Vulnerability Analysis of the

AMAZON BIOME

and its Protected Areas

Amazon Vision
Protected areas beyond borders

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Vulnerability Analysis of the AMAZON BIOME and its Protected Areas

Over the last decade, widespread transformational ecological and socio economical change has become evident, related with a changing climate and the occurrence of extreme weather events. Climate is changing, harming vulnerable people and places, disrupting natural systems, endangering species and altering the capacity of landscapes to provide ecosystem services. We can anticipate that under these evolving conditions, this changing climate can derail development and conservation gains of many years.

In this context, the provision of more detailed and fine scale information on climate, climate variability and climate change, and assessments of how biodiversity, communities and economic sectors are likely to be exposed and harmed by them, have not been sufficient to enable proactive adaptation, and to support decision-making at different public policy levels. The international community adopted conceptual frameworks and directed significant investments to assess climate vulnerability as one single indicator, but without understanding that, at multiple scales and within complex systems, the array of existing and expected climate risks, and the sources of resilience required to address negative impacts also need to be assessed.

In this report, we tried to overcome these barriers, critically evaluating different hypotheses inherent to an integrated approach to support climate adaptation and resilience building in the Amazon Biome, a region acknowledged worldwide not only for its biodiversity richness but also for the ecosystem services it provides at the local, regional and global scales. Our analyses aim to contribute to the efforts being made by the Latin American Technical Cooperation Network on National Parks, other Protected Areas and Wildlife (REDPARQUES, from its Spanish name) to consolidate the conservation vision in the region through technical models of major threats to biodiversity and ecosystem services.

Although the Amazon region has been defined in many ways, for the purpose of this study we took into account the biogeographic Amazon as defined by Olson & Dinerstein (1998). The resulting polygon spans 6,851,583.24 km^2 within the political jurisdiction of nine countries.

See Figure 1 page 3

Almost 30% of the biome (1,857,246.10 km^2) corresponds to different kinds of protection categories. These include 388 protected areas belonging to all categories of IUCN, 11 Ramsar sites, 7 UNESCO Biosphere Reserves and seven UNESCO world heritage sites. These areas represent the core of REDPARQUES' work aimed at building resilience of the Amazon biome to face the negative impacts of climate change.

See Figure 2 page 4

Conceptual Framework

The latest report (AR5-2014) of the Intergovernmental Panel on Climate Change (IPCC) states that climate adaptation calls for a risk-based approach that takes into account complex interactions between climate and social and ecological systems. The report highlights the need for 'climate-resilient pathways' that, in the case of the Amazon Biome, combine climate risk reduction and climate resilience building to reach the goal of conserving a healthy and sustainable landscape.

The project 'Protected Areas, Natural Solutions to Climate Change' (NASCC)[1] takes this recommendation into account, and moves forward to address the challenge of understanding and managing present and future climate changes, risks and impacts through the search for improved resilience and adaptive capacity. Our work focuses on assessing, planning and mainstreaming climate adaptation

1 Funded by the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMUB, after its German name) and WWF Germany.

into the Amazon Vision, based on the following key concepts:

- **Climate risks:** climate risk is the potential effect on natural and human systems facing extreme weather and climate events, and related to climate change. An effect generally refers to impacts on 'lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system' (IPCC-AR5, 2014).
- **Climate Resilience:** defined as 'The capacity of an ecological or socio-economic system to absorb (climate-related) disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks' (IPCC-AR5, 2014, drawing on Holling, 1973).

The comprehensive conceptual framework here is ***to manage and reduce current and future climate risks through its effective management and climate smart conservation, and by building and strengthening protected areas' resilience through an understanding of both risks and existing ecosystems resilience, and social and institutional adaptive capacity.***

Figure 1 | Boundaries and figures of the Amazon Region

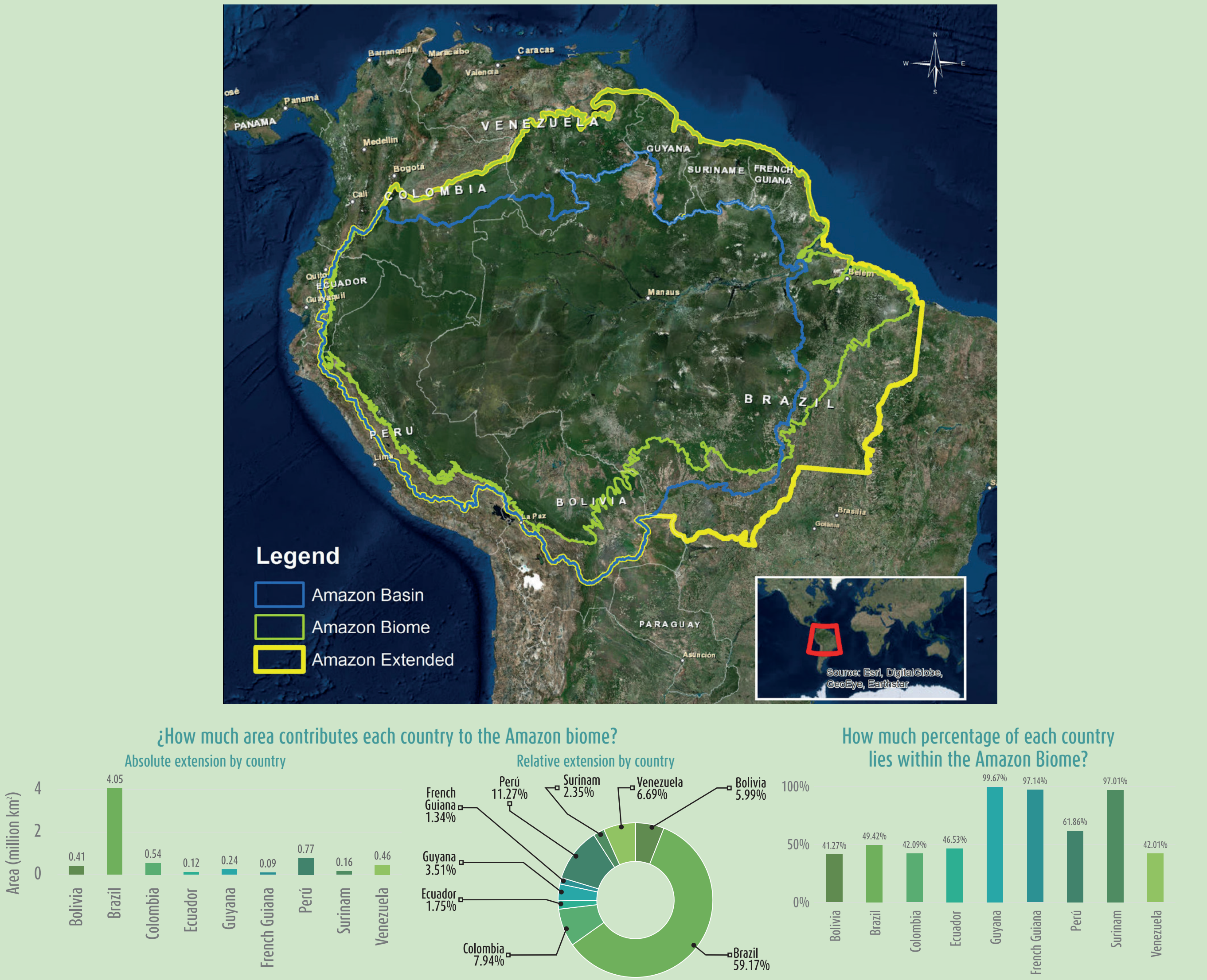
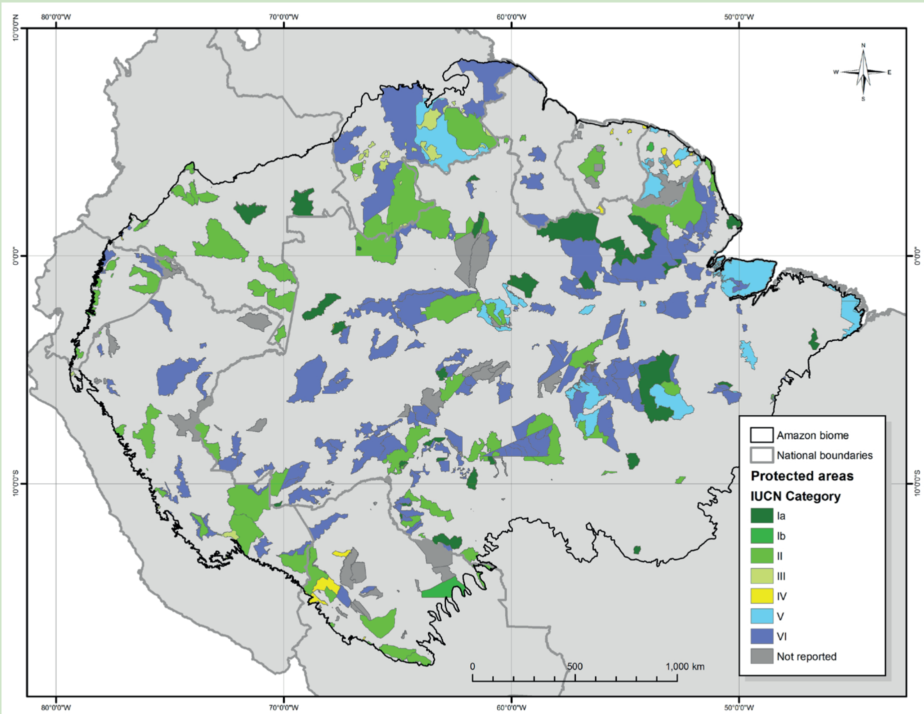


