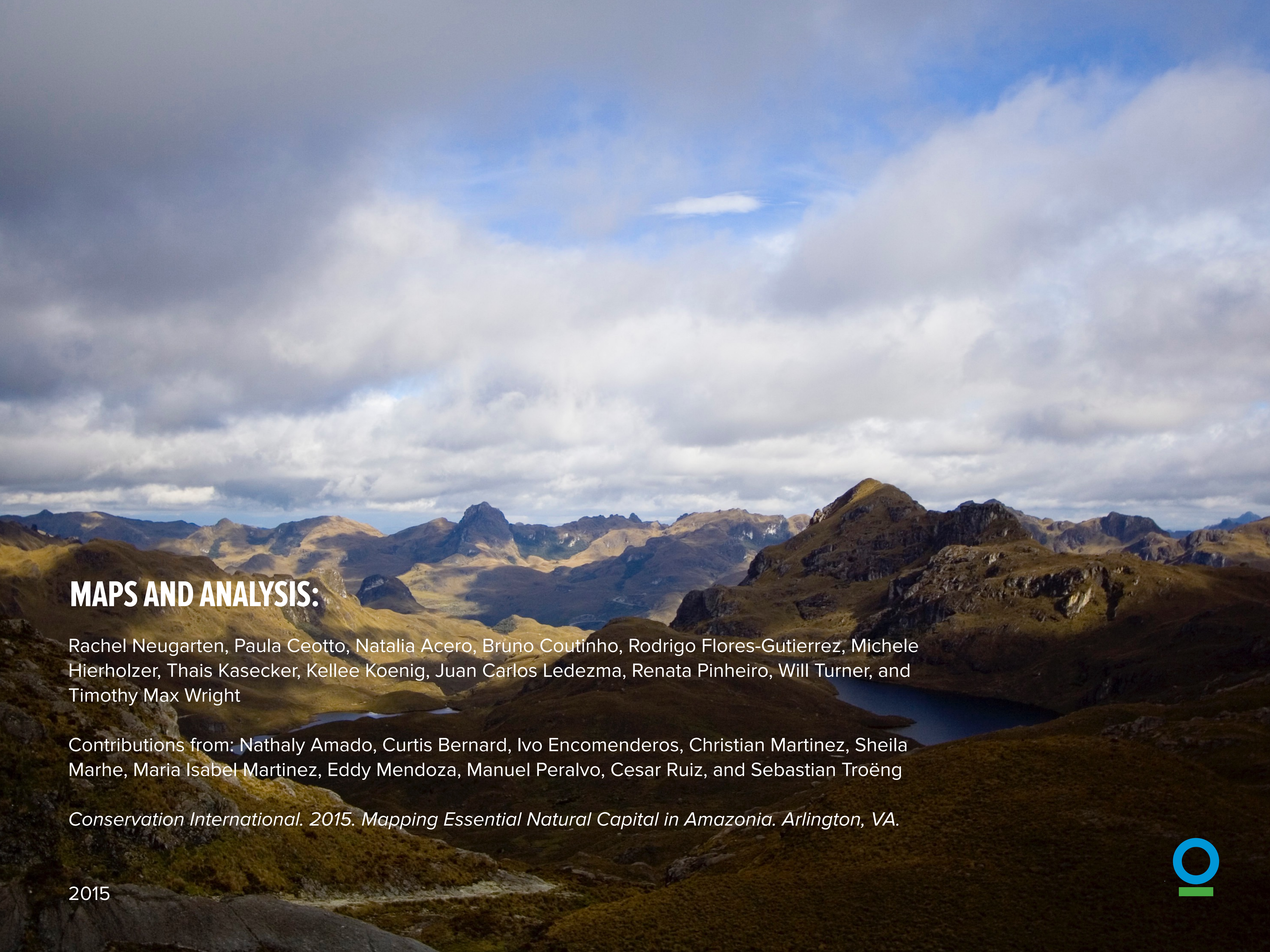
AMAZONIA

MAPPING ESSENTIAL NATURAL CAPITAL



MAPS AND ANALYSIS:

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Conservation International. 2015. Mapping Essential Natural Capital in Amazonia. Arlington, VA.

2015


NATURAL CAPITAL
MAPPING EXPLAINED
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MAPPING ESSENTIAL NATURAL CAPITAL IN AMAZONIA

Natural capital refers to the species and ecosystems that provide flows of ecosystem services that support economic activity and human well-being. Examples of natural capital include forests that regulate our climate, the rivers that provide sources of clean water, the stocks of fish that feed us, and the soil in which we grow crops. In order to protect and manage our natural capital, we need to know where it is located. Maps of the most important, or "essential", natural capital, are needed by governments, development banks, conservation organizations, and other actors seeking to meet conservation targets and ensure sustainable development for their people.

Amazonia, which encompasses parts of nine countries in South America, contains the largest tropical forest in the world. Its forests contain roughly 25% of the world's forest biomass carbon stocks, and nearly 10% of the world's known biodiversity. The Amazon River is responsible for over 15% of the fresh water that reaches the world's oceans. Around 34 million people live in Amazonia, including 375 different indigenous groups. People in Amazonia, as well as the rest of South America and the globe, depend on the natural capital contained within Amazonia for local and global climate regulation, provision of fish, fresh water for drinking and hydropower, and conservation of the planet's biodiversity. However, Amazonia is under threat. Deforestation has already led to the loss of approximately 13% of its original forest cover, primarily due to agricultural expansion, logging, and infrastructure development.

Conservation International led a project to map essential natural capital to support conservation and sustainable development in the region. We brought together existing data and conducted new spatial analyses to identify places important for biodiversity, fresh water, climate mitigation and adaptation, and non-timber forest products. We hope that the following maps will be useful to decision makers seeking to conserve and sustainably manage the most important places for biodiversity and human well-being in the region.

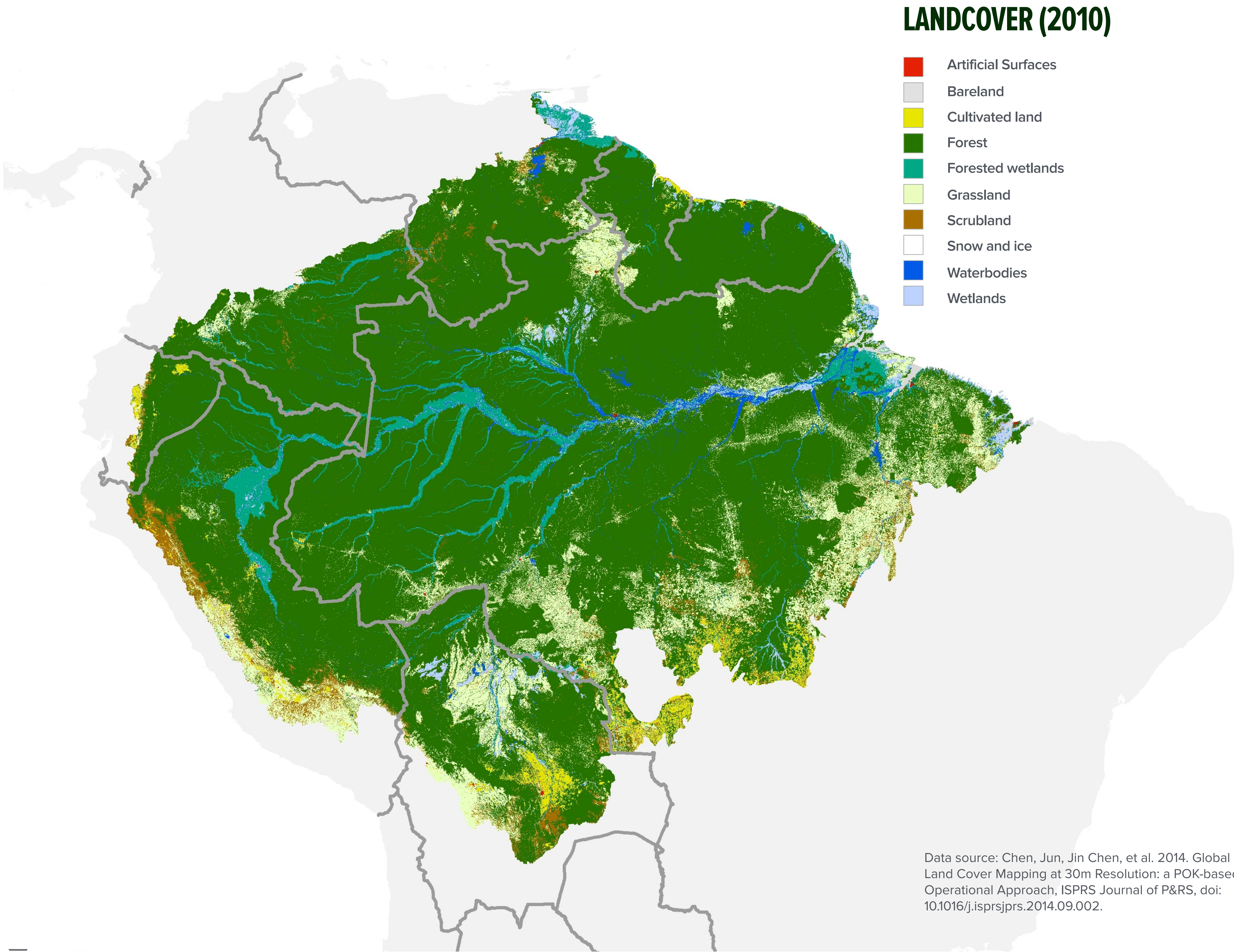
We define Amazonia as the vast region of tropical rainforest of northern South America, including the forests of the drainage basins of the Rio Amazonas and its tributaries, the forests of southern (in Venezuela) and southwestern (in Colombia) tributaries of the Rio Orinoco, and the forests of the Guianas, the rivers of which drain into the Atlantic. Amazonia can be divided conceptually into three zones: Green, Red, and Yellow.

Green Zone: Approximately 47% of Amazonia falls within formally designated protected areas or indigenous lands and territories. These areas present opportunities for strengthening management in order to ensure conservation of biodiversity and ongoing provision of ecosystem services.

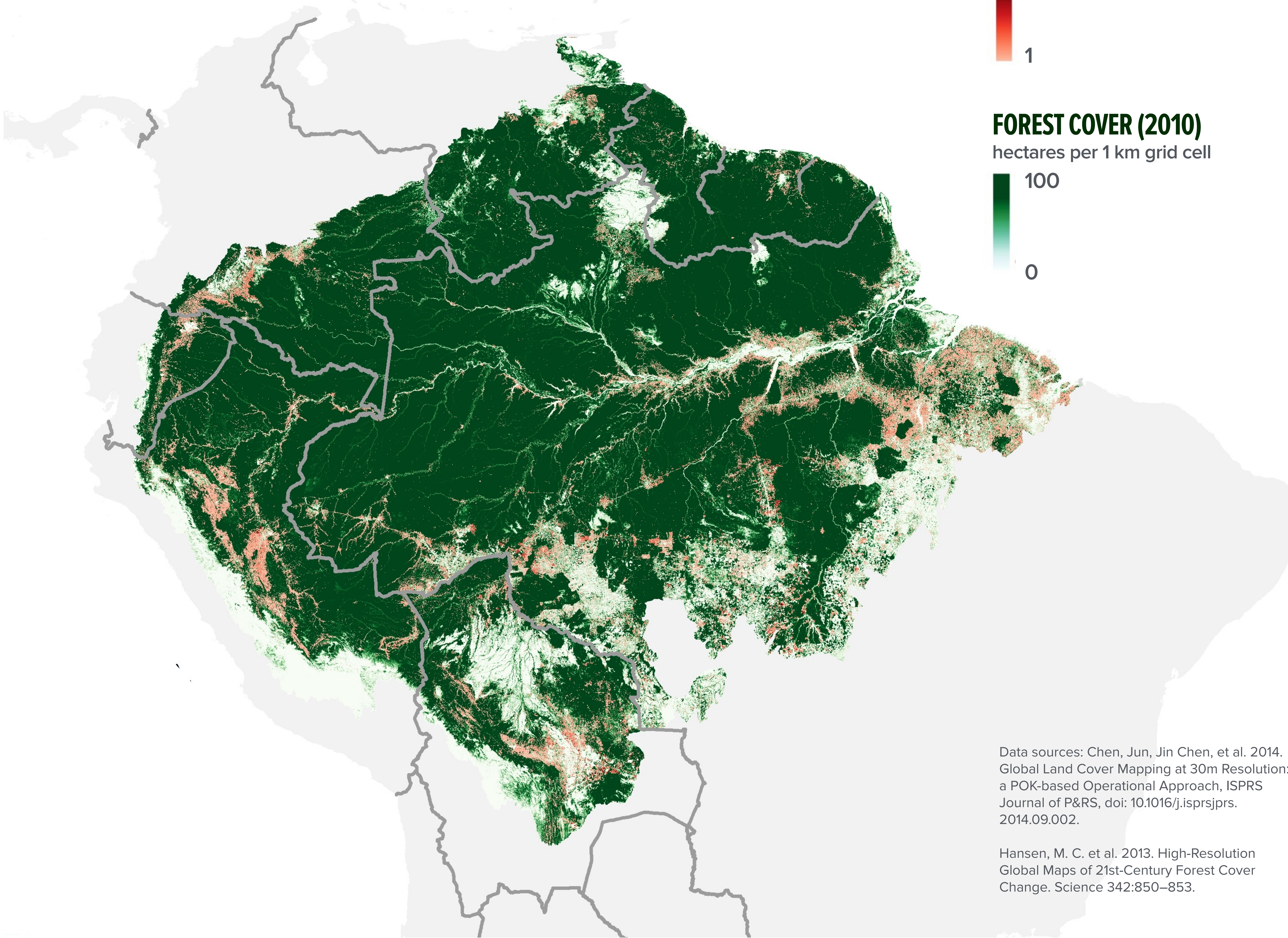
Red Zone: About 7% of Amazonian forests haves been converted to agriculture, developed into cities, or degraded to meet demand for food, homes, power, and jobs. These areas might be targeted for restoration or agricultural intensification, to take pressure off remaining natural habitats.

Yellow Zone: An estimated 46% of Amazonia remains as mostly forest or other natural habitat, and currently is unprotected. These areas are comprised of government-owned areas, private lands, concessions, or other land uses. They may present opportunities for protection, restoration, or other strategies such as community conservation agreements, payments for ecosystem services, or integrated conservation and poverty alleviation projects.


