

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biodiversity impact assessment will be constrained by the type of analysis being undertaken. For example, in order to implement a scenario within a land use change model, the scenario and assumptions associated with the scenario need to be able to be converted to modifications of the model rules.

6.1 General scenarios

General assumptions about how the world will develop can have a significant impact on the expected changes in biodiversity, and so biodiversity assessments. For example, assumptions on how human populations are likely to grow and whether their diets, and so demand for particular products including meat, are going to change. How transport infrastructure and technology are likely to develop (which can reduce production and transport costs and open up areas to deforestation), will also influence biodiversity impact assessments. For example in Brazil, according to IBGE, Brazilian rural producers have experienced continuous productivity gains, Brazilian livestock productivity is extremely low in global terms, around 1 animal per ha, and beef production is the main cause of deforestation. Therefore, in scenarios for the next 40 or 50 years, it is important to incorporate likely trajectories of productivity gains. These trajectories would vary according to the product and to the region in the country and will depend not only on research and development, but also on technology adoption. Nonetheless, it is possible to include estimated trajectories, so as to evaluate how the different policy scenarios would evolve, depending on productivity gains.

In many models, standard trajectories for population and dietary changes are taken from 'off the shelf scenarios' and often relate to big scenario development processes, such as in the IPCC assessments. For example, the GLOBIOM model, used within the REDD-PAC project, uses the SSP scenarios developed for use within the IPCC assessments. The global scenarios within GLOBIOM include assumptions on the development of technical progress, food demand, wood demand, macroeconomic indicators (GDP/POP) and bioenergy demand. Productivity gains in crop production are partly endogenous to the model through projected switches between productions systems (Cohn et al 2014).

6.2 REDD+ related policies

Although REDD+ refers to five specific activities related to climate change mitigation actions within the forest sector (reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks), there are multiple ways of implementing each of these activities depending on the national priorities and circumstances. These can range from implementing new laws and regulations and increasing the enforcement of existing ones (command and control measures) to providing payments for ecosystem services preservation (incentive based measures). The most effective measure depends on the national context. For example, where the main drivers of deforestation and forest degradation are subsistence agriculture and fuelwood collection approaches could include supporting alternative livelihoods or provision of fuel efficient stoves. In assessing the biodiversity impacts of REDD+ policies it is important to consider what REDD+ policies are likely to be implemented in that country.

For example, Brazil, as outlined in section 2.1, has already had significant success with reducing deforestation, in a large part by increasing command and control actions. Policies on climate change mitigation within the forest sector in Brazil are likely, on the one hand, to build on the country's previous success in limiting deforestation through improved monitoring and enforcement, and on the other, to develop at least some component of transmitting financial benefit to landowners, through some form of payment for environmental services, building on pilot schemes in operation in the Atlantic Forest. It is possible to approach the development of scenarios for REDD+ based on these two main axes, with scenarios of high and low levels of command and control and high and low levels of incentives.

Additionally, policies which are less directly aimed at reducing deforestation may also have significant impacts on the drivers of land use change including deforestation. For example, agricultural policies, such

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as the low carbon agriculture policy in Brazil (ABC) may lead to improved efficiency of agriculture, which could reduce the demand for new land, although it may also increase the profitability of agricultural expansion. In undertaking scenario assessments it is not possible to test all options at one time. For example, within the REDD-PAC project, the plan is to firstly implement a suite of scenarios with different levels of command and control linked to the current forest code. The project will then explore additional policy option scenarios linked to incentives, and the Brazilian ABC programme.

6.2.1 Command and Control

Command and control policies for achieving REDD+ objectives depend on the national context but include both the laws and regulations that specify restrictions on deforestation and also the ability to enforce or incentivize those restrictions. For example, as discussed previously, in Brazil the main law for restricting deforestation is the Forest Code and a key element for reducing deforestation has been enforcing the code through the PPCDAm. It is likely that a great part of REDD+ implementation in Brazil will be through investment of REDD+ funds in intensification of these efforts, which could include extending the programme of surveillance and control into the Cerrado biome through the PPCerado policy.

Developing and understanding the impact of policy options can be complicated by complexity in the law. For example, in Brazil, the law designates the APPs based on the characteristics of the location (such as slope, elevation and proximity to rivers). Mapping these areas is not a simple process, especially in delineating restrictions along river margins, where the preserved land area depends on the river width. Additionally, there are specific requirements, in terms of forest recovery, for small properties and the definition of small properties varies according to the municipality where the property is located (from 5 to 110 ha).