Figure 2 | Extension of protected areas in the Amazon Biome

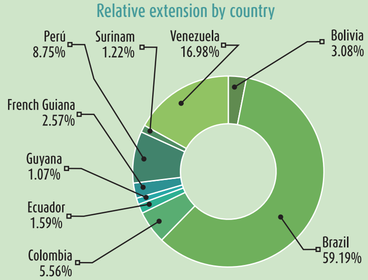


Protected areas sources:
• Bolivia, Brazil, Colombia, Ecuador and Perú: Data were given by each country's Environmental Ministry

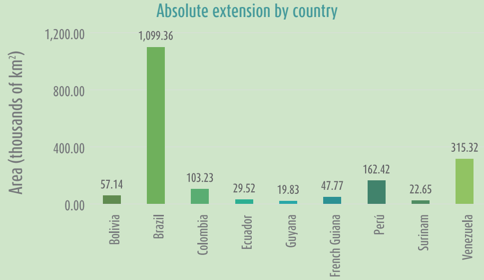
• Venezuela, Guyana, French Guiana and Suriname: IUCN and UNEP-WCMC (2015), The World Database on Protected Areas (WDPA) [On-line], 08/2015], Cambridge, UK: UNEP-WCMC. Available at: www.protectedplanet.net

How much area do protected areas cover within the amazon Biome by country?

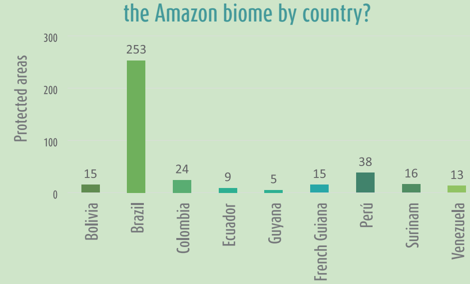
Relative extension by country



Absolute extension by country



How many protected areas are there within the Amazon biome by country?



Methods

Our analyses focus on the assessment of climate risks and the identification of sources of ecosystem resilience within the Amazon biome. We seek to ensure the inclusion of critical links between climate change, climate variability and extreme weather events, and ecosystems and ecosystem services, focusing particularly in protected areas. We developed our methods based in part on IPCC –AR5 and other existing and proven tools that add value by combining them in a logical framework methodology. The framework approach allows our project to have the flexibility to be implemented both in the context of specific protected areas of the Amazon Biome and in the context of each country's needs and capacities.

The first step of the methodology aims to understand the context and possible evolution of climate conditions in the Amazon Biome, and to assess them as either potential hazards and / or drivers of change. The main hypothesis tested in this step was the physical exposure of the landscape to climate change scenarios, climate variability and extreme weather events.

The next phase of the methodology is a climate risk assessment that includes a technical evaluation of the Amazon Biome's capacity to provide three ecosystem services under current and future climate and land use conditions. The three ecosystem services selected are: (i) carbon storage; (ii) species habitat; (iii) freshwater provision and regulation. In this step, we measured climate risk as a physical effect on the quantity and timing of the ecosystem service provided.

The final step is the assessment of ecosystems resilience. This phase is built on the results of the climate risk assessment, and aims to identify sectors of the Amazon where there is less risk of losing the capacity to provide the targeted ecosystem services. To implement this step, we consider that those areas are the more resilient, and that this largely depends on key biophysical factors sources of ecological strength. The resilience assessment looks for those resilience factors and provides indication of places in the Amazon Biome where the resilience factors are concentrated.