STUDY REGION
AMAZONIA
STUDY AREA
Caracas
Port of Spain
VENEZUELA
Georgetown
Paramaribo
Cayenne
GUYANA
SURINAME
FRENCH GUIANA
Boa Vista
Bogota
COLOMBIA
Negro
Quito
ECUADOR
Manaus
Santarem
Belem
Sao Luis
Amazonas
Iquitos
Madeira
BRAZIL
Porto Velho
Ucayali
Mamoré
PERU
Lima
Cuzco
BOLIVIA
Grande
La Paz
Santa Cruz de La Sierra
Cuiaba
Brasilia
Sucre



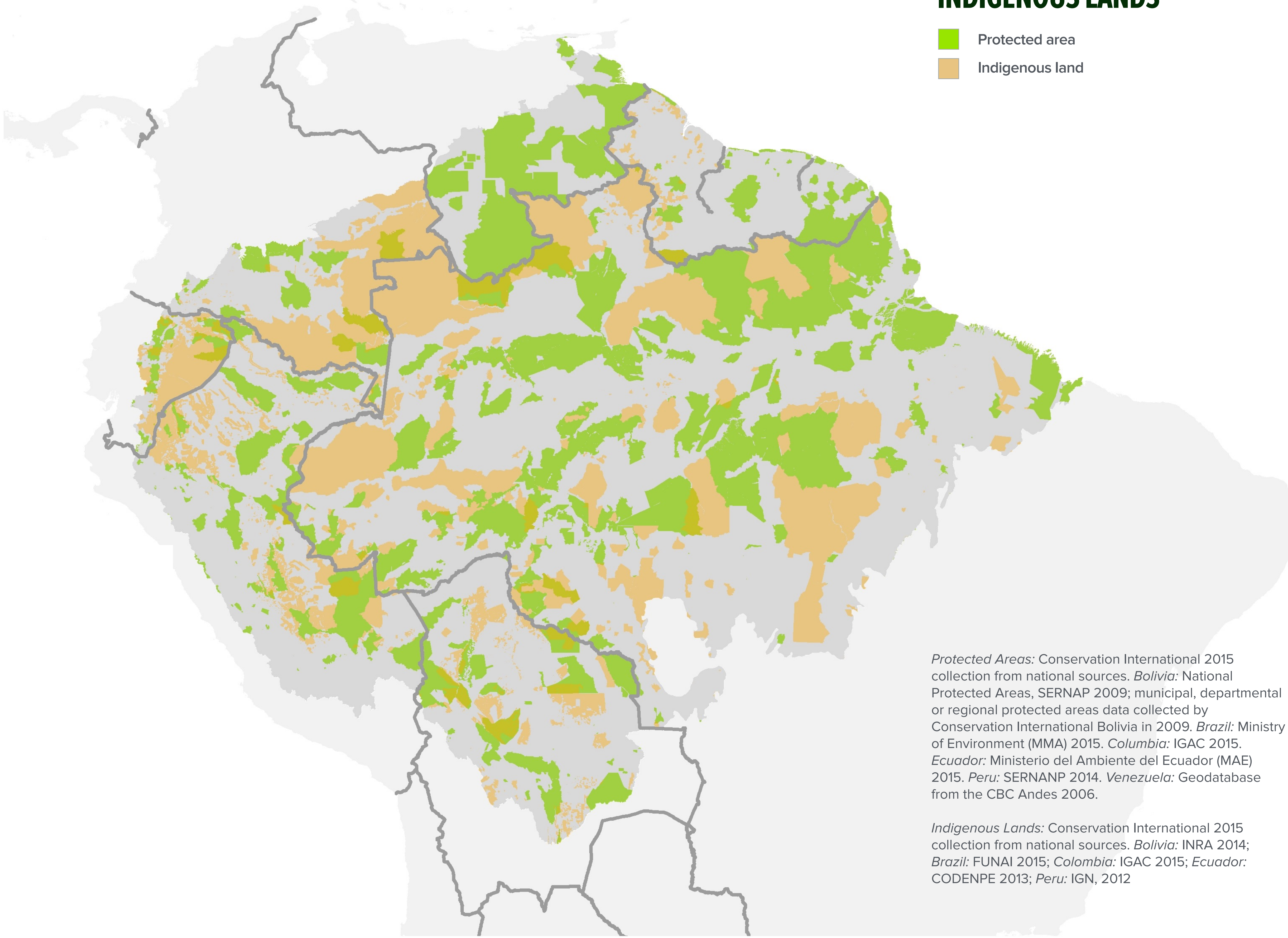
Data source: Chen, Jun, Jin Chen, et al. 2014. Global Land Cover Mapping at 30m Resolution: a POK-based Operational Approach, ISPRS Journal of P&RS, doi: 10.1016/j.isprsjprs.2014.09.002.



Data sources: Chen, Jun, Jin Chen, et al. 2014. Global Land Cover Mapping at 30m Resolution: a POK-based Operational Approach, ISPRS Journal of P&RS, doi: 10.1016/j.isprsjprs.2014.09.002.

Hansen, M. C. et al. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342:850–853.

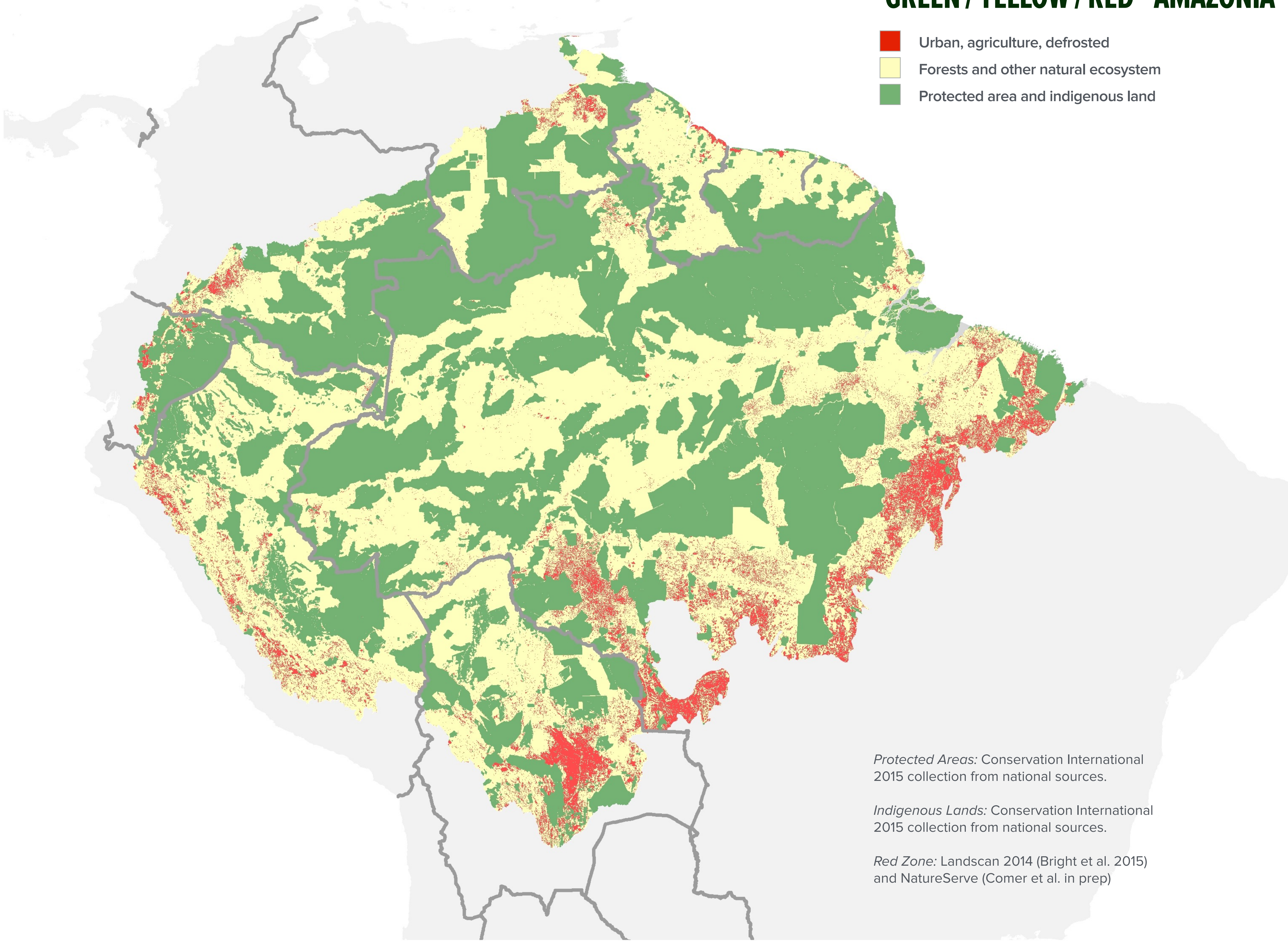
PROTECTED AREAS AND INDIGENOUS LANDS



Protected Areas: Conservation International 2015 collection from national sources. *Bolivia:* National Protected Areas, SERNAP 2009; municipal, departmental or regional protected areas data collected by Conservation International Bolivia in 2009. *Brazil:* Ministry of Environment (MMA) 2015. *Columbia:* IGAC 2015. *Ecuador:* Ministerio del Ambiente del Ecuador (MAE) 2015. *Peru:* SERNANP 2014. *Venezuela:* Geodatabase from the CBC Andes 2006.

Indigenous Lands: Conservation International 2015 collection from national sources. *Bolivia:* INRA 2014; *Brazil:* FUNAI 2015; *Colombia:* IGAC 2015; *Ecuador:* CODENPE 2013; *Peru:* IGN, 2012

"GREEN / YELLOW / RED" AMAZONIA



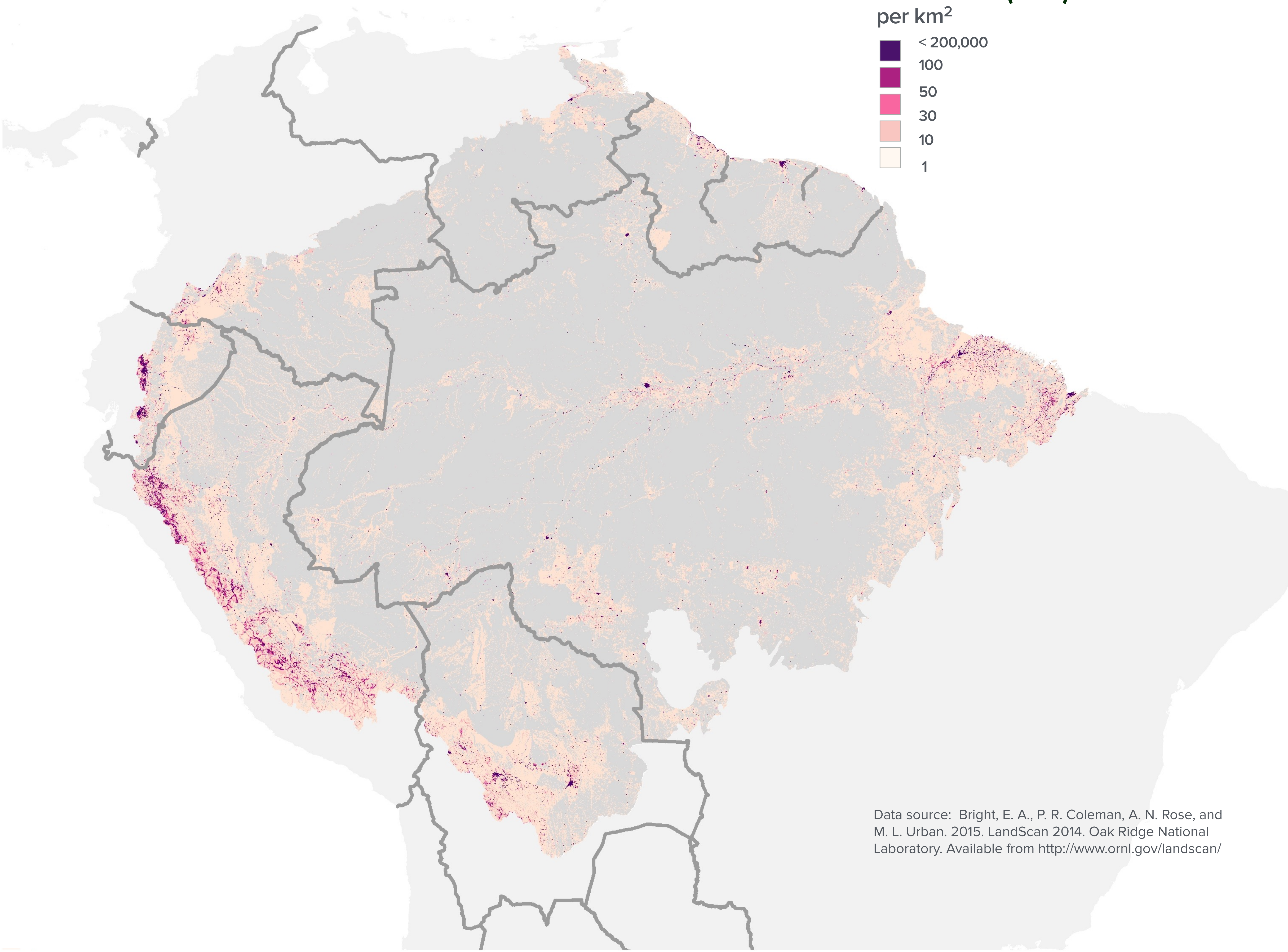
Protected Areas: Conservation International 2015 collection from national sources.

Indigenous Lands: Conservation International 2015 collection from national sources.

Red Zone: Landscan 2014 (Bright et al. 2015) and NatureServe (Comer et al. in prep)

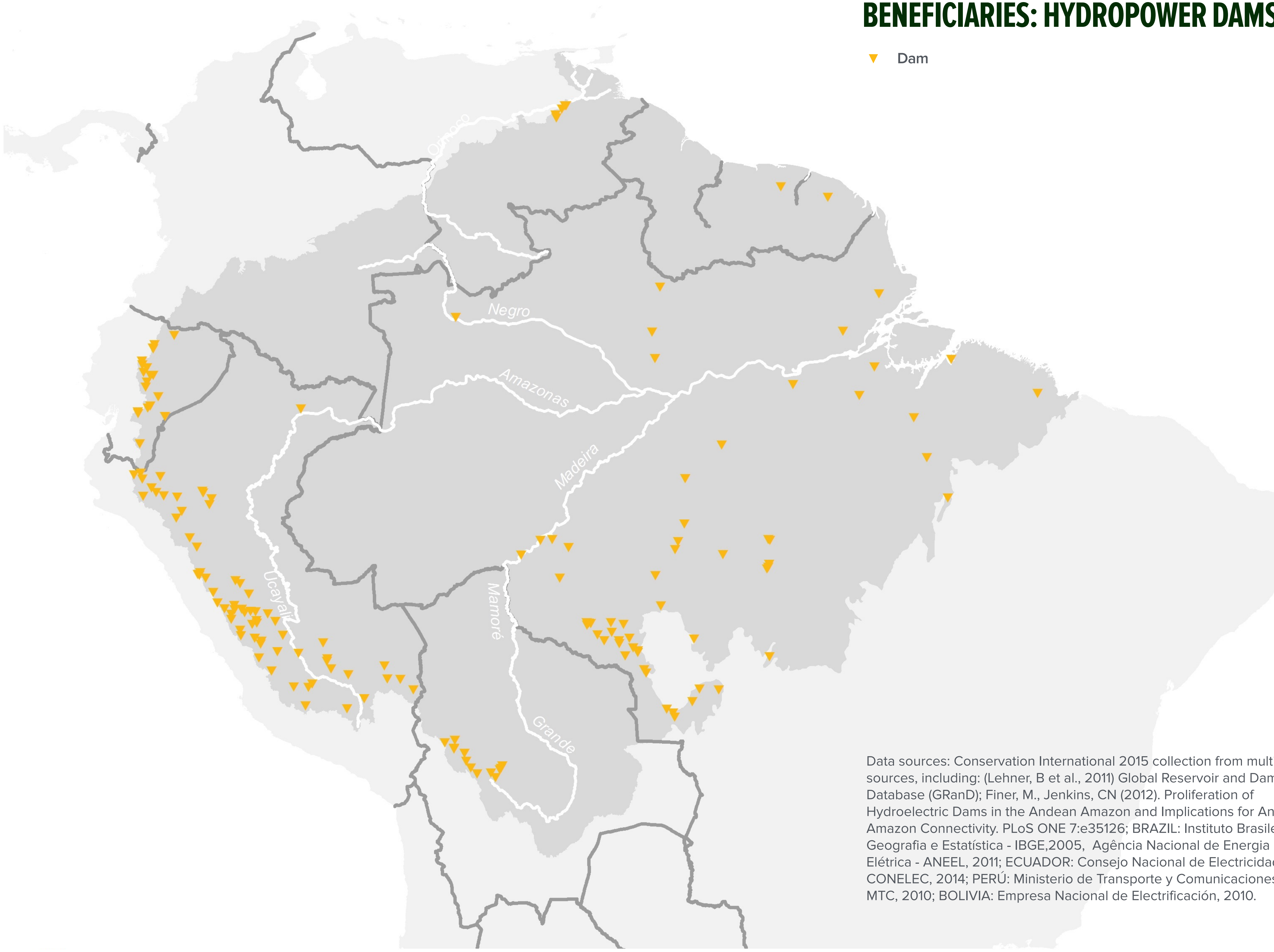
BENEFICIARIES: POPULATION

POPULATION (2014)