The complexities of laws mean that simplifications can be needed for assessing and modeling policy options. In the example of Brazil's Forest Code, at the most simple level the model can assume that the Forest Code is completely effective and the requirements for reducing deforestation and restoration are always met. The overall limits for legal reserves can be considered (80% in the Amazon biome etc.) without taking into account the dispensations given to small farmers. These limits can be easily input into a model as land use change restrictions, setting, *a priori,* that in the Amazon biome, only up to 20% of the total land can be transformed into pasture or crop production. The other 80% or more have to be used for native forest. Additionally, as the legal limits are intended for rural properties, one important scenario is that an instrument which allows the transfer of recovery requirements, such as CRAs will be used. If a model assumes that the producers can use CRA to exchange deforestation rights inside each state, then the land use restrictions would have to be met at the state level (rather than farm level and so simplifying the modelling). Setting the land use restrictions assuming a CRA and not considering the special treatment of small farms may be a simplifying starting strategy, it would be a conservative assumption in terms of forest coverage. In a further stage, it may be possible to map the percentage area for small properties in each municipality and use this information to refine the simulations, through refining the state level limits within a CRA system.

As discussed in section 3, mapping the locations of restrictions in land use can support an assessment of the potential biodiversity impacts of a policy scenario in which the law is fully enforced. Including land use change modeling in the biodiversity impacts assessment, as done in REDD-PAC, enables an evaluation of the impact of enforcing these restrictions on agricultural production and the potential for displacement of pressures into other areas (such as biodiversity rich non-forested areas). In REDD-PAC we plan to explore the impact of varying the level of enforcement of the Forest Code both in terms of restrictions on new deforestation and restoration requirements (see Table 3).

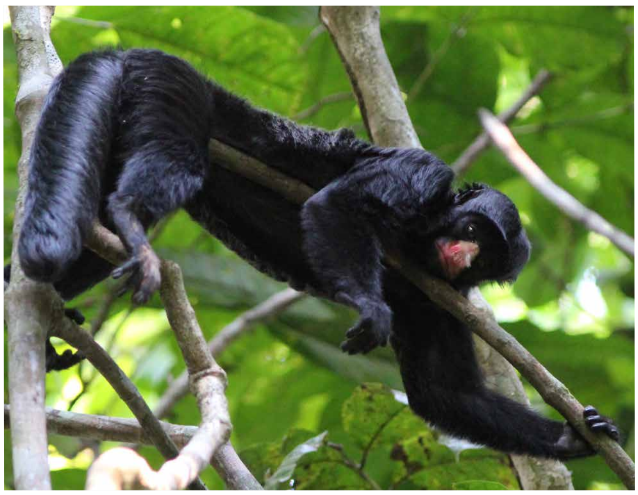
Table 3: Example of REDD+ scenarios currently planned to be tested with GLOBIOM- Brazil for the REDD-PAC project

		Legal Amazon	Cerrado	Other Biomes
Scenario 1 - Only PPCDAM	Enforcement of Legal Reserves	Yes	No	No
	Forest Restoration on illegally deforested area	Yes	No	No
Scenario 2 - if enforcement remained as 2000 level	Enforcement of Legal Reserves	No	No	No
	Forest Restoration on illegally deforested area	No	No	No
Scenario 3 - PPCDAm and PPCerrado are effective	Enforcement of Legal Reserves	Yes	Yes	No
	Forest Restoration on illegally deforested area	Yes	Yes	No

6.2.2 Incentives

Several proposals have been made for the development of a system of incentives, such as payment for environmental services or tax breaks, which enable landowners to benefit financially from the services that are provided if they manage ecosystems well. Many past modelling efforts have considered REDD+ scenarios that involve payments per tonne of carbon in an area (assuming a carbon value based on what is achieved in voluntary carbon markets). However, REDD+ is unlikely to evolve as a global scale voluntary carbon market which expands to such an extent that demand equals potential global supply. Countries are currently discussing how a results-based payment mechanism for REDD+ may work including the potential involvement of funds and markets, but this is yet to be resolved. Within Brazil, chapter 10 of the new Forest Code anticipates the possibility of using different financial incentives for forest conservation and recovery. For example, there can be tax deductions in the purchase of equipment and inputs for the maintenance and recovery of legal reserve and permanent preservation areas. Besides this, activities for maintaining legal reserves and permanent preservation areas are eligible for payments or incentives due to environmental services. The “Bolsa Verde” (Green Grant) programme was created in June 2011 to make biodiversity conservation payments to families in extreme poverty who are living in areas considered important for preservation of Brazilian biomes, mainly within the *Legal Amazon*.