Climate variability and climate change in the Amazon Biome

Climate patterns in the Amazon Biome are recurrently altered by extreme climate variability phases and are gradually modified in response to long-term tendencies in climate change. Though monthly air temperatures vary considerably, the mean tendency has markedly increased in the last 30 years.
See Figure 3 page 6

Nonetheless, climate variability patterns have specific characteristics at the subregional level (Espinoza *et al.* 2009); thus, the expression of climate variability and climate change also shows spatial and temporal differences–from inter seasonal to inter decadal variations–and includes extreme phenomena that cause disasters, particularly during abnormally rainy periods. Many of the variability indicators at the inter annual and inter decadal scales show more pronounced relationships with climatic processes in the tropical Pacific than with those in the Atlantic (Table 1). The El Niño phenomenon in the Eastern Pacific results in precipitation deficits in large parts of the Amazon region during all year´s seasons, especially during the period December-January-February (austral summer). The distribution of air temperature anomalies also has a different spatial distribution, the greatest positive anomalies taking place during the austral summer.

Climate change and forest fires in the Amazon

Climate has a direct effect on forest fires in the Amazon due to changes in precipitation and temperature, and indirectly by changing the vegetation's composition and structure (Cochrane & Barberei 2009, Pausas & Bradstock, 2007). Thus, mayor forest fires in the Amazon are conditioned by large-scale climate variability such as El Niño (Cochrane *et al.* 1999; UNEP, 2002; Alencar *et al.* 2006). However, intense drought periods and forest fires, as those that happened in the south eastern Amazon in 2005, were not necessarily associated to the El Niño phenomenon (IPCC, 2007; Fig. 4).
See Figure 4 page 7

Current fire occurrence patterns are undoubtedly very different from historic patterns, as a consequence of human activity. Changes in frequency, intensity and location have been dramatic since the 1970's (Cochrane & Barber 2009), when construction of the road network that connected the Brazilian Amazon with the rest of the country opened colonization opportunities. Changes in forest fires in the region were to be expected, as slash and burn is the main practice in establishing and maintaining large areas for agriculture and cattle raising along the expanding road network. Fire occurrence density in the Amazon during the period 2001-2015 (Fig.

Table 1 | Climate variability indices in the Amazon Biome

Regulating process	Sector of the Amazon where the effect is greatest	
	Precipitation	Temperature
Inter annual variability	Very notorious in north western, northern and southern Amazon. Not noticeable in the other parts.	The direct (positive) effect of El Niño and La Niña is very notorious in northern Amazon.
Temperature variability in the northern Atlantic	No outstanding effect on precipitation.	Evident effect on temperature.
Inter decadal variability in the Pacific	Notorious inverse effect in the extreme eastern part.	Basically no effect.
Inter decadal variability in the Atlantic	Basically no effect on precipitation	Notorious inverse effect in the extreme eastern part of the watershed.

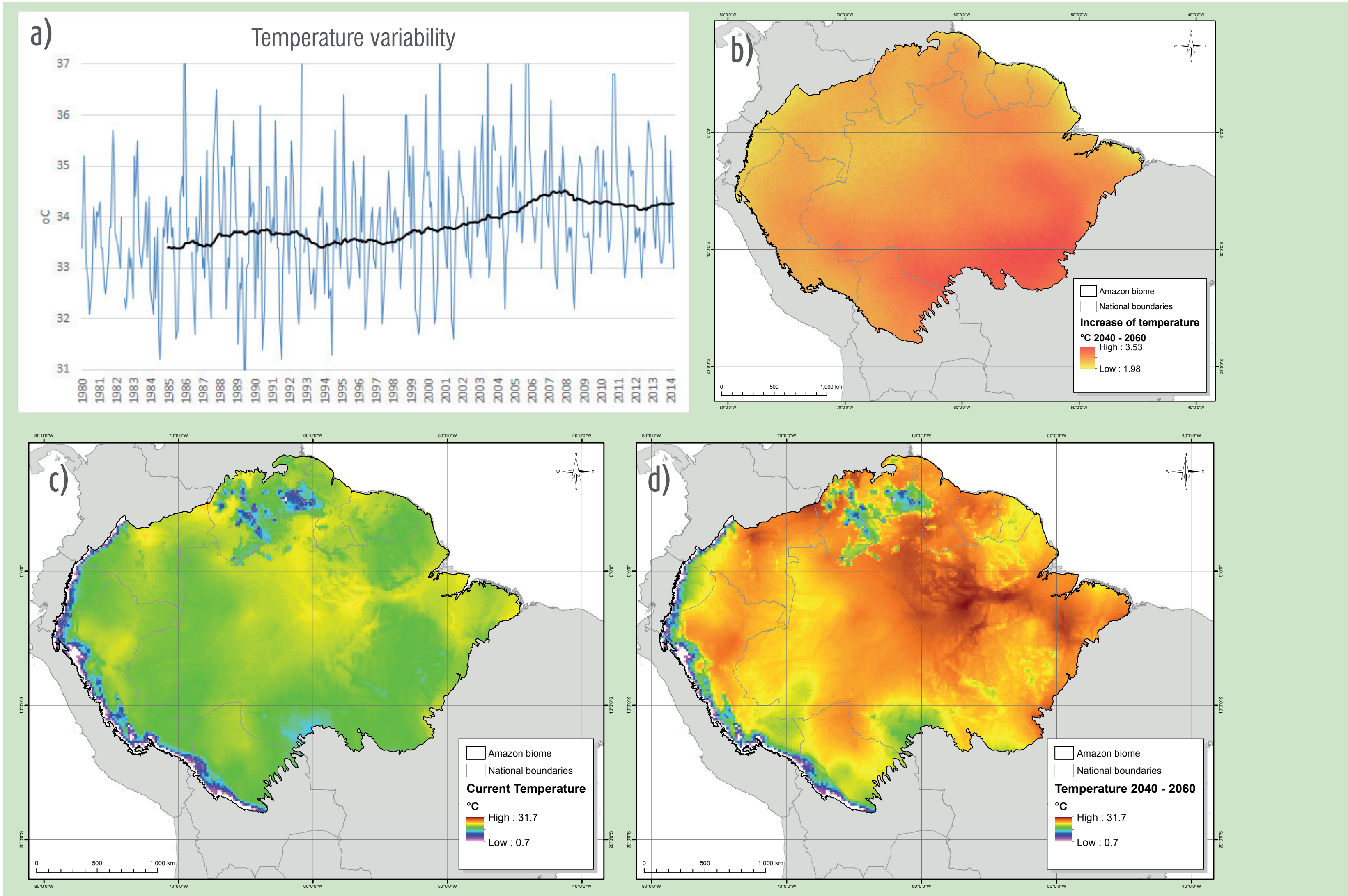
Figure 3

a) Variation in temperature recorded at the Vásquez Cobo Airport station in Leticia

b) Projected temperature change based on a pessimistic RCP85 scenario for the Amazon Biome

c) Current temperatures (Hijmans *et al.*, 2005)

d) Temperatures for future modeled conditions averaging 2040-2060 (Hijmans *et al.*, 2005)