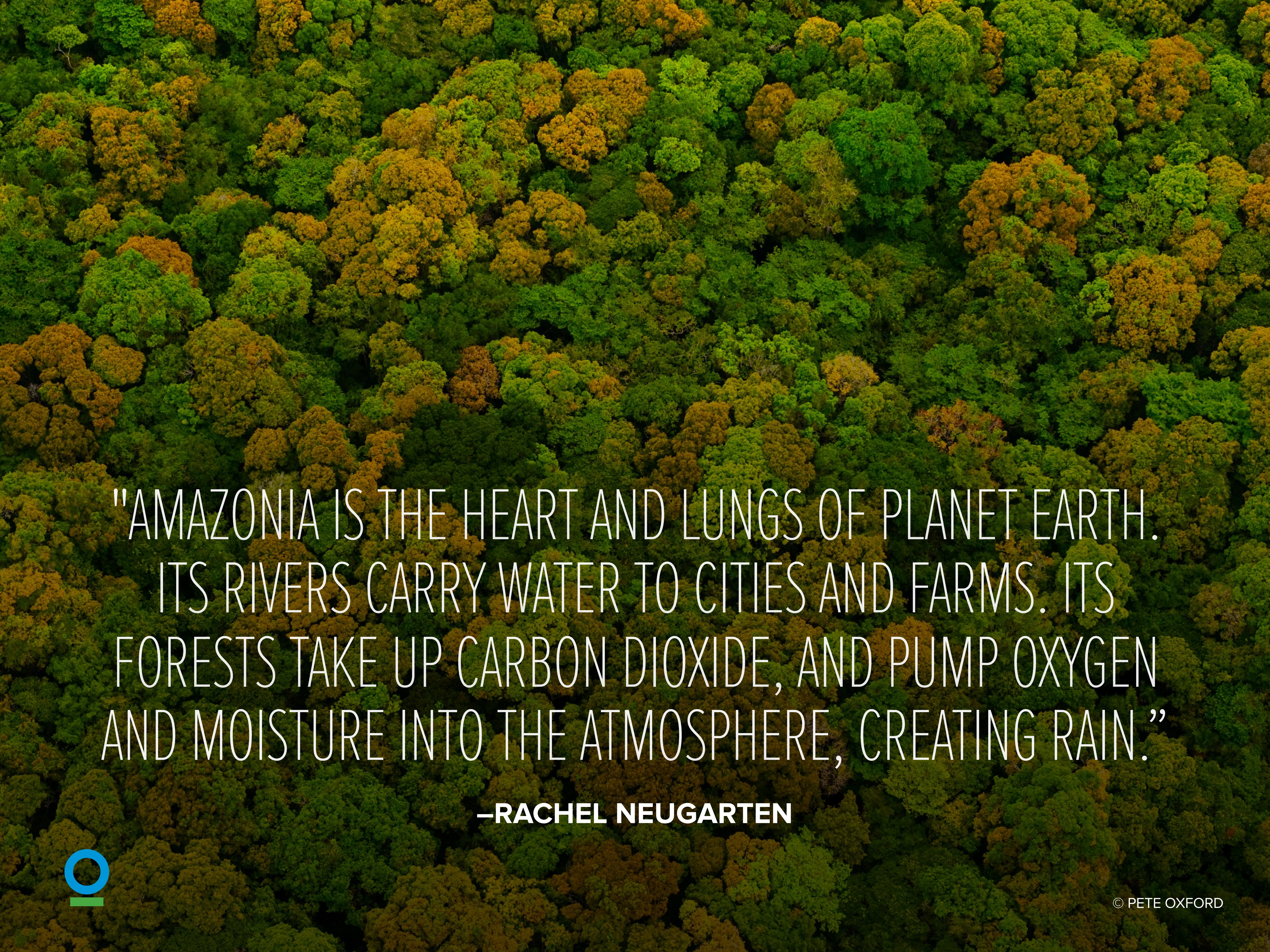


Data source: Bright, E. A., P. R. Coleman, A. N. Rose, and M. L. Urban. 2015. LandScan 2014. Oak Ridge National Laboratory. Available from http://www.ornl.gov/landscan/

BENEFICIARIES: HYDROPOWER DAMS



Data sources: Conservation International 2015 collection from multiple sources, including: (Lehner, B et al., 2011) Global Reservoir and Dam Database (GRanD); Finer, M., Jenkins, CN (2012). Proliferation of Hydroelectric Dams in the Andean Amazon and Implications for Andes-Amazon Connectivity. PLoS ONE 7:e35126; BRAZIL: Instituto Brasileiro de Geografia e Estatística - IBGE,2005, Agência Nacional de Energia Elétrica - ANEEL, 2011; ECUADOR: Consejo Nacional de Electricidad – CONELEC, 2014; PERÚ: Ministerio de Transporte y Comunicaciones - MTC, 2010; BOLIVIA: Empresa Nacional de Electrificación, 2010.


"AMAZONIA IS THE HEART AND LUNGS OF PLANET EARTH. ITS RIVERS CARRY WATER TO CITIES AND FARMS. ITS FORESTS TAKE UP CARBON DIOXIDE, AND PUMP OXYGEN AND MOISTURE INTO THE ATMOSPHERE, CREATING RAIN."
–RACHEL NEUGARTEN
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BIODIVERSITY
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MAPPING ESSENTIAL NATURAL CAPITAL FOR BIODIVERSITY

Biodiversity—the variability among species, ecosystems, and ecological processes—is fundamental to the planet's health and humanity's survival. It is the essential base of natural capital which supports human well-being and economic activity. The Amazonian region is one of the richest areas of biodiversity on the planet, containing around 2.5 million insect species, 2,200 fish, 1,294 birds, 427 mammals, 428 amphibians, 378 reptiles and 40,000 plant species. To date, there are over 2,000 species known to be useful for food, medicine, and other purposes, but many more have yet to be discovered.

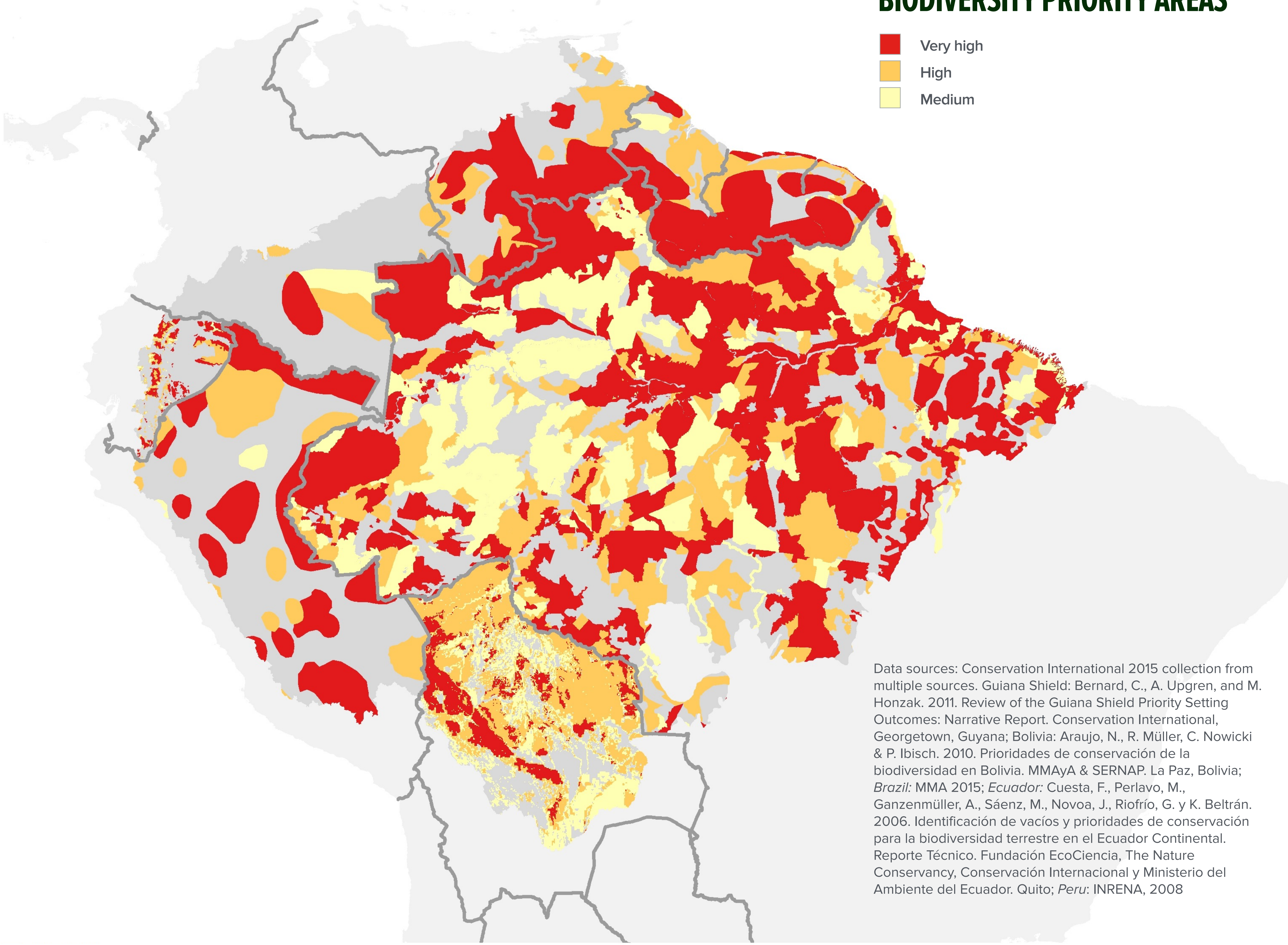
Areas of essential natural capital for biodiversity include habitats harboring threatened and protected species, threatened and unique/rare ecosystems, exceptionally high species richness, endemic and restricted-range species, migratory and congregatory species, including spawning grounds, and areas where key evolutionary and ecological processes occur. We collected maps of existing biodiversity priority areas that had been defined at the national scale (by Brazil, Bolivia, Ecuador, and Peru) or at the regional scale (for the Guiana Shield). These priority areas were defined using different criteria, but the goal in all cases was to facilitate the safeguarding of the most important sites. We classified all sites as medium, high, or very high priority based on their original level of priority as defined by each country or region.

We found that 34% of existing biodiversity priority areas are already contained within protected areas, and 25% are contained within indigenous lands. This means that many important biodiversity areas currently have no protection. These areas could be considered for future conservation or for sustainable management, through the use of community conservation agreements, for example.

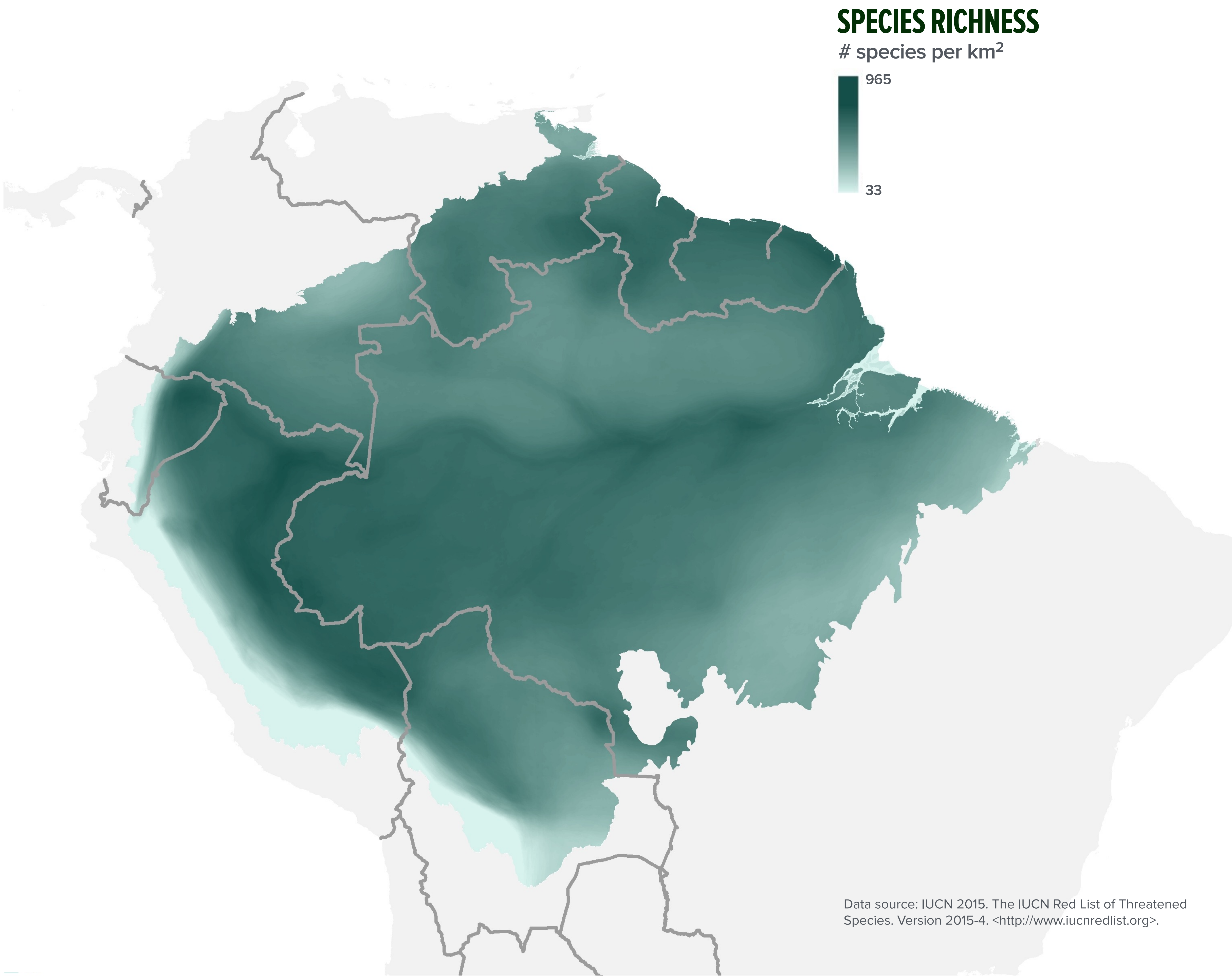
We also conducted our own analysis, focusing on one dimension of importance for biodiversity: endemism, generally defined as species that are restricted to a particular area. Areas with high endemism, therefore, are home to unique and irreplaceable species. Species range data from the IUCN Red List database (2014) on mammals, amphibians, reptiles, and birds were used to identify areas with the largest number of range-restricted species (a proxy for endemism.) This analysis resulted in a map of species richness (total number of species in a given place) as well as maps of weighted endemism (areas with larger numbers of range-restricted species.) We repeated the analysis at two spatial scales: once for the entire region and once within sub-regional zones, known as "zones of endemism", defined by scientists based on species' evolutionary and phylogenetic characteristics. This resulted in two maps: a regional weighted endemism map, and a map of weighted endemism within each zone, which were then combined for a final map of 'essential natural capital' for biodiversity (defined here as important areas for endemic species.)

This analysis identified areas in the Andes region and in the Guiana Shield as having a very high level of endemism, as well as regions like the várzea of the Amazonas River, the Brazilian coast ("Salgado Paraense"), the transition area to Cerrado bioma on the Araguaia basin and the confluence area between the Negro and Solimões Rivers. We found that only 27% of these areas are contained in protected areas, and 20% in indigenous lands. These areas should be targeted for strengthened management, protection, or community-based conservation efforts, in order to conserve their unique global biodiversity values.