One of the issues to be considered when implementing incentive policies is additionality; whether the policy is acheiving additional emissions reductions than would otherwise occur. To achieve additionality, compensation would be allocated to land owners in areas of high carbon flux, and there would be no compensation for those already managing stocks well. If resources are allocated on the basis of carbon stocks they may have little impact on emissions. There is a strong question globally, including in Brazil, about whether remuneration should relate to stocks or to fluxes of carbon. The solution being discussed in Brazil has been a hybrid approach, in which payments are higher in areas of high pressure or flux, but there is also some payment in other areas.



White-nosed Bearded Saki by Rich Hoyer. Licensed under a Creative Commons Attribution 2.0 Generic (CC BY 2.0). Accessed 15 July 2014. https://flic.kr/p/cojJm1

Policy option scenarios for incentive payments need to consider rates currently applied where PSA schemes are in operation and the prices likely to operate in any carbon market that emerges. A challenge with incentive payments, which are difficult to explore within land use change models is land tenure. For example, 67% of endangered forest areas in the Brazilian Amazon contain rural establishments with ill-defined or non-clarified tenure (Börner et al. 2010). Tenure problems may negatively affect PSA instruments, as for payments to be effective instruments environmental service providers need to have the right to prevent others from deforesting the land area under conservation agreement; and it has to be clear who the service provider is. In the Brazilian Amazon, insecure property rights favor forest clearing (Araújo et al. 2008).

6.2.3 Other policy approaches

In looking at the impact of policies on deforestation and reforestation, it is important to not only consider those policies which directly address these issues. Wider agriculture and development policies are also likely to have impacts on land use and therefore biodiversity. Within Brazil, the ABC policy is likely to impact how agriculture develops in the future and affect deforestation. There are six lines of actions covered by ABC in Brazil including: recovery of degraded pasture land, adoption of an integrated system of pasture-crop-forest, increase the use of direct planting systems, incentivizing biological nitrogen fixation in the soy production, and increasing the plantation of commercial forests. Including a model scenario which implements all actions of the ABC programme would require thinking about how each component of the programme could be included in the model.

6.3 Biodiversity friendly scenarios?

Policies for achieving climate change mitigation actions within the forest sector are likely to have significant impacts on biodiversity, which will vary depending on how they are implemented. Many REDD+ activities are closely related to the biodiversity aims specified within the Convention on Biological Diversity’s Aichi targets (see Table 4). However, the

Table 4: Key synergies between the Aichi Biodiversity Targets and the UNFCCC (from Miles et al 2013)

	Aichi Biodiversity Targets (CBD Decision X/2)	REDD+ elements (UNFCCC Decision 1/CP.16) (*activities*, guidance and safeguards)
	5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced	*Reducing emissions from deforestation* *Reducing emissions from forest degradation* *Conservation of forest carbon stocks*
	7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity	*Sustainable management of forests* REDD+ actions are to be consistent with conservation of natural forests and biological diversity and are to incentivize the protection and conservation of natural forests and their ecosystem services
	11: By 2020, at least 17% of terrestrial areas are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas	*Conservation of forest carbon stocks* REDD+ activities should be consistent with the objective of environmental integrity and take into account the multiple functions of forests and other ecosystems
	14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable	*Conservation of forest carbon stocks* *Enhancement of forest carbon stocks* REDD+ activities should promote and support full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities
	15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.	*Reducing emissions from deforestation* *Reducing emissions from forest degradation* *Conservation of forest carbon stocks* *Sustainable management of forests* *Enhancement of forest carbon stocks*

specific ways in which policies are implemented are likely to have significant consequences for their impact on biodiversity. It may be possible to make small modifications to REDD+ policies to ensure that they achieve multiple objectives.

Maps can be used to identify locations where actions for reducing deforestation and forest degradation can have multiple benefits (see section 3.1). In some countries biodiversity priorities could be included as one basis for directing investment in REDD+ implementation. In order to assess the potential of REDD+ to contribute to achieving biodiversity conservation objectives, for example in the REDD-PAC project, it is important to explore scenarios in which the 'biodiversity-friendliness' of REDD+ implementation is enhanced to determine whether this is likely to make a difference in the ultimate biodiversity-related outcomes.

There are a range of options for incorporating biodiversity considerations into REDD scenarios, for example within the REDD-PAC project these include:

a. Application of restrictions within the model in relation to areas of high priority for biodiversity. This could include the expansion of protected areas in line with the national biodiversity targets of 30% for the Amazon biome and 17% for other biomes, and taking into account the plans for creation or expansion of conservation units and indigenous lands in the PPCAdm and PPCerrado; or
b. Increasing costs of conversion in these areas through penalties or other means; or
c. Increasing the value of standing forest in these areas. This would simulate increasing incentive payments within areas important for biodiversity; or
d. Using a phased approach to REDD+ policy implementation to prioritize areas important for biodiversity through time, for example assuming that enforcement of the Forest Code may occur first in these areas.