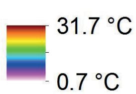
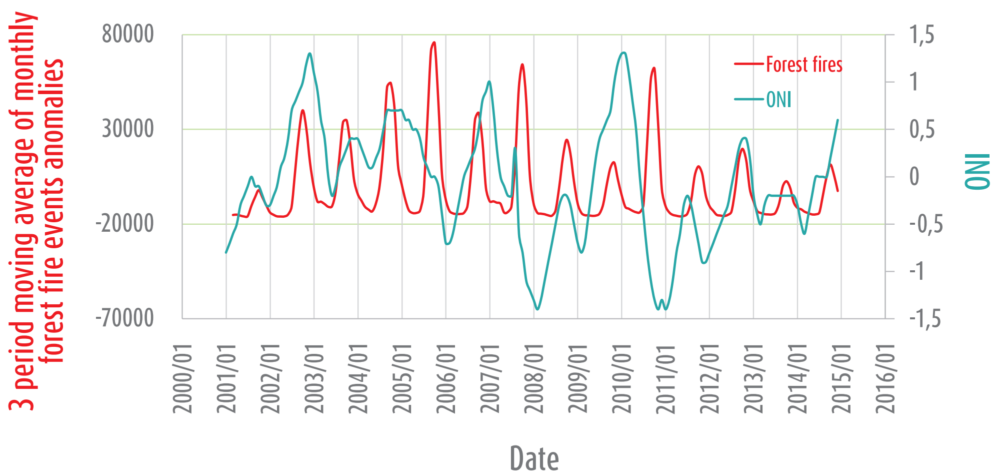
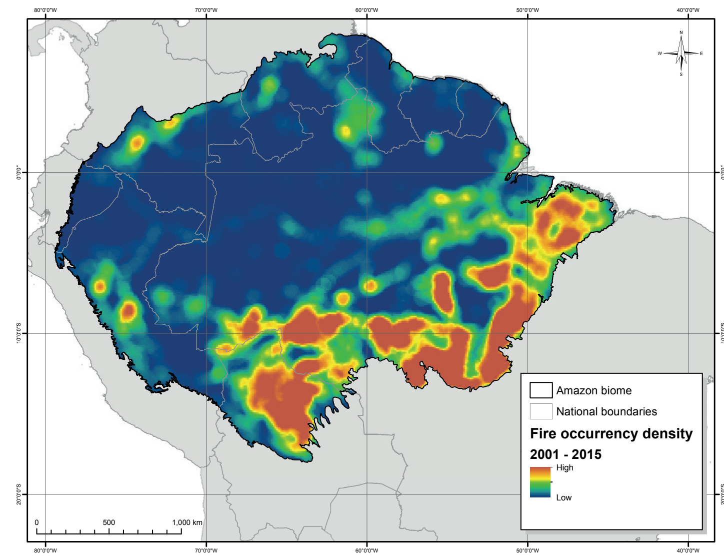


Figure 4 Left: Correlation between forest fire periods and the Oceanic Niño Index (ONI).
Right: Fire occurrence density (MODIS sensor hotspots) for the period 2001 - 2015





4) has been concentrated in Brazil, in the southern part of the biome, as well as in the Colombian Andean piedmont, the Beni region in Bolivia, and the Pucallpa region in Peru, where the main deforestation fronts are located.

Droughts and floods

The response of the Amazon Biome to climate variability and change, from the biophysical point of view, is far from uniform (Fig.5). For example, in 1996-1997, 2005 and 2010, the south eastern Amazon experienced severe droughts, especially in 2005 when the episode was the longest in the last 40 years and had the greatest intensity in the last 100 years (Marengo *et al*. 2008). During this extreme event, fluvial navigation on the Madeira River and on the central Amazon River had to be suspended and local communities had to be movilized to avoid becoming isolated due to low water levels (Pinho *et al*. 2014).
See Figure 5 page 8

Even though droughts and floods make part of the region's natural variability, since they have occurred in the past and will continue to occur in the future, during the last decade their intensity has been unprecedented in recent history. This indicates that, in spite of the high level of uncertainty in climate information, they will continue to increase in the future (Marengo *et al*. 2013).

Changes in net forest productivity

Extreme climatic events also have an impact on the structure and function of the Amazon forest. Water supply of the Amazon forests during dry seasons is regulated mainly by the access of roots to water present in the soil and its redistribution to the forest ecosystem, allowing high transpiration and photosynthesis rates (Malhi *et al*. 2008). Due to the influence of soil moisture on the capacity of the Amazon forests to respond to drought impact (Miers *et al*. 2009), areas with the greatest soil moisture deficit have a net biomass loss during these events (Phillips *et al*. 2009); during the 2005 drought, more than 70 million ha in the western Amazon experienced a strong water deficit (Saatchi *et al*. 2013; Fig. 6).
See Figure 6 page 8

Forest fires data set was provided by the University of Maryland and NASA FIRMS. ONI Index was provided by the NOAA Center for Weather and Climate Prediction.

Figure 5 a) Water balance for the year 2000. b) Changes in water balance between 2000 and 2005. c) Changes in water yield between 2000 and 2010