BIODIVERSITY PRIORITY AREAS



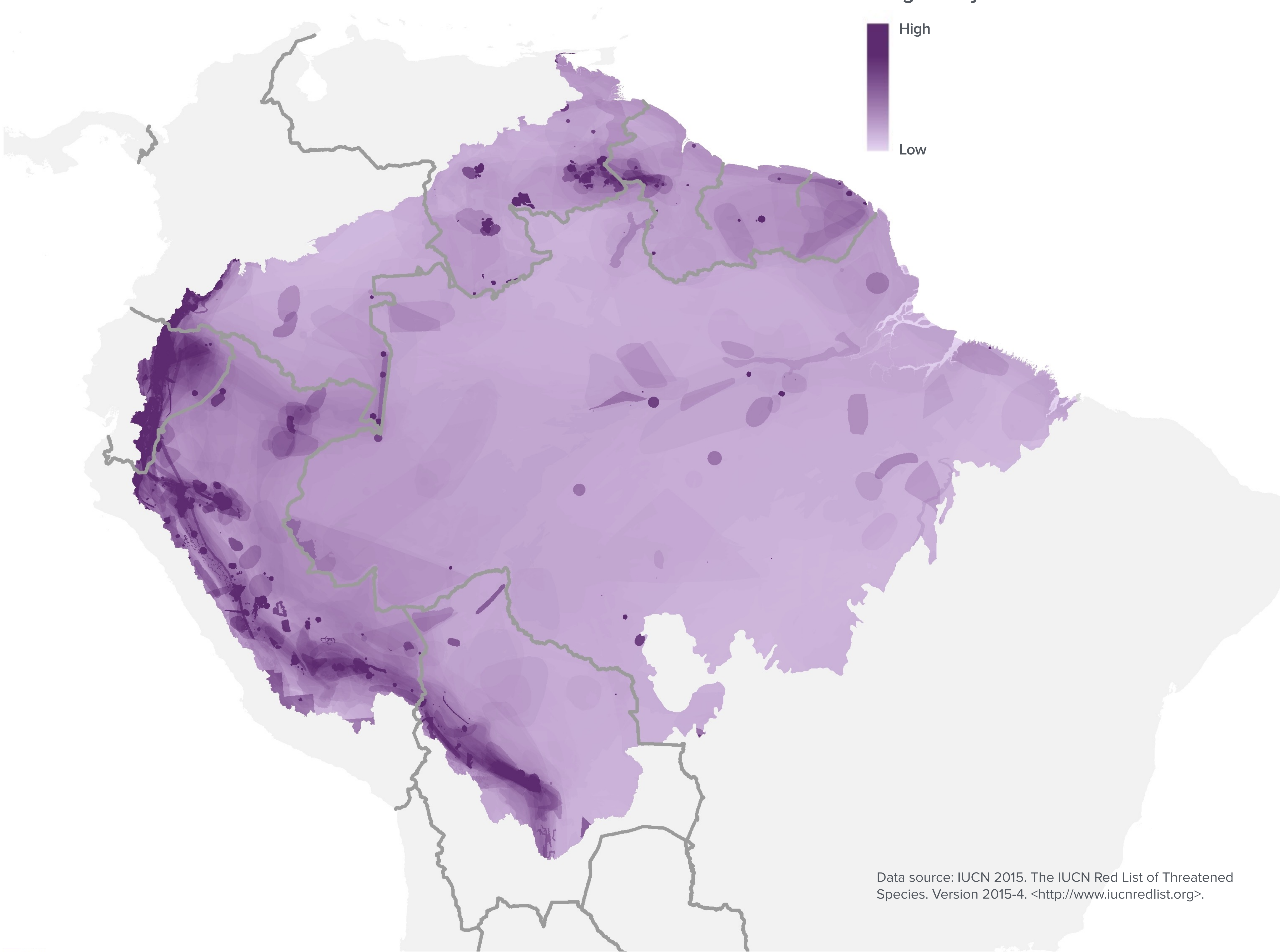
Data sources: Conservation International 2015 collection from multiple sources. Guiana Shield: Bernard, C., A. Upgren, and M. Honzak. 2011. Review of the Guiana Shield Priority Setting Outcomes: Narrative Report. Conservation International, Georgetown, Guyana; Bolivia: Araujo, N., R. Müller, C. Nowicki & P. Ibisch. 2010. Prioridades de conservación de la biodiversidad en Bolivia. MMAyA & SERNAP. La Paz, Bolivia; *Brazil:* MMA 2015; *Ecuador:* Cuesta, F., Perlavo, M., Ganzenmüller, A., Sáenz, M., Novoa, J., Riofrío, G. y K. Beltrán. 2006. Identificación de vacíos y prioridades de conservación para la biodiversidad terrestre en el Ecuador Continental. Reporte Técnico. Fundación EcoCiencia, The Nature Conservancy, Conservación Internacional y Ministerio del Ambiente del Ecuador. Quito; *Peru*: INRENA, 2008



Data source: IUCN 2015. The IUCN Red List of Threatened Species. Version 2015-4. <http://www.iucnredlist.org>.

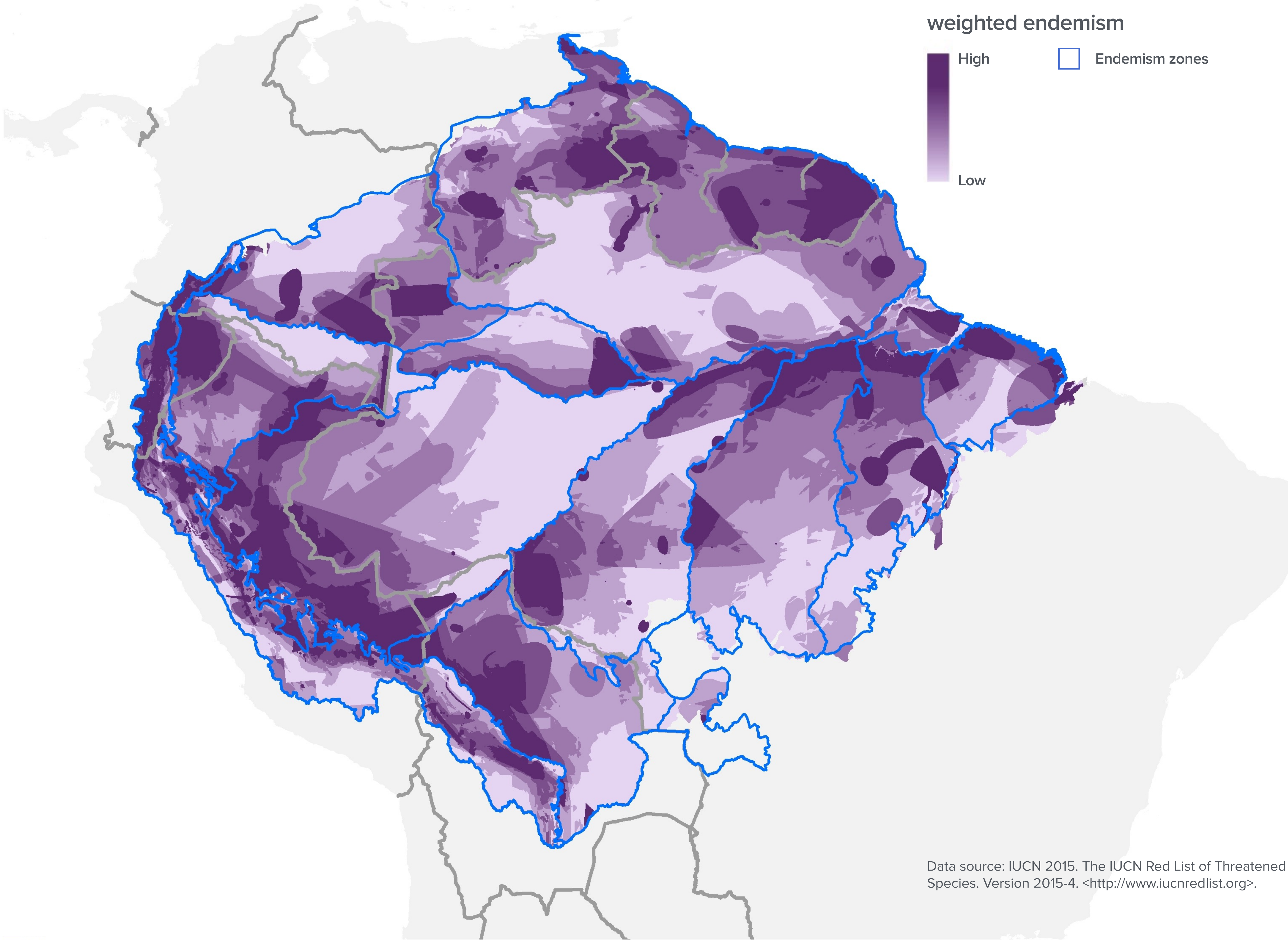
WEIGHTED ENDEMISM (ENTIRE REGION)

range rarity index



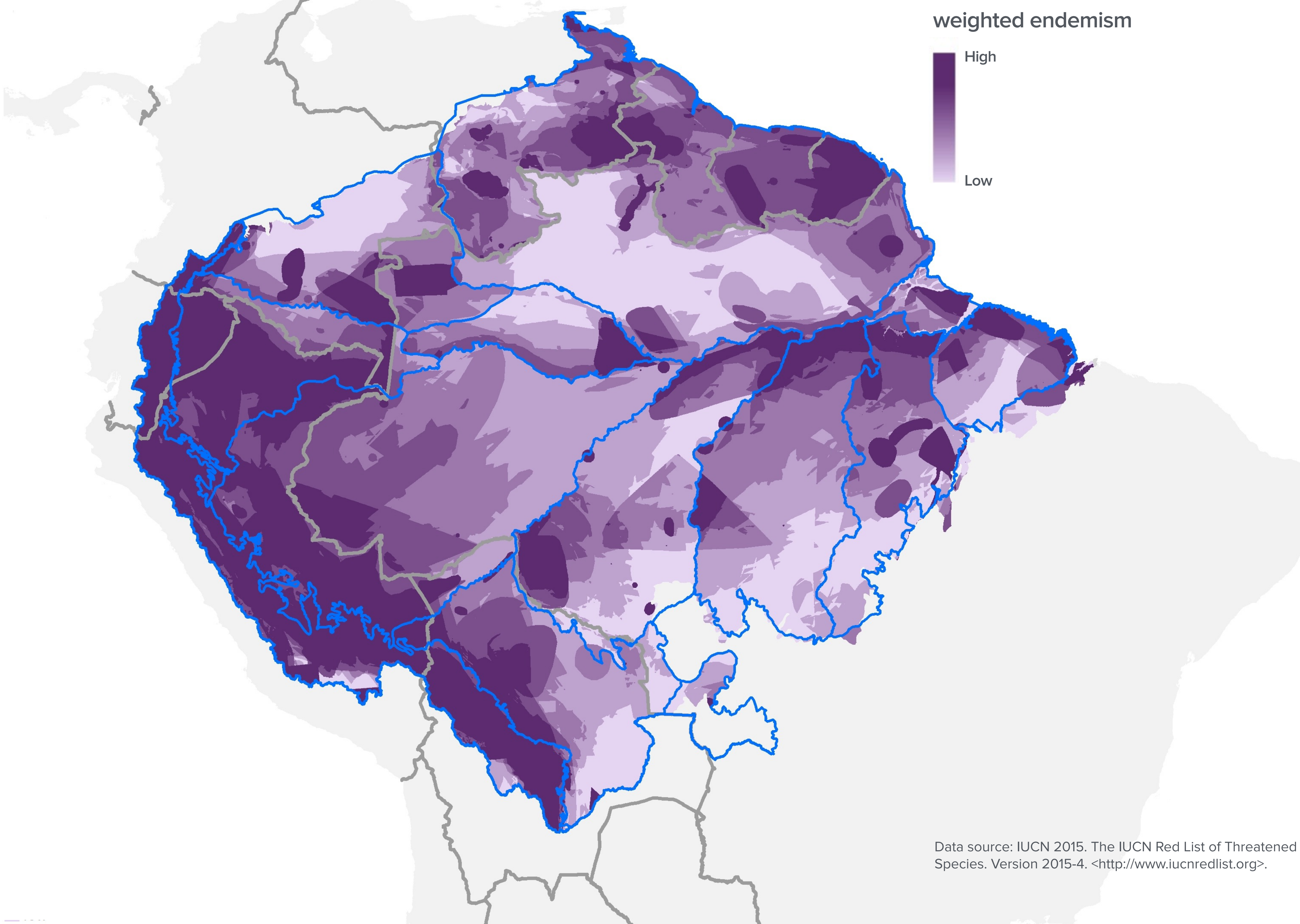
Data source: IUCN 2015. The IUCN Red List of Threatened Species. Version 2015-4. <http://www.iucnredlist.org>.

WEIGHTED ENDEMISM (WITHIN ZONES OF ENDEMISM)



Data source: IUCN 2015. The IUCN Red List of Threatened Species. Version 2015-4. <http://www.iucnredlist.org>.

WEIGHTED ENDEMISM (ENTIRE REGION PLUS ZONES OF ENDEMISM)



Data source: IUCN 2015. The IUCN Red List of Threatened Species. Version 2015-4. <http://www.iucnredlist.org>.


MANY IMPORTANT BIODIVERSITY AREAS
CURRENTLY HAVE NO PROTECTION.
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FOREST CARBON & CLIMATE MITIGATION

MAPPING ESSENTIAL NATURAL CAPITAL FOR FOREST CARBON & CLIMATE MITIGATION

Tropical forests are critically important for long-term global climate regulation because they sequester and store carbon dioxide (CO_2), a major greenhouse gas, from the atmosphere and, when they are lost, CO_2 is emitted back into the atmosphere. Recent studies have shown that deforestation accounts for between 12-20% of global greenhouse gas emissions, making it the second biggest contributor to global CO_2 emissions after the consumption of fossil fuels. Amazonia is particularly important because it is the largest contiguous rainforest in the world and stores almost one-third of all tropical biomass carbon. Despite national and international efforts to stop deforestation in Amazonia, forests continue to be lost to agricultural expansion for soy, oil palm plantations, timber and cattle grazing. The ability to quantify the amount of carbon that is stored in Amazonian forests and identify where it is being lost is essential for informing international emission targets and national climate policies.

Mapping essential natural capital for climate mitigation involves identifying areas of importance for the long-term maintenance of biotic carbon stock within natural ecosystems, and the reduction of potential greenhouse gas emissions from anthropogenic activities within those ecosystems, such as from land use change. To achieve these objectives we mapped two aspects of natural capital for climate mitigation; biomass carbon stock and potential avoided CO_2 emissions.

Mapping biomass carbon stock requires information on the current land cover and the density of vegetation biomass. For the purpose of this analysis only forest biomass, both above-ground and below-ground, was considered. Soil carbon was not included in the biomass carbon assessment, nor was post-deforestation land-use emissions, such as emissions associated with agriculture.

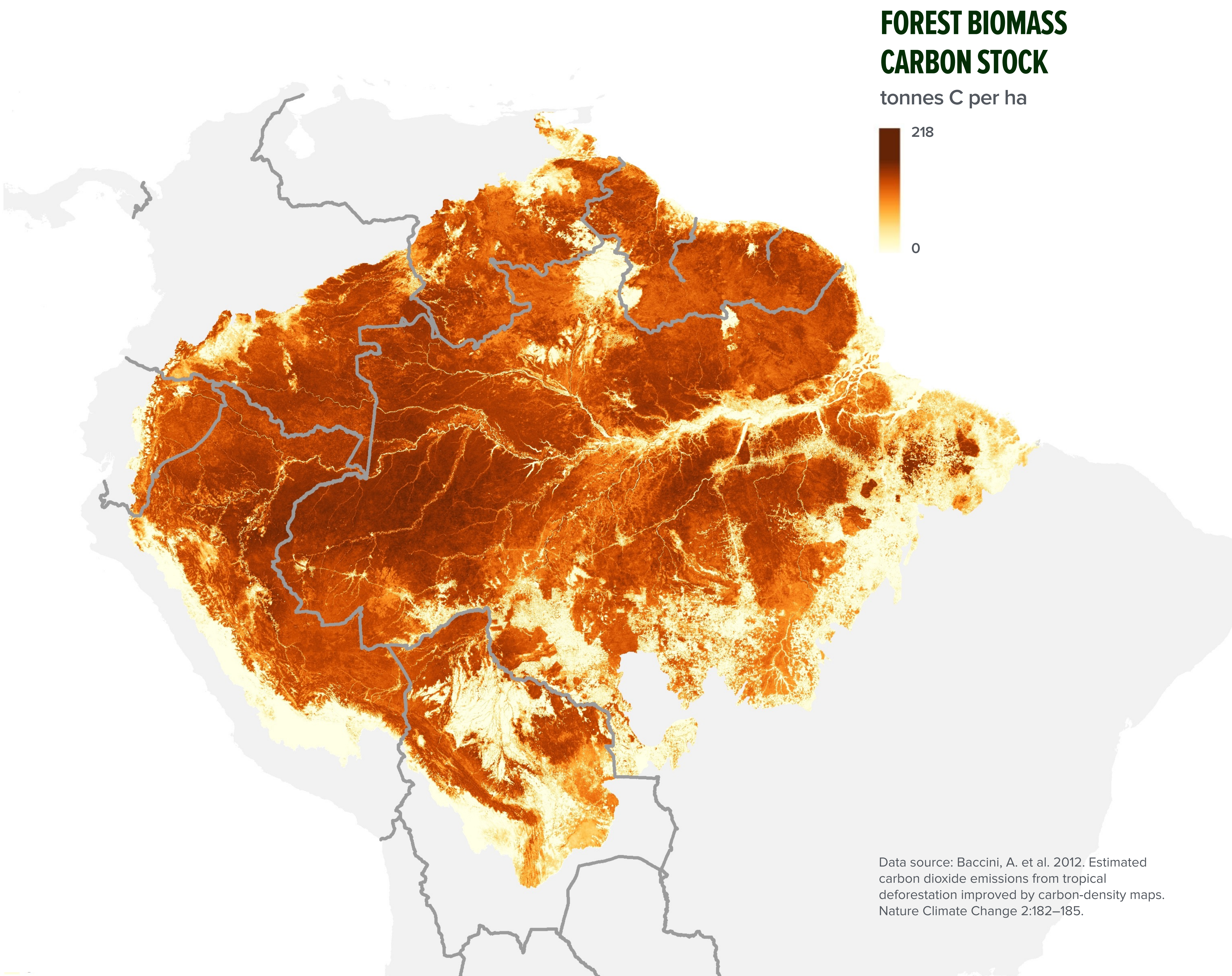
The areas of the highest forest carbon stock are located in areas that remain undisturbed in the central Amazon Basin and the remote portions of the northern Amazon Basin and Guyana Shield. These areas could be targeted for conservation to achieve long-term maintenance of forest carbon stocks. There are low values along the Andean edge on the west, where the forests have naturally less biomass and there is a mix of both forest and natural non-forest land-cover, and in the southern/eastern portion of the Brazilian Amazon, which has been heavily deforested for agriculture. It is important to mention that non-forest ecosystems also contain important carbon stocks that, if conserved or sustainably managed, also contribute to mitigation of global climate change.