Options (a) and (c) correspond roughly to the enforcement and incentive axes discussed above, i.e. restrictions and enforcement effort (investment) could be concentrated (or not) in areas deemed important for biodiversity conservation, and/or a premium rate of incentive could be applied for effective management that maintains forest in ways that support conservation of biodiversity in such areas. Therefore, consideration of biodiversity effectively forms a third component in the REDD+ scenario space for Brazil, and there is the potential for scenarios of high and low levels of command and control and incentives which are either implemented in a biodiversity focused way or not.

7. Conclusions

Considering the potential impacts of REDD+ on the environment and biodiversity can support the achievement of multiple benefits from REDD+ and help in minimising the risk of negative impacts, and therefore support the REDD+ safeguards. It can also contribute to understanding the potential synergies between REDD+ and a country's commitments under the Convention on Biological Diversity.

Maps, spatial analysis and land use change models are useful tools for assessing the potential environmental and biodiversity impacts of REDD+. Such assessments can focus on different aspects of the environment and biodiversity, including priority areas for biodiversity conservation, species ranges and ecosystem services.

Maps and spatial analyses can highlight the relative distributions of factors affecting potential emissions (including carbon stocks and deforestation pressures), those affecting the types of REDD+ activities that are appropriate (including the locations of different management regimes, such as protected areas or community forest management), and those factors affecting the potential for multiple benefits from REDD+ actions (such as the locations of important species or ecosystem services).

Land use change models can strengthen such assessments by projecting the likely future land use changes and pressures under a range of global or national scenarios, and can be used to explore the impacts of different policy options. It is important to clarify the assumptions included in the models. For example, models vary in the way they treat the dynamics of land once it is no longer cultivated, and the assumptions about regeneration will affect the land cover projections resulting from the model. Similarly, assumptions about the effect of protected areas and other land designations can have a major influence on model results.

Assumptions about regeneration of natural land covers are especially important in relation to the REDD+ activity of enhancement of forest carbon stocks.

Protected areas can have an important role in both REDD+ and biodiversity conservation; however, their impact will vary depending on the land use restrictions they carry and how effectively they are implemented.

Whichever assessment method is used, it is important that the assessment is tailored to the national context, so that it focuses on the policy and biodiversity issues of greatest national importance. This includes taking account of the variation in definitions of land uses and land covers, including those of forest and natural forest. For example, the national definition of forest can alter which areas are eligible for REDD+.

As the world is an uncertain place in terms of both the general context and the specific policies which will be implemented for REDD+, it is useful to apply a range of scenarios to explore the potential impacts of different policy options under a range of global conditions. In particular, when considering the biodiversity impact of REDD+ it is useful to assess the extent to which adjusting REDD+ policies to target multiple benefits may affect the emissions reductions that can be achieved and the biodiversity impact.

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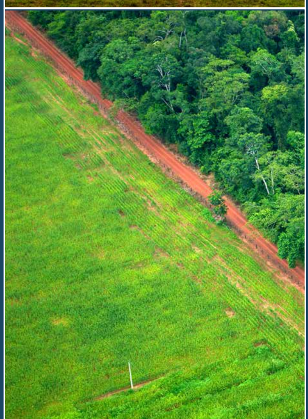

Climate change and biodiversity loss are currently two of the key global challenges facing people and ecosystems. REDD+ policies aim to reduce carbon dioxide emissions from the forest sector and so contribute to climate change mitigation. As the conversion of natural ecosystems (for example, into agricultural land) also remains the main driver of biodiversity loss, REDD+ policies have the potential to provide biodiversity benefits. However, there are also some potential risks including displacement of land use change to non-forest areas. Understanding the potential impacts of REDD+ on biodiversity can help support the development of policies which enhance the potential benefits and minimise risks.

Therefore, the report highlights how spatial analysis and land-use modelling can help in understanding the potential impacts on biodiversity, ecosystems services (and thus Convention on Biological Diversity objectives) of policy options for achieving REDD+ objectives. The report is a deliverable of the REDD-PAC project. The overall project aims to support the development of policies for achieving REDD+ goals and evaluate their impact on biodiversity using land use change models to assess the impact of possible policy options, focusing on Brazil and the Congo Basin. Options for the REDD-PAC project's analyses in Brazil are used to illustrate the report's main points.

Contact:

UNEP World Conservation Monitoring Centre
219 Huntingdon Road
Cambridge, CB3 0DL, United Kingdom
Tel: +44 1223 814636
Fax: +44 1223 277136
E-mail: climate@unep-wcmc.org
www.unep-wcmc.org

UNEP WCMC

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