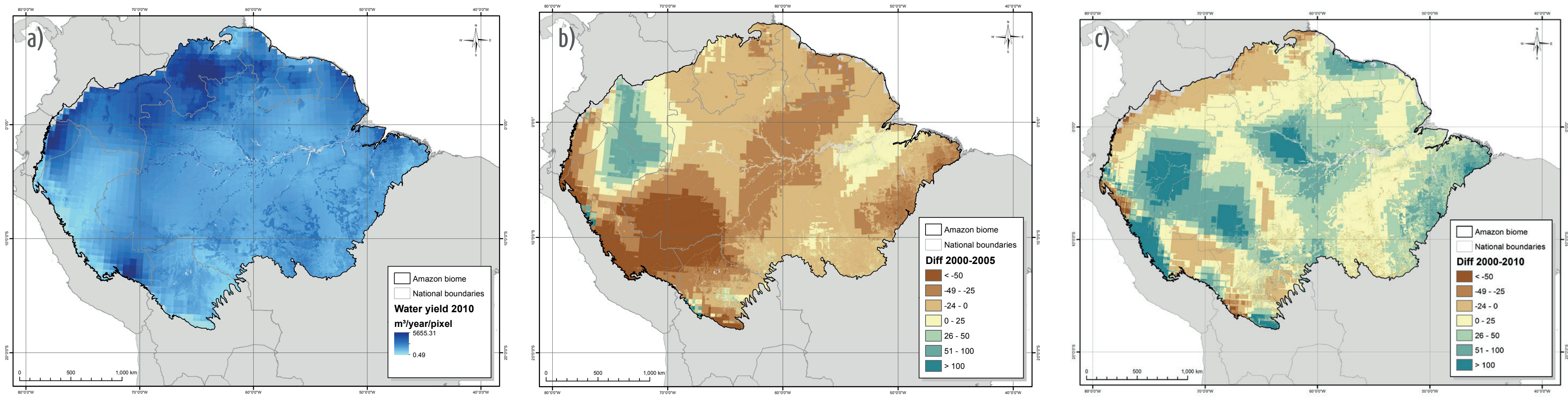
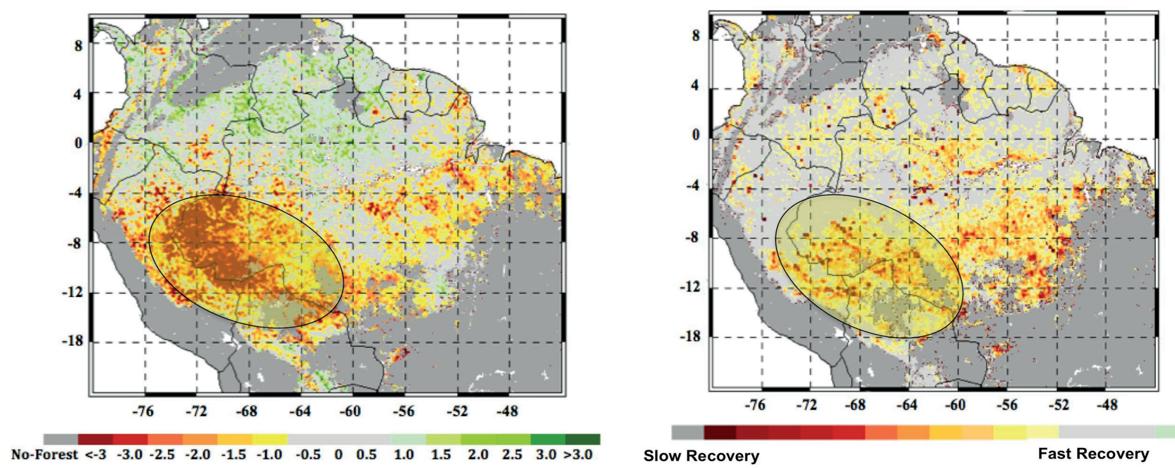


Figure 6 Spatial distribution and severity of drought in 2005 and recovery range rates. (Adapted from Saatchi *et al.*, 2013)



Protected areas in the Amazon and climate risk

We generated a representation of the Amazon Biome's risk in the face of climate change, based on the integration of the regional climate change index (Giorgi, 2006) and the sociocultural vulnerability index (Torres *et al.*, 2012), and taking into account differences in precipitation and temperature, and seasonality of these two variables between the current climate standard and the future climate scenario, for both the dry and wet seasons. Overall, the greatest risk is located in the eastern part of the biome, in the state of Pará in Brazil, as well as in the southern area in the state of Rondônia and Mato Grosso (Fig. 7a). Risk hotspots were also identified in the states of Amazonas in Brazil and Loreto in Peru; and in the northern part of Guyana.

A total of 134 (or 34.81%) protected areas are facing high risk, covering 345,000 km^2, or 18.58% of the biome's total protected area (Fig. 7b). Nonetheless, protected areas contribute to reducing the level of climate change risk by 10% in all the Amazon biome.

Climate change and its impact on ecological integrity in the Amazon

We evaluated climate risk by modelling the possible impact on the distribution of representative species of different functional attributes in the Amazon Biome, bearing in mind that ecological integrity of protected areas depends on maintaining the ecological relationships among its objects of conservation (Fig. 8).
See Figure 8 page 10

We selected these species also by their contribution to providing different ecosystem services: cultural, as is the case of the jaguar (*Panthera onca*) and the scarlet macaw (*Ara macao*); procurement, as is the case of the fig tree (*Ficus maxima*); or support, as is the case of the lowland tapir (*Tapirus terrestris*), which disperses seeds of more than 200 types of plants throughout the territory. Using MAXENT, we took presence data and WorldClim bioclimatic variables as entry points for modelling expected future distributions of species in different climate change scenarios for the period 2040-2060.
See Table 2 page 11

Our preliminary results suggest that the zones with the greatest probability of gaining species distribution area in the face of climate change scenario RCP8.5- 2050 are concentrated in the central part of the Amazon. Therefore, a high rate of species turnover with respect to the present could take place in these areas. On the other hand, the zones more susceptible to losing species distribution area are located in the periphery of the biome. This analysis shows, at a small scale, how the species range can shift, with consequences on trophic networks and functioning of the biome.
See Figure 9 page 11

Figure 7 a) Integrated climate change risk index for the Amazon Biome. b) Integrated climate change risk index for protected areas in the Amazon Biome.

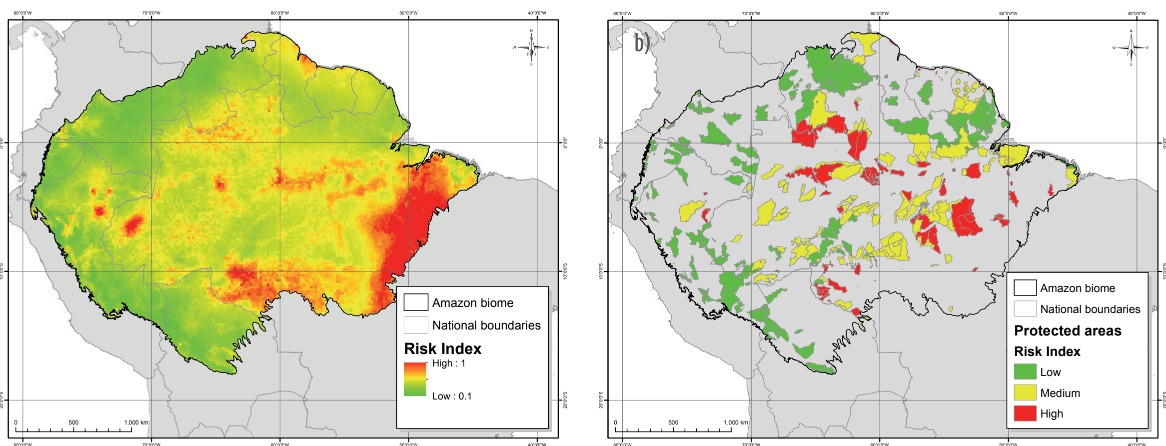


Figure 8 Feeding relationships among species selected for analysing distribution variations under climate change conditions. The relationships of *Sarcoramphus papa* and *Panthera onca* are currently being verified.