The potential avoided emissions map combines forest biomass information with the likelihood that a forested area will be deforested in order to assess areas that are both important for carbon stocks and are highly vulnerable to deforestation. For this analysis, a simple proximity-based model was used to calculate the future rate of forest loss based on the historical deforestation within 20 kilometers. This rate was combined with the remaining forest biomass carbon to get the projected carbon loss per year, and then converted to CO_2 equivalents (CO_2e) to get the projected annual emissions.

Based on this analysis, deforestation is predicted to occur primarily along roads, rivers, and agricultural frontiers. There is high vulnerability to deforestation in the southern Brazilian Amazon, and portions of the Bolivian and Peruvian Amazon. The interior of the Amazon region has relatively low rates of deforestation, primarily due to how remote and inaccessible those areas are.

There are some interesting differences between the potential avoided emissions map and the previous vulnerability map. Two areas of particular concern are in central Peru, where there has been a lot of loss within high biomass forests, and in the central Brazilian Amazon along what is known as the "soy road," the route which soy is transported from the fields in the south to the coast for export. These areas could be targeted for conservation or sustainable management to avoid future emissions from deforestation.

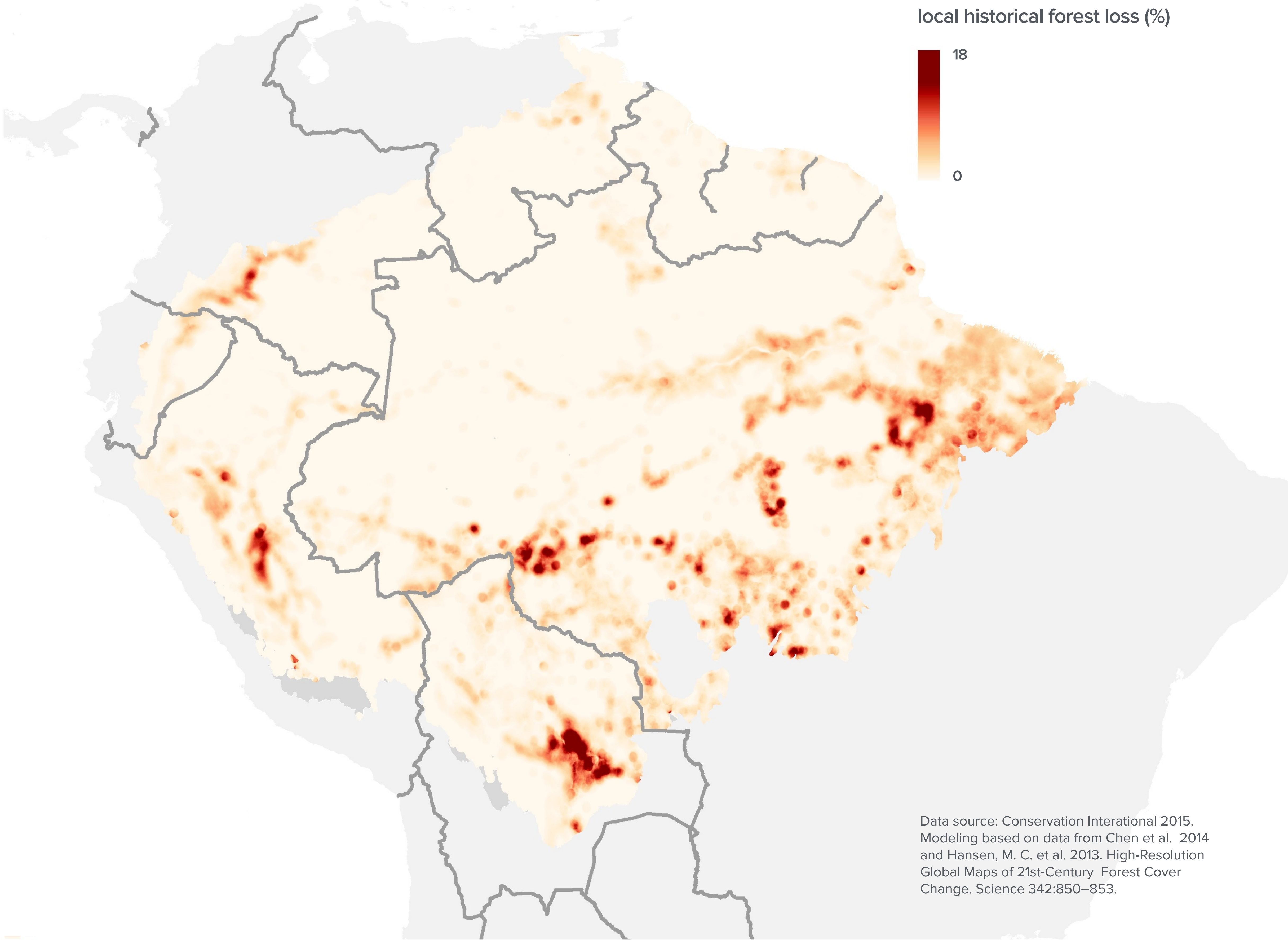
Although protected areas and indigenous lands only cover 46% of the study area, they collectively account for 54% of the total carbon stock. However, deforestation continues within these areas. Ensuring these areas are effectively conserved could maintain their critically important role for mitigating global climate change.



Data source: Baccini, A. et al. 2012. Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change 2:182–185.

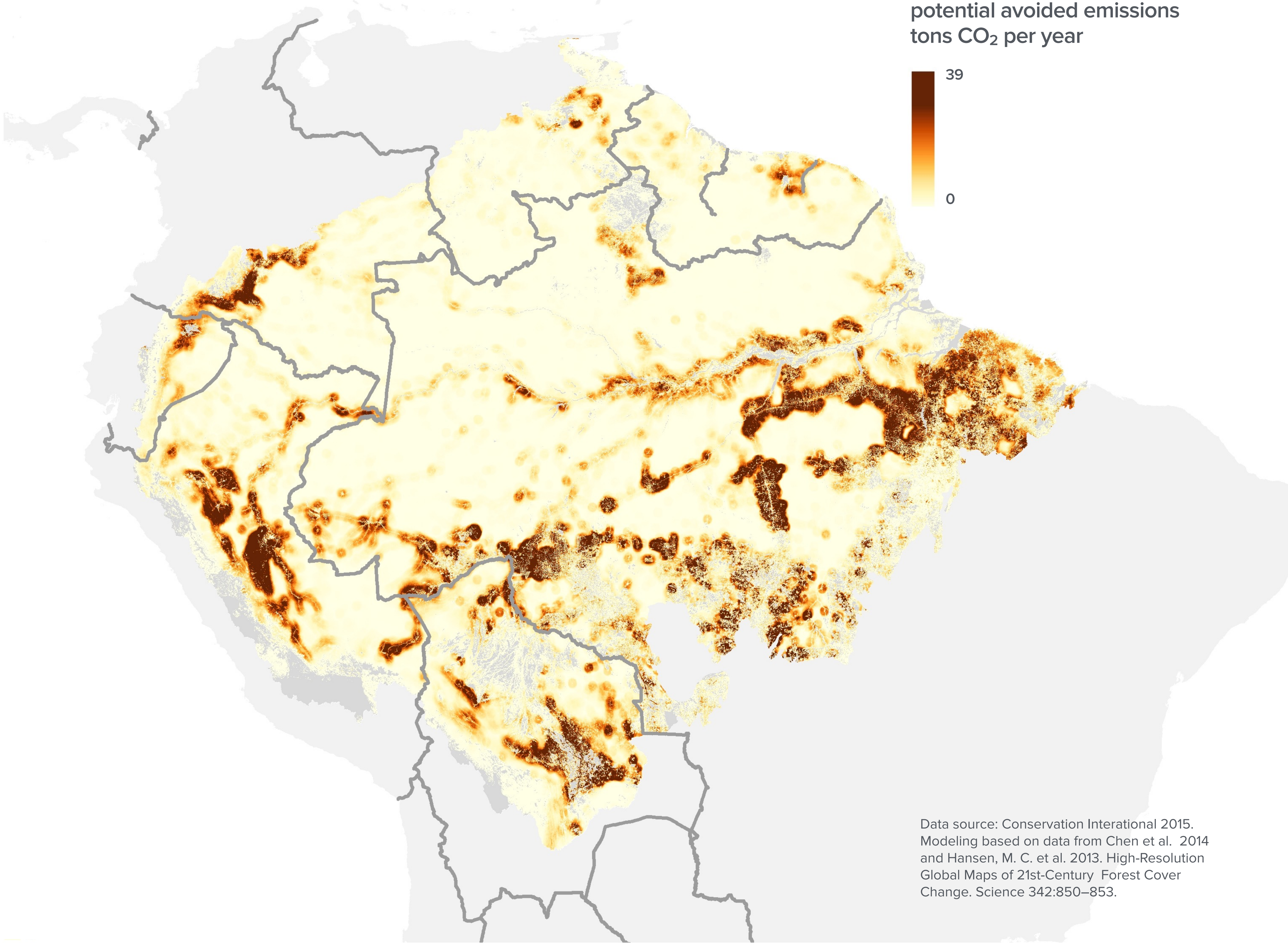
VULNERABILITY TO FUTURE DEFORESTATION

local historical forest loss (%)



Data source: Conservation Interational 2015. Modeling based on data from Chen et al. 2014 and Hansen, M. C. et al. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342:850–853.

POTENTIAL AVOIDED CO_2 EMISSIONS FROM DEFORESTATION



Data source: Conservation Interational 2015. Modeling based on data from Chen et al. 2014 and Hansen, M. C. et al. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342:850–853.


ALTHOUGH PROTECTED AREAS AND INDIGENOUS LANDS ONLY COVER 46% OF THE STUDY AREA, THEY COLLECTIVELY ACCOUNT FOR 54% OF THE TOTAL CARBON STOCK.
© CRISTINA MITTERMEIER


FRESH WATER
©CRISTINA MITTERMEIER

MAPPING ESSENTIAL NATURAL CAPITAL FOR FRESH WATER

Water is the most essential natural resource, a core component of both human well-being and a thriving economy. Ecosystems such as forests, wetlands, and rivers are essential for capturing water, filtering out contaminants, and allowing it to flow to the people who need it. Successful water management relies on the identification of water supply areas and making the link to downstream users, be they households, cities, or hydropower dams. The Amazonian region is the world's largest source of freshwater relatively untouched by human activity. The Amazonian river system encompasses 6.9 million square kilometers, 13 major tributaries, and an extensive river network that discharges an equivalent of 20% of the planet's surface water flows to the Atlantic ocean every year. The river network supports the regional economy, providing food, transportation services, water for domestic use, and energy production, among other benefits. The Amazonian rainforest also plays a crucial role in the global and regional climate system via hydrological feedbacks, acting as a moisture pump that replenishes atmospheric moisture that falls as rain elsewhere in South America and beyond.

Essential natural capital for fresh water is defined as ecosystems important for the provision of freshwater ecosystem services. These include forests, rivers, or other ecosystems that provide water for human use or hydropower production (water quantity), avoided erosion and sedimentation (water quality), or provide a stable flow of water (flow regulation).

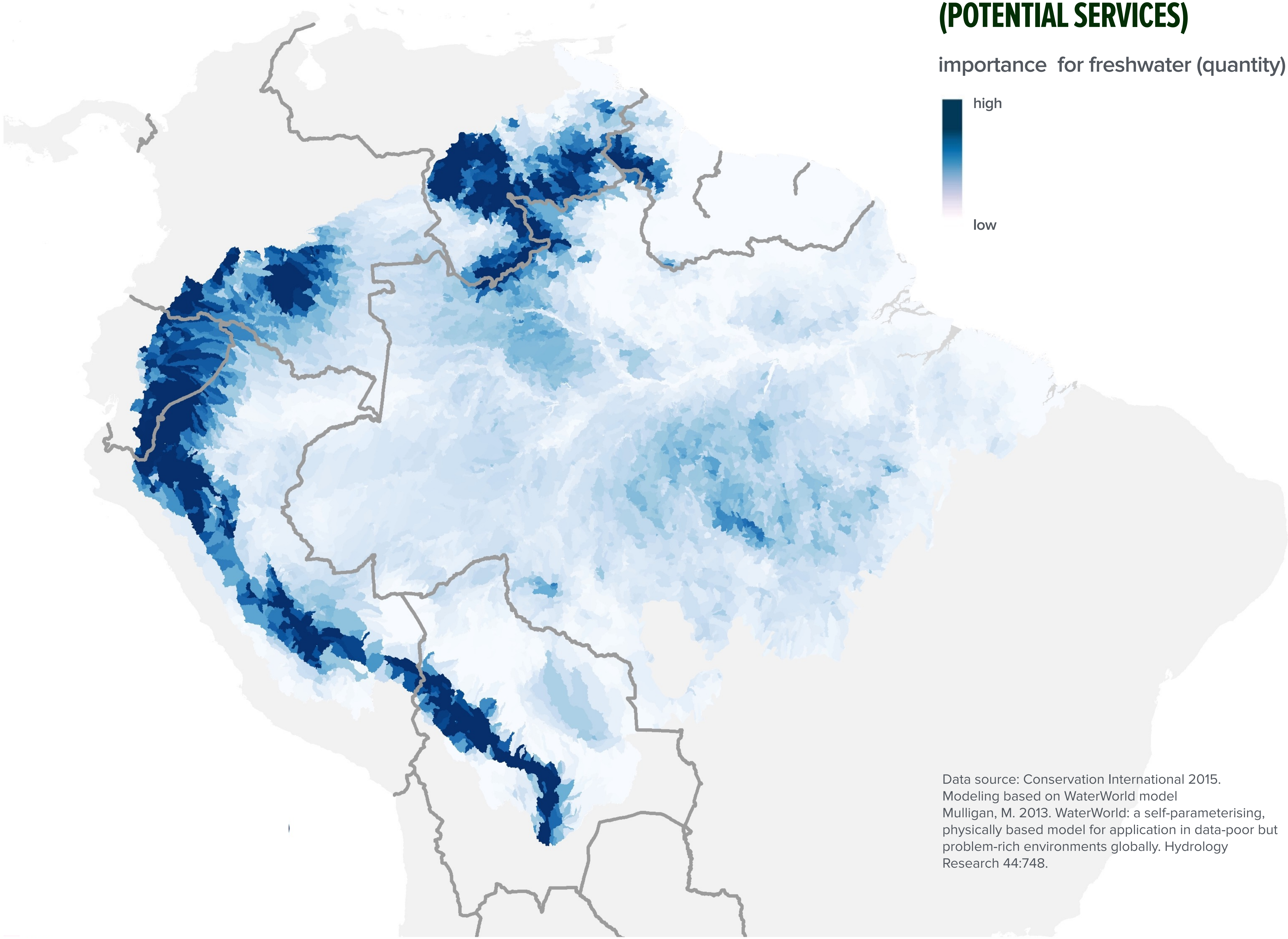
To map essential natural capital for fresh water, we used an eco-hydrological model, WaterWorld, to identify places important for providing fresh water for two key beneficiaries in Amazonia: population centers and hydropower facilities. The WaterWorld model relies on biophysical variables such as temperature, precipitation, land cover, solar radiation, and topography, as well as land cover data, to map ecosystems that are particularly important for providing "potential" fresh water services (those that are not necessarily used by people). We found that the ecosystems providing the highest inputs for water quantity are located across the Andean mountain chain and the Orinoquian Basin, with areas of medium importance distributed throughout the central Amazon basin. Important areas for flow regulation are located at the northern/central Amazon basin and Guiana Shield. The areas of highest importance for water quality are located in the mountainous Andean region and the high elevation areas in the northeast around Venezuela, mainly due to steep slopes with high sensitivity to vegetation loss.

We then weighted these important supply areas by the amount of service demanded by downstream water users (population centers and hydropower dams) to identify areas important for "realized" fresh water services (those actually being used by beneficiaries). We did this by estimating water use per person or per unit of hydroelectricity produced. The resulting maps were combined in overall maps of potential and realized freshwater services. The areas of the highest importance are located in the northwest, southwest and east of the Amazonia region due the presence of beneficiaries in those areas. It is important to highlight that even though the Guiana Shield has high potential freshwater ecosystem service values, there are not many people using the available water therefore its relative importance is downgraded in the final map.

The extent of essential natural capital for freshwater that is currently within protected areas ranges between 20-25% depending on the threshold used to define "essential" areas. Similarly, 26-30% of "essential" natural capital for fresh water is contained within indigenous lands. This means that many areas important for fresh water are currently not protected; these areas could be targeted for payments for ecosystem services (PES) or restoration to ensure the ongoing provision of this vital resource.

IMPORTANCE FOR FRESHWATER QUANTITY (POTENTIAL SERVICES)

importance for freshwater (quantity)

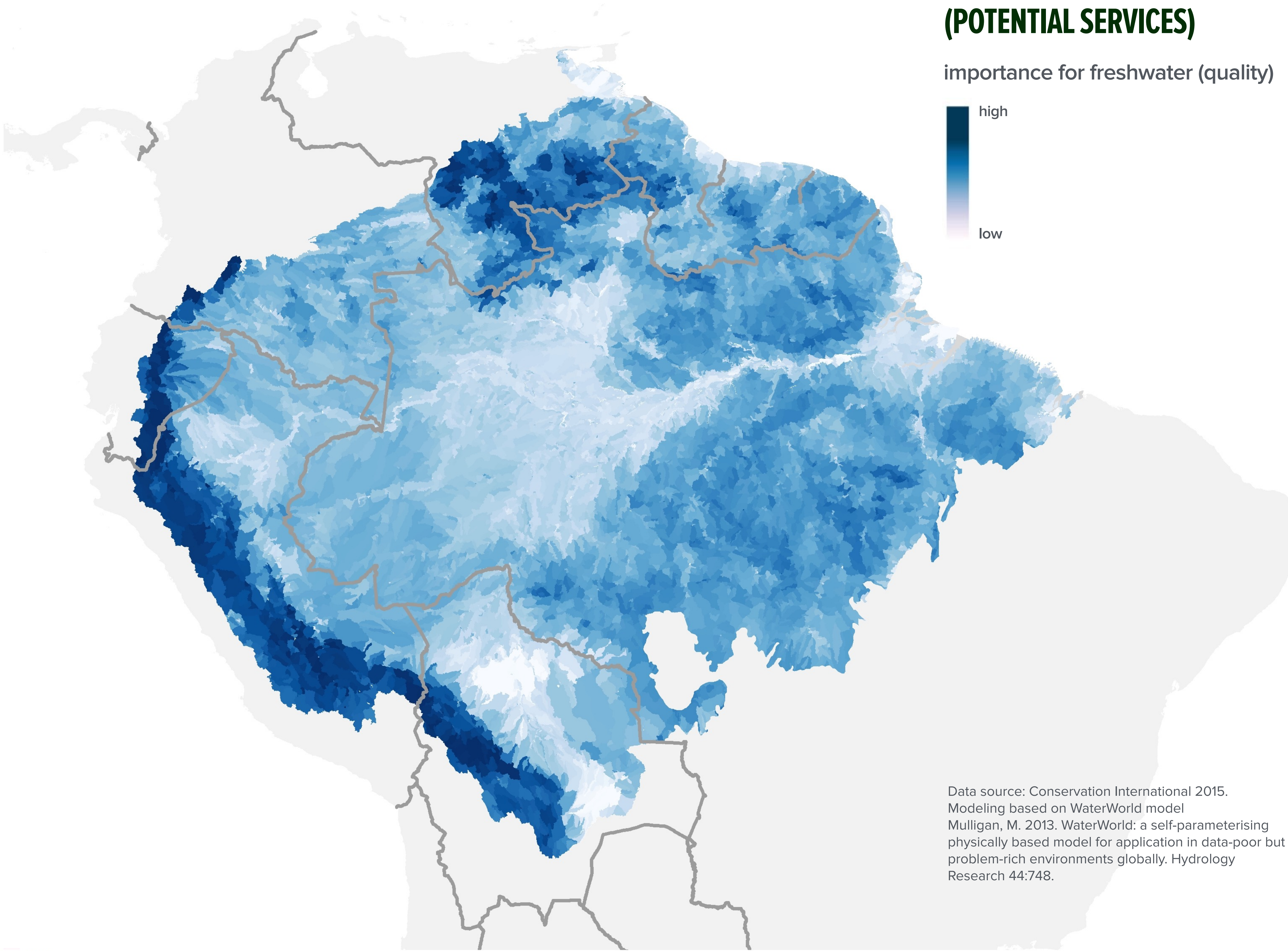


high

low

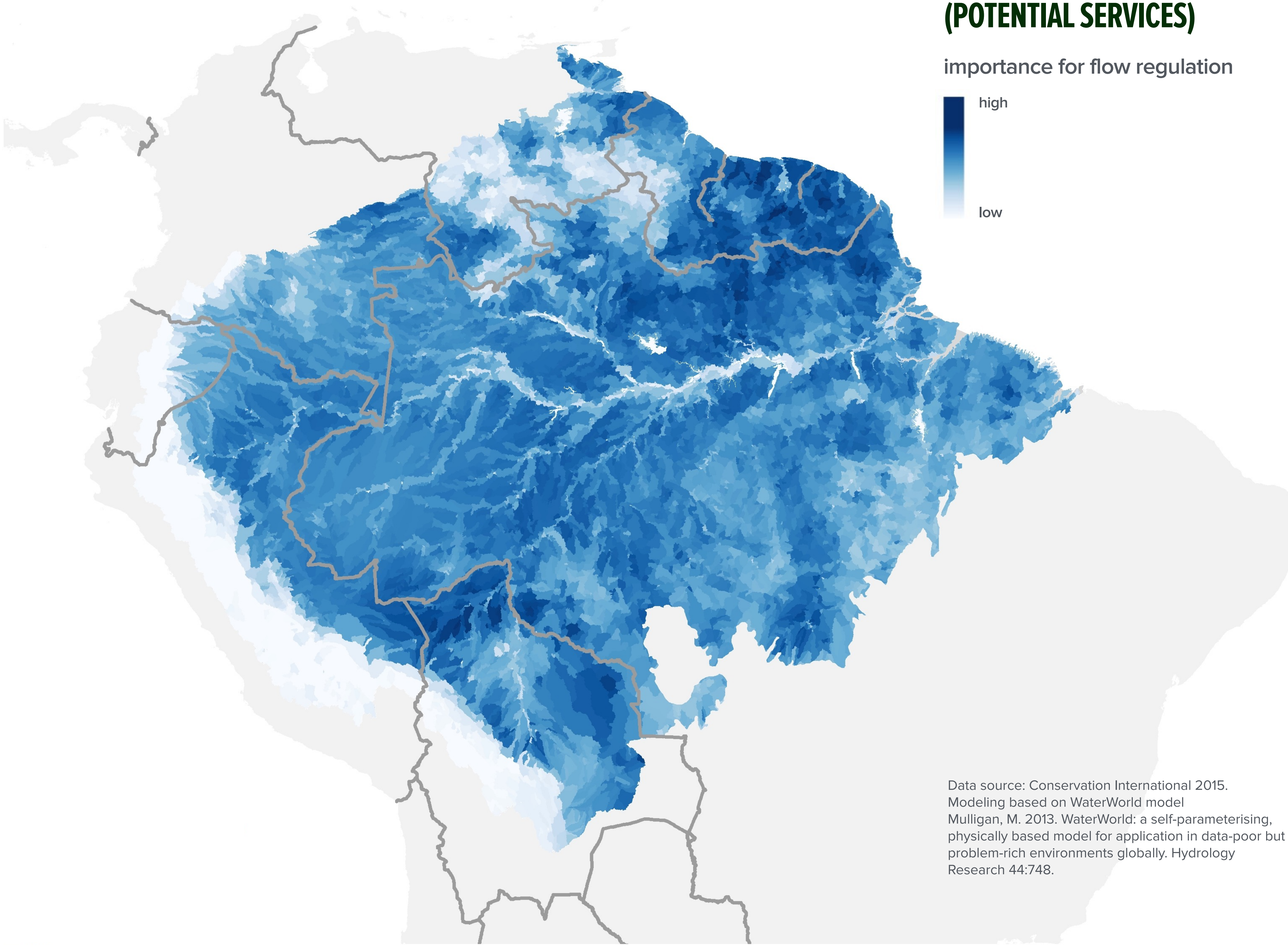
Data source: Conservation International 2015.
Modeling based on WaterWorld model
Mulligan, M. 2013. WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.

IMPORTANCE FOR FRESHWATER QUALITY (POTENTIAL SERVICES)



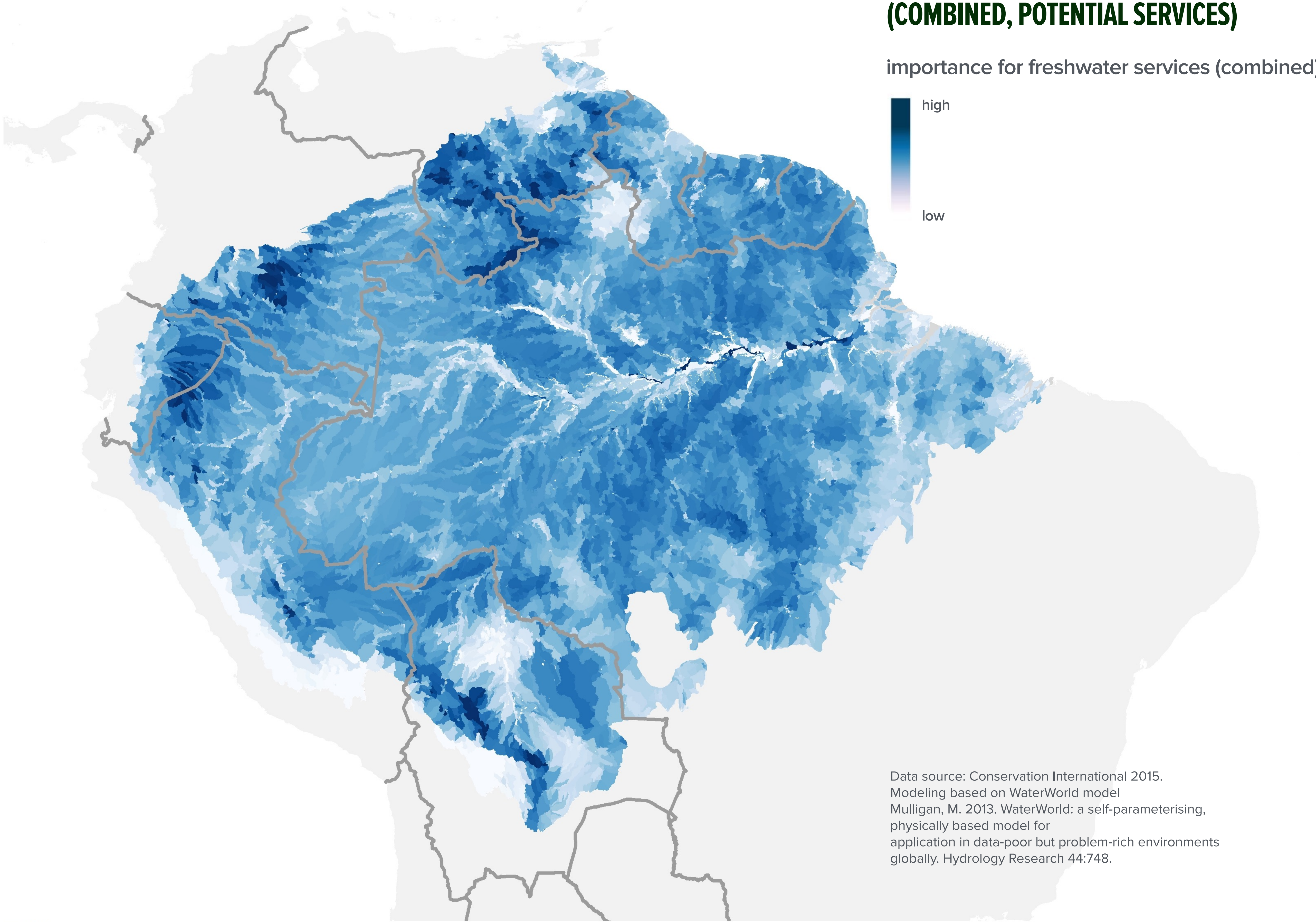
Data source: Conservation International 2015. Modeling based on WaterWorld model Mulligan, M. 2013. WaterWorld: a self-parameterising physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.

IMPORTANCE FOR FRESHWATER FLOW REGULATION (POTENTIAL SERVICES)



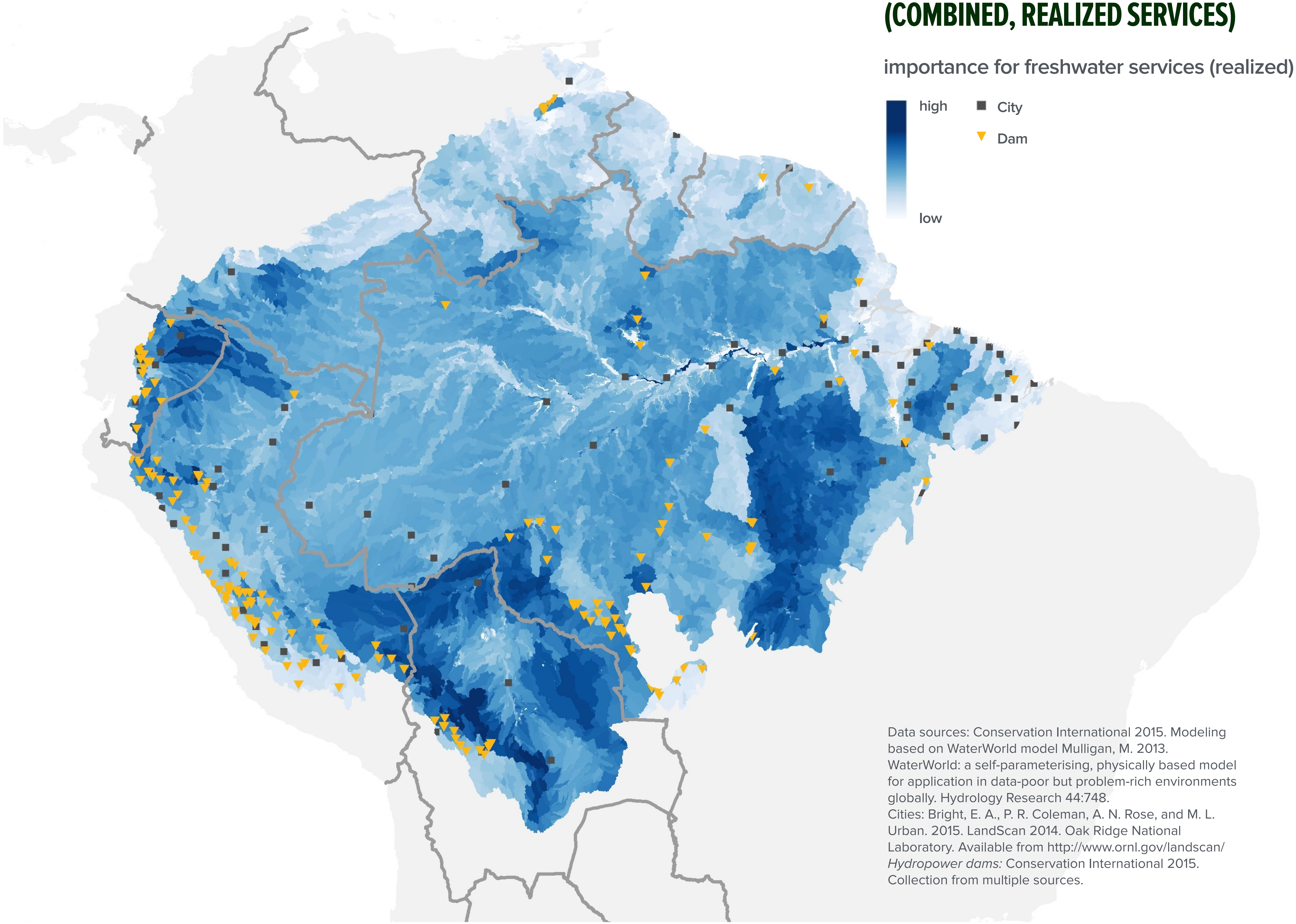
Data source: Conservation International 2015.
Modeling based on WaterWorld model
Mulligan, M. 2013. WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.