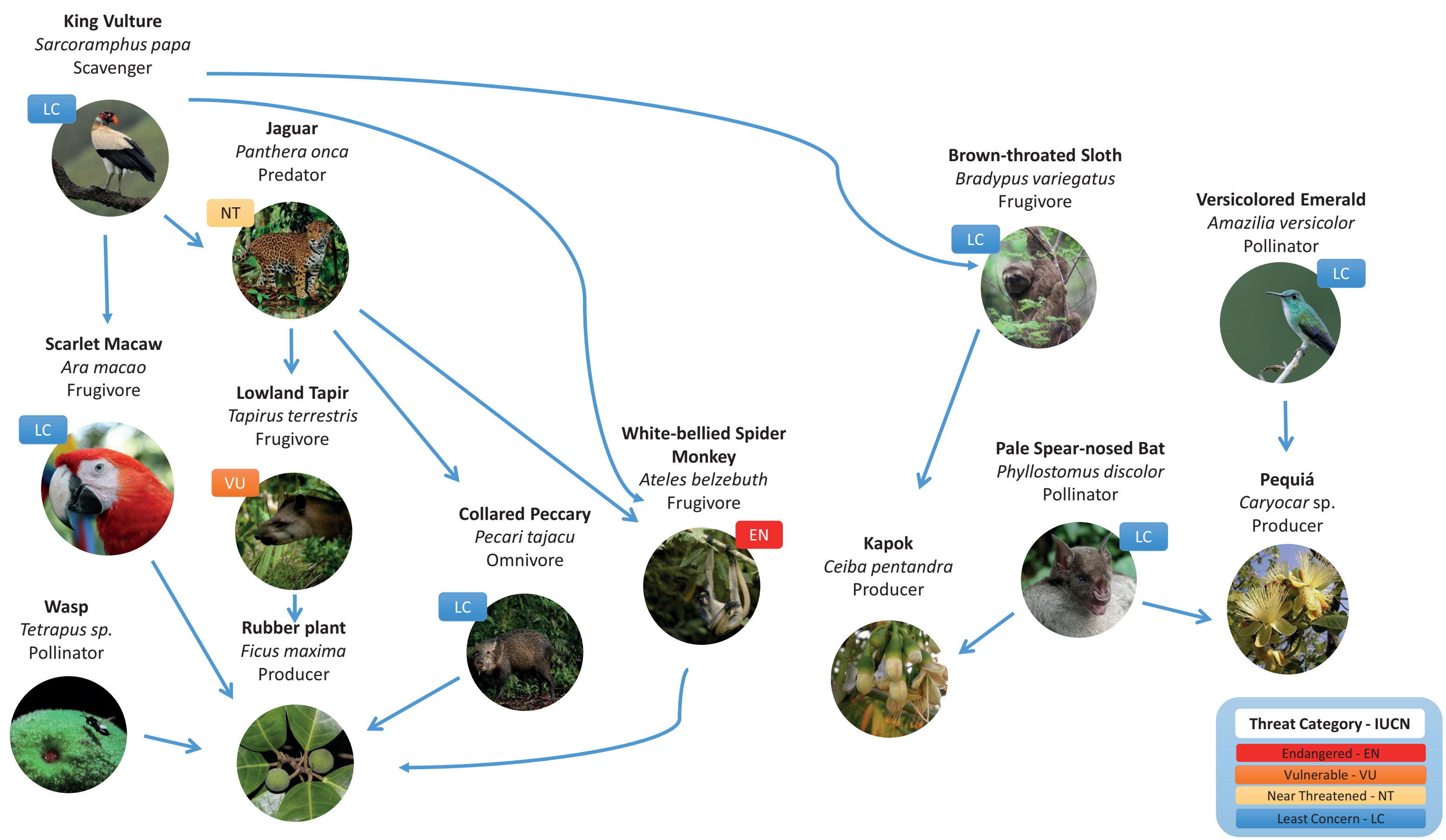


Photo Credits:

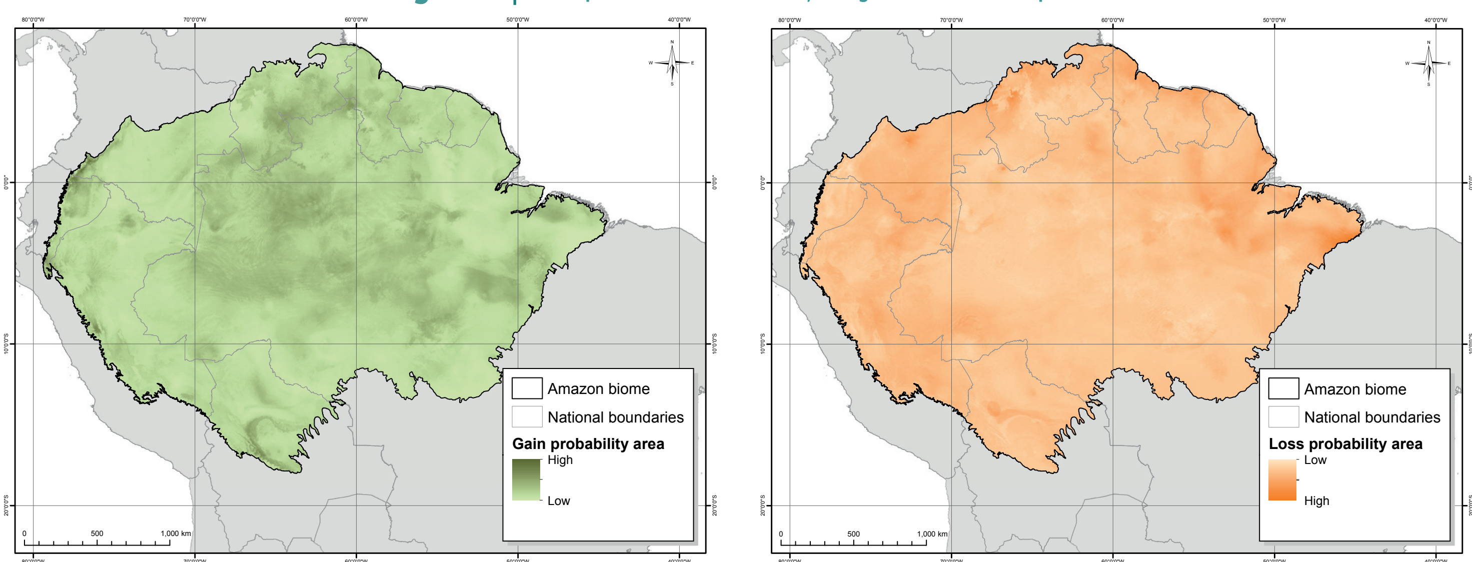
• *Ficus máxima*: Guerrit Davidse • *Ateles belzebuth*: Pete Oxford • *Tetrapus* sp: Christian Ziegler • *Tapirus terrestris*: Guillaume Feuillet • *Pecari tajacu*: Adrian Hepworth • *Panthera onca*: Frans Lanting • *Bradypus variegatus*: Adriano G. Chiarello • *Amazilia versicolor*: Nick Athanas • *Sarcoramphus papa*: Alessandro Abdala • *Phyllostomus discolor*: Programa de Conservación de los Murciélagos de Paraguay – PCMPy • *Caryocar* sp: wikipedia.org • *Ara macao*: parfaitimage.com