IMPORTANCE FOR FRESHWATER ECOSYSTEM SERVICES (COMBINED, POTENTIAL SERVICES)

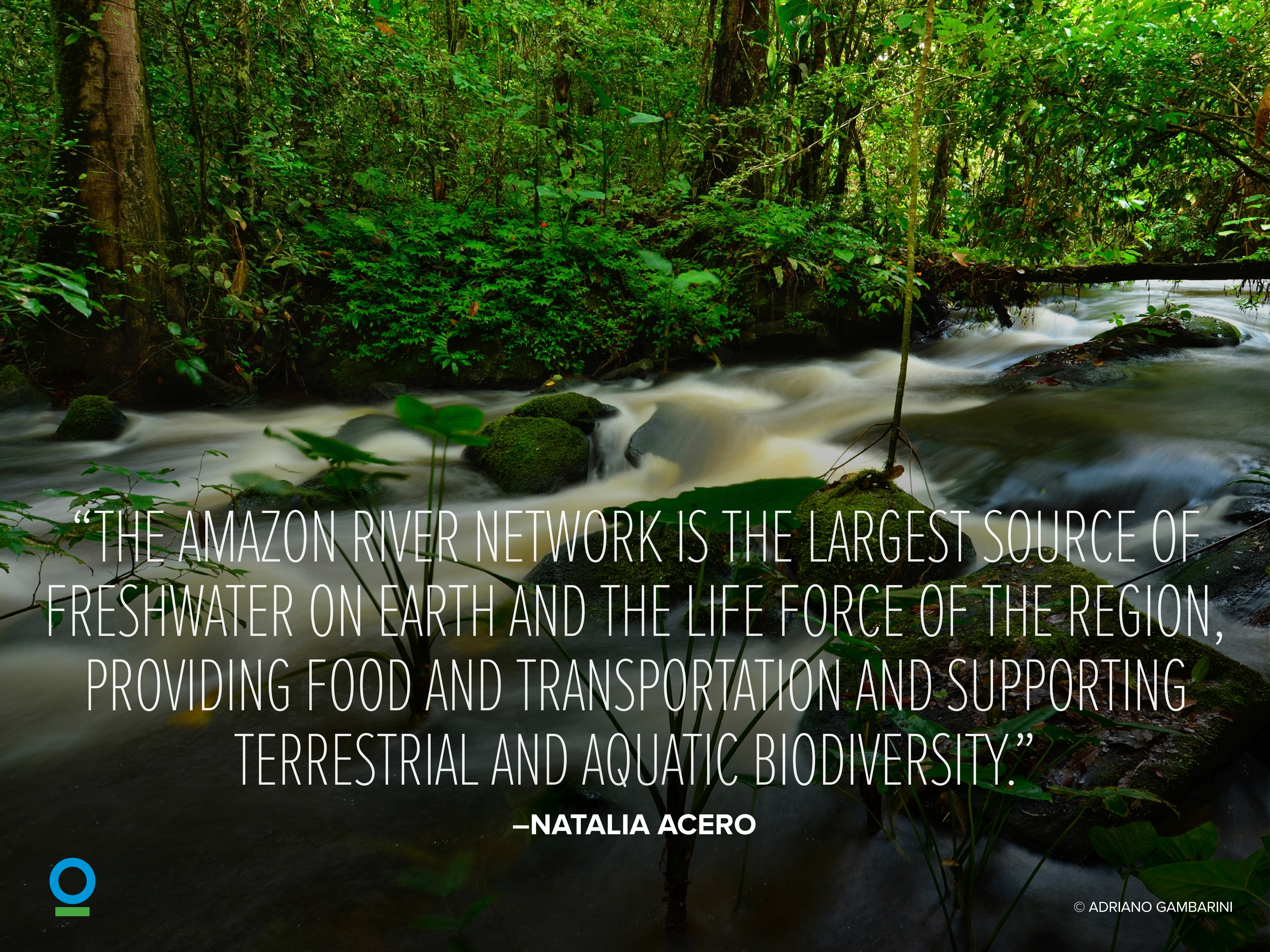


Data source: Conservation International 2015.
Modeling based on WaterWorld model
Mulligan, M. 2013. WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.

IMPORTANCE FOR FRESHWATER ECOSYSTEM SERVICES (COMBINED, REALIZED SERVICES)



Data sources: Conservation International 2015. Modeling based on WaterWorld model Mulligan, M. 2013. WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.
Cities: Bright, E. A., P. R. Coleman, A. N. Rose, and M. L. Urban. 2015. LandScan 2014. Oak Ridge National Laboratory. Available from http://www.ornl.gov/landscan/
Hydropower dams: Conservation International 2015. Collection from multiple sources.


"THE AMAZON RIVER NETWORK IS THE LARGEST SOURCE OF FRESHWATER ON EARTH AND THE LIFE FORCE OF THE REGION, PROVIDING FOOD AND TRANSPORTATION AND SUPPORTING TERRESTRIAL AND AQUATIC BIODIVERSITY."
–NATALIA ACERO
© ADRIANO GAMBARINI

NON-TIMBER FOREST PRODUCTS

MAPPING ESSENTIAL NATURAL CAPITAL FOR NON-TIMBER FOREST PRODUCTS

Ultimately, all our food comes from nature. Natural capital is important for providing numerous benefits that support food security, including game animals, fish, fruit, nuts, seeds, edible and medicinal plants, fuel wood used for cooking, and many others. Natural capital also provides soil and water quality, climate regulation, and pest control, which allows us to grow crops and livestock. In Amazonia, examples of essential natural capital for food security include forests, savannas, or other natural habitats that provide edible plants, fruits, nuts, habitat for hunted species, or other wild sources of food; rivers and wetlands that provide fish and other food sources; and ecosystems that provide soil and water quality, climate regulation, pest control, pollination, or other ecosystem services that support agricultural and livestock production.

This analysis focuses on *non-timber forest products (*NTFPs), which include fruits and nuts, vegetables, fish and game, medicinal plants, resins, essences and a range of barks and fibers such as bamboo, rattans, and a host of other palms and grasses. We used two approaches to map important areas for non-timber forest products: an approach based on land use categories and a modelling-based approach. For the first approach, we collected data on land use categories where people are allowed to collect NTFPs, including indigenous lands, extractive reserves, certain categories of protected areas, community forest lands, or others. These areas were combined in a single map.

The modelling approach was based on the work of researchers from Ecosystem Services for Poverty Alleviation (ESPA) (Porro et al. 2008). It combines two primary inputs: 1) species occurrence data for species of known importance for NTFPs, and 2) accessibility to people. For the first input, point occurrences of 112 wild species important for food in Amazonia including plant species (such as fruits, nuts, and palms) and animal species (such as mammals hunted for game). The species occurrence map was created using spatial data on ecosystems (forests, woodlands, mangroves, grasslands, wetlands, and other habitat types) in South America. The accessibility map was created using spatial data on roads, rivers, train tracks, land cover, urban areas, international borders, elevation, and slope as all of these features influence travel time, an aspect of accessibility. These two inputs (species occurrence and accessibility) were multiplied by each other to create a final map of places that have a) a relatively large number of species of known importance for NTFPs and are b) more accessible to people. Generally, the model indicates that places closer to human populations (around the edges of Amazonia, particularly in the southeast and along the Andes) are likely more important for NTFPs. Areas along the Guiana Shield coastline, where there are more people, and along rivers and roads are also likely important for NTFPs. While the two approaches (land use and modelling) result in different maps, both potentially indicate areas that are important to consider for sustainable management of non-timber forest products. Within indigenous lands, protected areas, and extractive reserves, management should be strengthened to ensure the continued supply of NTFPs and avoid over-harvesting of sensitive species, such as mammals. In areas that are not currently in some kind of formal land use designation, other forms of management may be appropriate, such as community-based conservation and monitoring by local people.

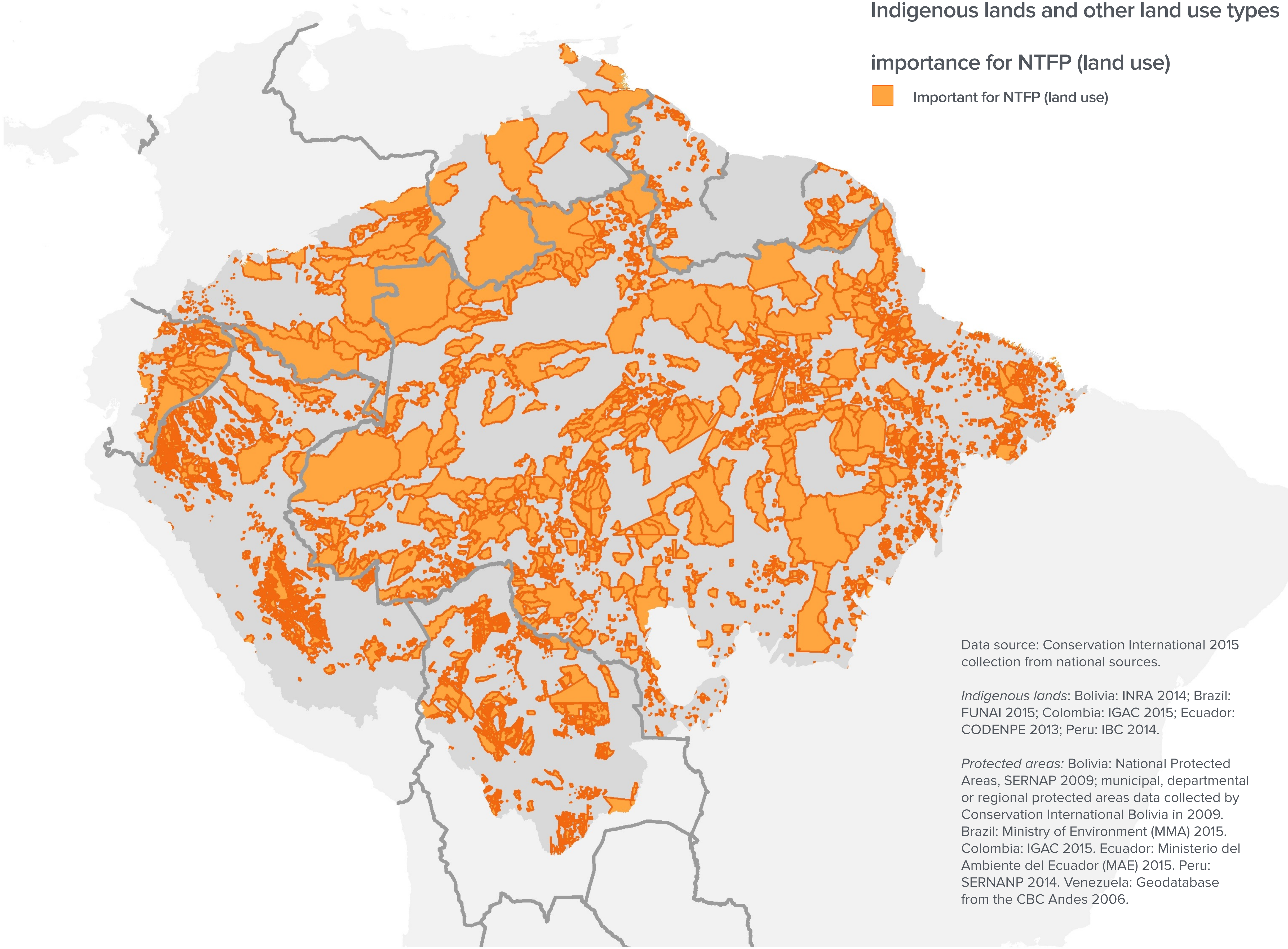
Porro, R., J. Borner, and A. Jarvis. 2008. Challenges to Managing Ecosystems Sustainably for Poverty Alleviation: Securing Well-Being in the Andes/Amazon. Situation Analysis prepared for the ESPA Program. Amazon Initiative Consortium,. ESPA-AA, Belém, Brazil.

IMPORTANT AREAS FOR NON-TIMBER FOREST PRODUCTS (1)

Indigenous lands and other land use types

importance for NTFP (land use)

Important for NTFP (land use)



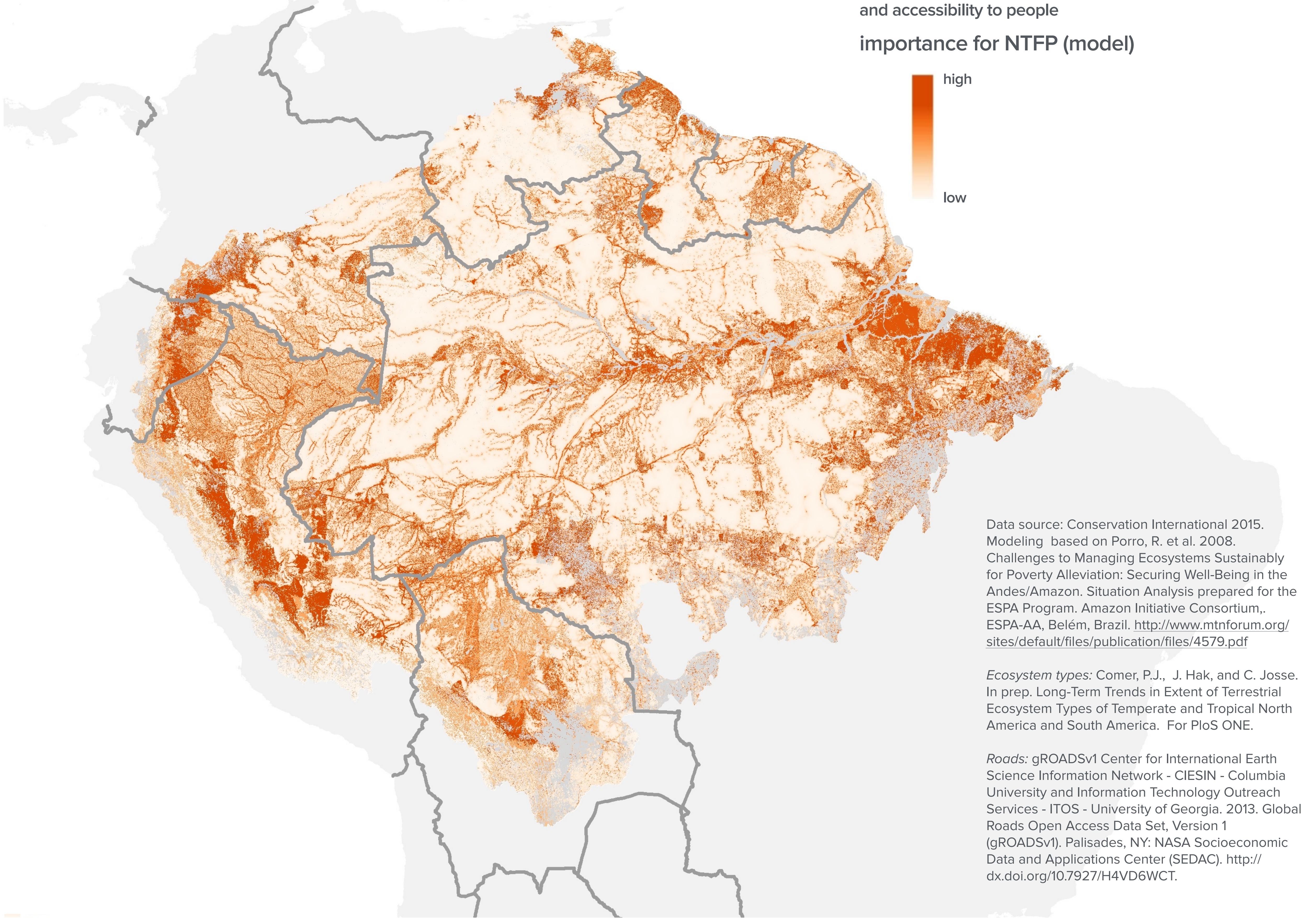
Data source: Conservation International 2015 collection from national sources.

Indigenous lands: Bolivia: INRA 2014; Brazil: FUNAI 2015; Colombia: IGAC 2015; Ecuador: CODENPE 2013; Peru: IBC 2014.