Table 2 | Most frequent variables used in explaining species distribution (in percentages)

Species	PPT1 of Warmest Quarter	PPT of Driest Month	Temperature Seasonality	Annual Precipitation	Maximum Temperature of Warmest Month	Annual Mean Temperature	Mean Temperature of Coldest Quarter
Ara macao	33.5	8.2	12.7	4.2	---	---	---
Amazilia versicolor	3.8	---	---	5	33.9	17.6	---
Bradypus variegatus	36	---	9.1	---	5	---	14.5
Caryocar villosum	20.4	---	5.2	16.4	14.7	---	---
Ficus maxima	14.7	15.4	9.4	---	7.7	---	15.6
Panthera onca	---	16.7	17	11.4	---	---	---
Pecari tajacu	6.1	17.6	20.1	---	---	---	---
Phyllostomus discolor	5.5	20.6	17.5	3.6	---	---	-- -
Tapirus terrestris	20.6	24.5	16.1	---	---	---	---
Sarcoramphus papa	15.1	12.3	21.8	---	---	---	---

PPT = total monthly precipitation

Figure 9 | Maps of areas with greater probability of gaining or losing total species distribution area, using the 10 selected species



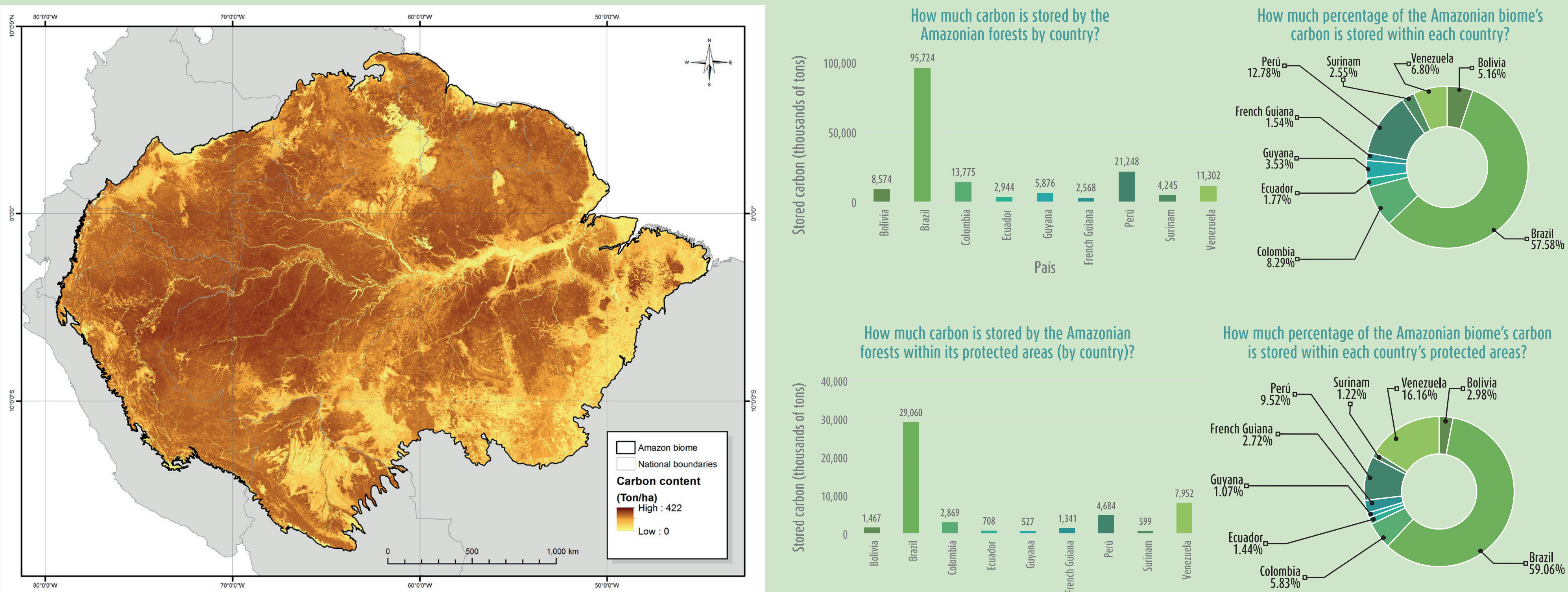
Carbon storage and deforestation

Undoubtedly, one of the main ecosystem services provided by the Amazon Biome at the global scale is carbon storage. According to the map (Fig. 10) of carbon density in tropical areas made by Baccini *et al.* (2012) based on satellite data, forests in the Amazon Biome are estimated to store 166,256.61 megatons of carbon, which correspond to 56.2% of total above-ground carbon stored by forests world-wide (FAO, 2015).

Currently, this ecosystem service is seriously at risk. In addition to observed and expected negative impacts of climate change, forest cover loss in the Amazon is alarming. During the period 2005-2013, 114,415.61 km^2 (1.7% of the biome) was deforested at an average annual deforestation rate of 0.25% (14,301.95 km^2/year), which is inadmissible under current global climate change conditions.

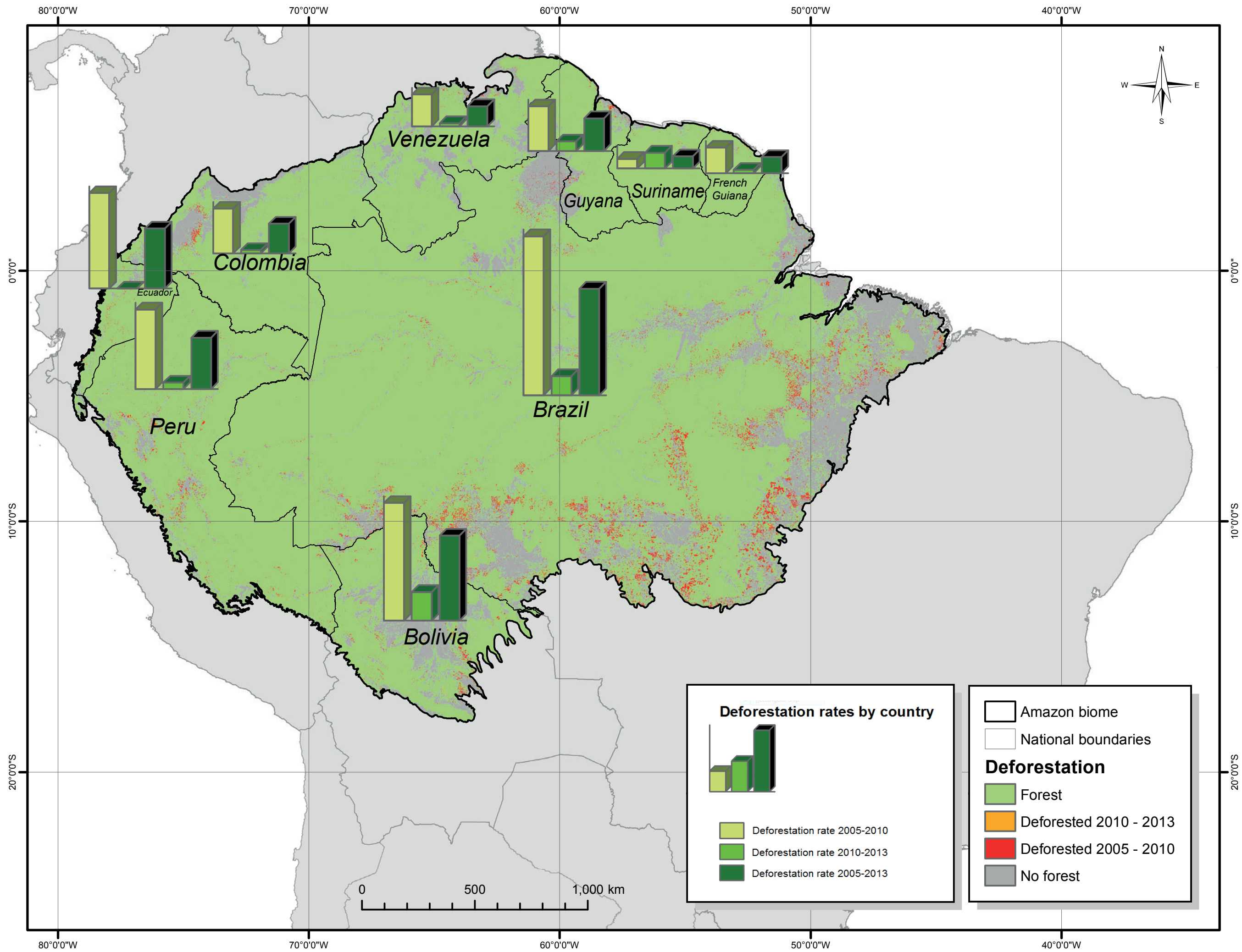
See Figure 11 page 13

Figure 10 | Magnitude of carbon storage in the Amazon Biome



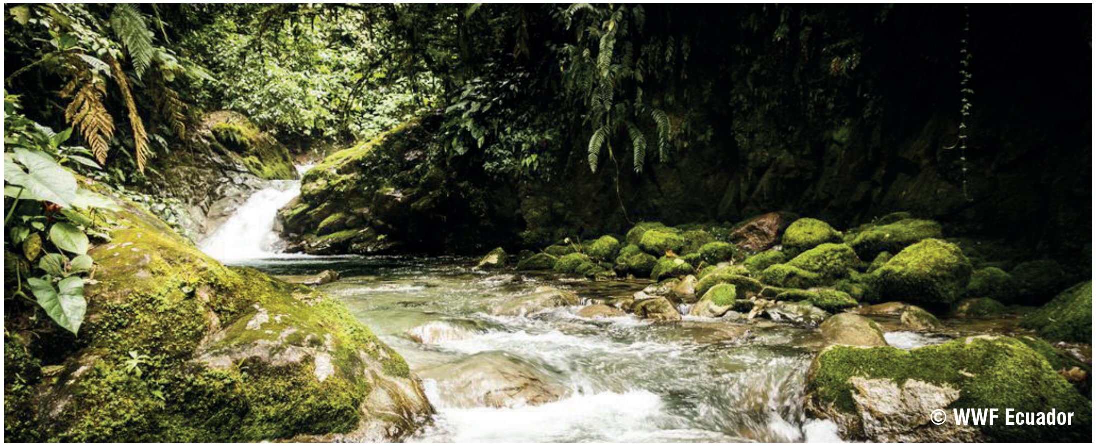
Carbon content data set by Baccini et al., 2012

Figure 11 | Deforestation rates in the Amazon Biome during the period 2005-2013



Conclusions

Based on the review of existing studies and analyses, we must highlight that both human and climate pressures, and the sum of the two, exacerbate change of the Amazon's biophysical conditions. However, in trying to maintain resilience as an attribute of function of the Amazon Biome, the best strategy has been to safeguard areas from major human disturbances. Although this approach cannot prevent the occurrence of climate change, controlling human pressures reduces its negative impacts on biodiversity, ecosystem services and human well-being by preserving ecological integrity at the biome level. This study has incorporated basic elements to characterize climate related risks and impacts, and propose actions to face them at the regional level, but we still need to complement further our biodiversity analyses to better understand ecosystem functions, determine uncertainties and improve mapping of details associated to potential climate change effects.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Recommendations

1. Use regional and biome-level approaches for designing and managing ecological networks of protected areas, and promote transboundary protected areas to increase resilience of key ecosystems and biomes.
2. Conduct further research to assess and strengthen the role of protected areas in reducing vulnerability to climate change, building resilience and supplying ecosystem services in the context of environmental change.
3. Promote knowledge at an interinstitutional level (industry, strategic sectors and others) on the importance of protected areas and their role as effective, cost-efficient strategies for ecosystem-based adaptation and mitigation.
4. Include the role of protected areas in climate change policies and strategies, and in development and land-use plans at the sectorial, regional, national and local levels.
5. Strengthen regional collaboration to implement the Amazon Conservation Vision led by REDPARQUES and promote the inclusion of protected areas in the commitments and actions of the international climate regime through the United Nations Framework Convention on Climate Change (UNFCCC).
6. Include climate change mitigation and adaptation criteria in protected areas design and management, including connectivity, representation and redundancy.
7. Expand, reshape, increase level of protection and/or create new protected areas to cover key ecosystems for facing climate change, and integrate existing protected areas through landscape approaches.

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This is another contribution to the Amazon Conservation Vision developed by the Amazon Countries under the CDB framework's program related to Protected Areas (CBD – PoWPA). To find out more about the Amazon Conservation Vision and the 'Protected Areas, Natural Solutions to Climate Change' (NASCC) project implemented by REDPARQUES with WWF's Living Amazon Initiative, thanks to funding from the German Ministry of Environment –BMUB- and WWF Germany, click here: http://bit.ly/1F99ezO

Prepared by: Cesar Suarez, Johanna Prüssmann, Carolina Lopez, Melissa Abud, Oscar Guevara, Analiz Vergara, Luz Adriana Zuñiga, Julia Gorricho, and Luis Germán Naranjo, November 2015.

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Amazon Vision

Protected areas beyond borders

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

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