Protected areas: Bolivia: National Protected Areas, SERNAP 2009; municipal, departmental or regional protected areas data collected by Conservation International Bolivia in 2009. Brazil: Ministry of Environment (MMA) 2015. Colombia: IGAC 2015. Ecuador: Ministerio del Ambiente del Ecuador (MAE) 2015. Peru: SERNANP 2014. Venezuela: Geodatabase from the CBC Andes 2006.

IMPORTANT AREAS FOR NON-TIMBER FOREST PRODUCTS (2)

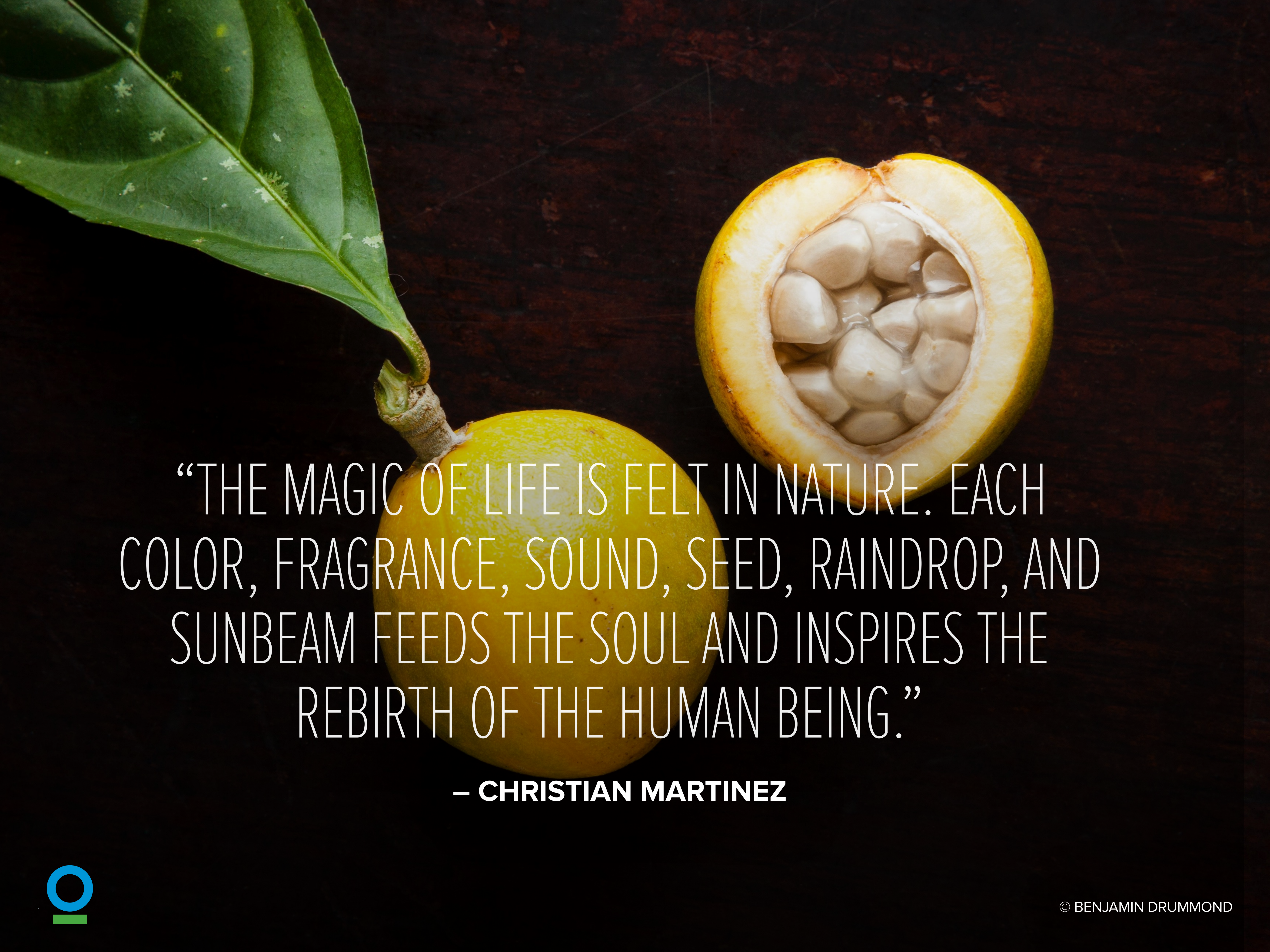
Model combining species occurrence and accessibility to people



Data source: Conservation International 2015. Modeling based on Porro, R. et al. 2008. Challenges to Managing Ecosystems Sustainably for Poverty Alleviation: Securing Well-Being in the Andes/Amazon. Situation Analysis prepared for the ESPA Program. Amazon Initiative Consortium,. ESPA-AA, Belém, Brazil. http://www.mtnforum.org/sites/default/files/publication/files/4579.pdf

Ecosystem types: Comer, P.J., J. Hak, and C. Josse. In prep. Long-Term Trends in Extent of Terrestrial Ecosystem Types of Temperate and Tropical North America and South America. For PloS ONE.

Roads: gROADSv1 Center for International Earth Science Information Network - CIESIN - Columbia University and Information Technology Outreach Services - ITOS - University of Georgia. 2013. Global Roads Open Access Data Set, Version 1 (gROADSv1). Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H4VD6WCT.


"THE MAGIC OF LIFE IS FELT IN NATURE. EACH COLOR, FRAGRANCE, SOUND, SEED, RAINDROP, AND SUNBEAM FEEDS THE SOUL AND INSPIRES THE REBIRTH OF THE HUMAN BEING."
– CHRISTIAN MARTINEZ
© BENJAMIN DRUMMOND


HUMAN VULNERABILITY
TO CLIMATE CHANGE
©CRISTINA MITTERMEIER

MAPPING HUMAN VULNERABILITY TO CLIMATE CHANGE

Climate models suggest that the eastern Amazonia may become drier by the end of the century, while western Amazonia is likely to experience increased precipitation and humidity. Extreme events including droughts, fires and floods have become frequent in the region, possibly caused by anthropogenic climate change. Other impacts of a changing climate include landslides in Peru and sea level rise which threatens coastal communities in Guyana and Suriname, as well as indirect impacts on food security throughout the region. Deforestation exacerbates drying trends, resulting in fire risks that are even higher and precipitation and humidity lower. While climate change has major impacts on species and ecosystems, our focus for this analysis is on climate change impacts on humans, and the role of ecosystems in reducing those impacts. The Amazonian region has a population of more than 33 million habitants, around 45% of which are considered to live in poverty, and are therefore the most vulnerable to these impacts. Ecosystems can reduce human vulnerability to climate change, by regulating local and regional climate, ensuring stable flows of fresh water for drinking and irrigation, and reducing impacts from severe droughts and floods.

Key steps involved in mapping vulnerability to climate change, and the role of ecosystems in helping people adapt, include identifying 1) the key climate-related threats people face within a given geography **(exposure)** ; 2) where (spatially) people are most sensitive to those threats **(sensitivity)**; 3) the resources those people have to ameliorate those threats **(adaptive capacity)**; and 4) the role that ecosystems can play in reducing the identified **vulnerability**(ies), defined as the combination of exposure, sensitivity and adaptive capacity.

This analysis focused on a single threat from climate change: impacts on water availability, which will result in changes in floods and droughts. **Figure 1.** Illustrates how selected indicators of exposure, sensitivity and adaptive capacity are believed to interact to influence human vulnerability to climate change impacts in Amazonia.

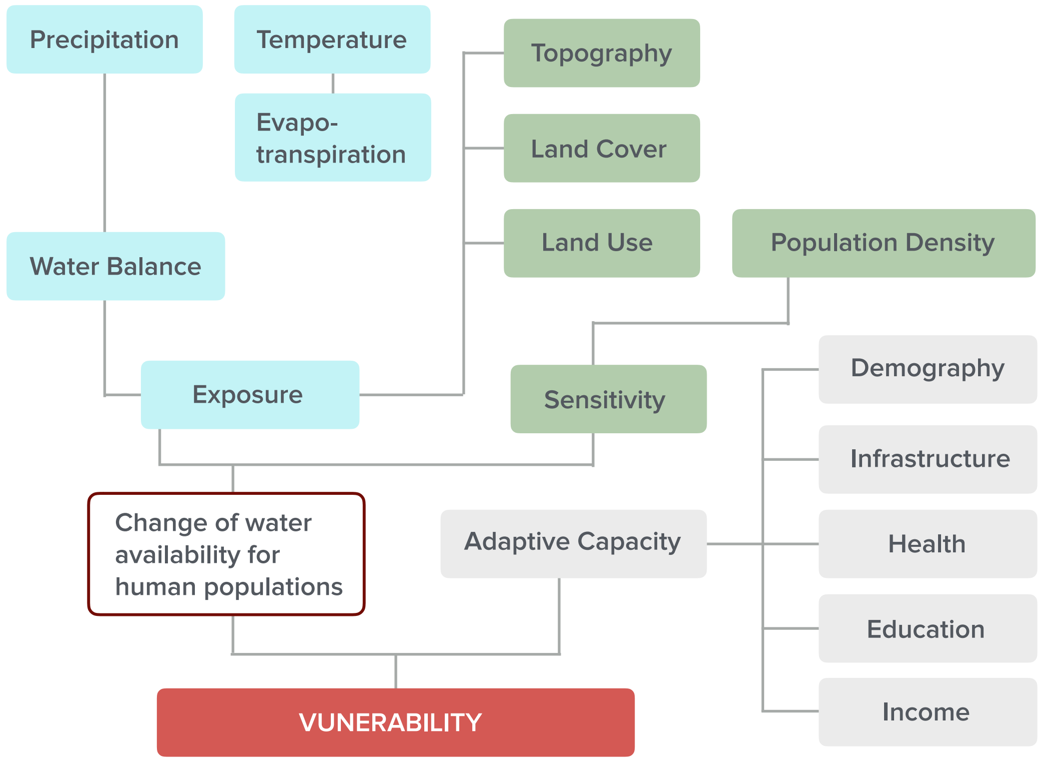


Figure 1. Conceptual diagram of the selected indicators believed to influence vulnerability of people to changes in water availability due to climate change. Exposure indicators are in blue, sensitivity indicators are in green, and adaptive capacity indicators are in gray.

For this analysis, **exposure** was defined as predicted changes in water balance due to climate change, based on the WaterWorld model. Areas predicted to have more change (i.e. wetter or drier) due to climate change were considered to have higher exposure. Results from this analysis indicate higher exposure in the northeastern and southern parts of the region due to a reduction of precipitation and increases in temperature.

Sensitivity was defined as a combination of topography, land cover, and soil type (already included in the WaterWorld model), and population density, which was mapped separately. The population map shows highest population density along the Andes, in Amazonia in Brazil, and along the coast of the Guiana shield.

Adaptive capacity was based on socioeconomic indicators believed to represent the capacity of people to cope with climate change. Selected indicators are summarized in Table 1. Each indicator was rescaled so that all values ranged from 0-1, where higher values indicate higher adaptive capacity. An index of adaptive capacity was calculated by taking the mean of all indicators (i.e. all indicators were given equal weight). The results were mapped (the spatial units of analysis for this map are administrative units, such as municipalities.) Overall, there is a trend of lower adaptive capacity in western Amazonia, which may be related to the difficulties of providing education, health and other basic societal needs in remote areas.

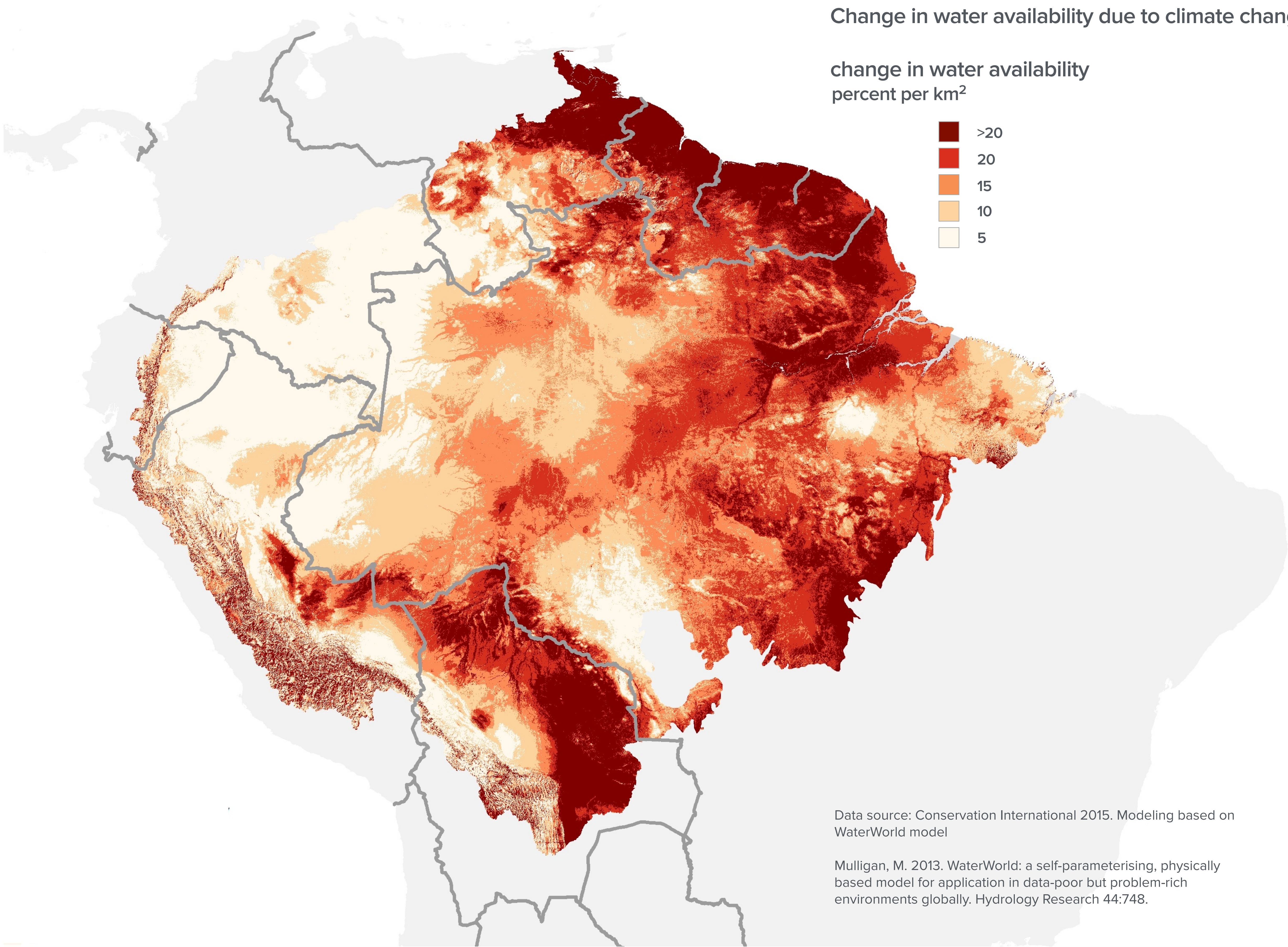
A map of **vulnerability** was created by combining the maps of exposure, sensitivity, and adaptive capacity. All maps were rescaled from 0-100, where 100 indicates higher vulnerability (i.e. higher exposure, higher sensitivity, or lower adaptive capacity), and then the maps were multiplied together. An average vulnerability score per administrative unit was then calculated and mapped. This map shows the more vulnerable areas in the Andean region, as these areas are highly prone to an increase in water flow, and in the northeast of Brazil, which is influenced by higher population densities, reduced water flows, and relatively low adaptive capacity of its municipalities. It is important to note this map focuses on only a single type of vulnerability (to change in water availability) and should not be considered representative of human vulnerability to other potential impacts from climate change.

Demography
Population under 5 years old- % of the population 5 or younger
Population above 60 years old - % of population 60 or above
Housing infrastructure
Access to piped water - % of houses with access to piped water
Access to sanitation - % of houses with sanitation structure
Health
Child mortality rate (under 5 years) – Rate of deaths of under 5 years old per 1000
Life expectancy – mean lifespan of the population
Education
Illiteracy rate - % of population above 15 years old with inadequate reading and writing skills
Men/women literate – proportion of men/women who are literate
Income
Gini Coefficient – an inequality measure of statistical dispersion intended to represent the income distribution of a nation's residents
Population below the extreme poverty line - % of population living on less than US $1.25 a day.

Table 1. Selected indicators of human adaptive capacity

EXPOSURE

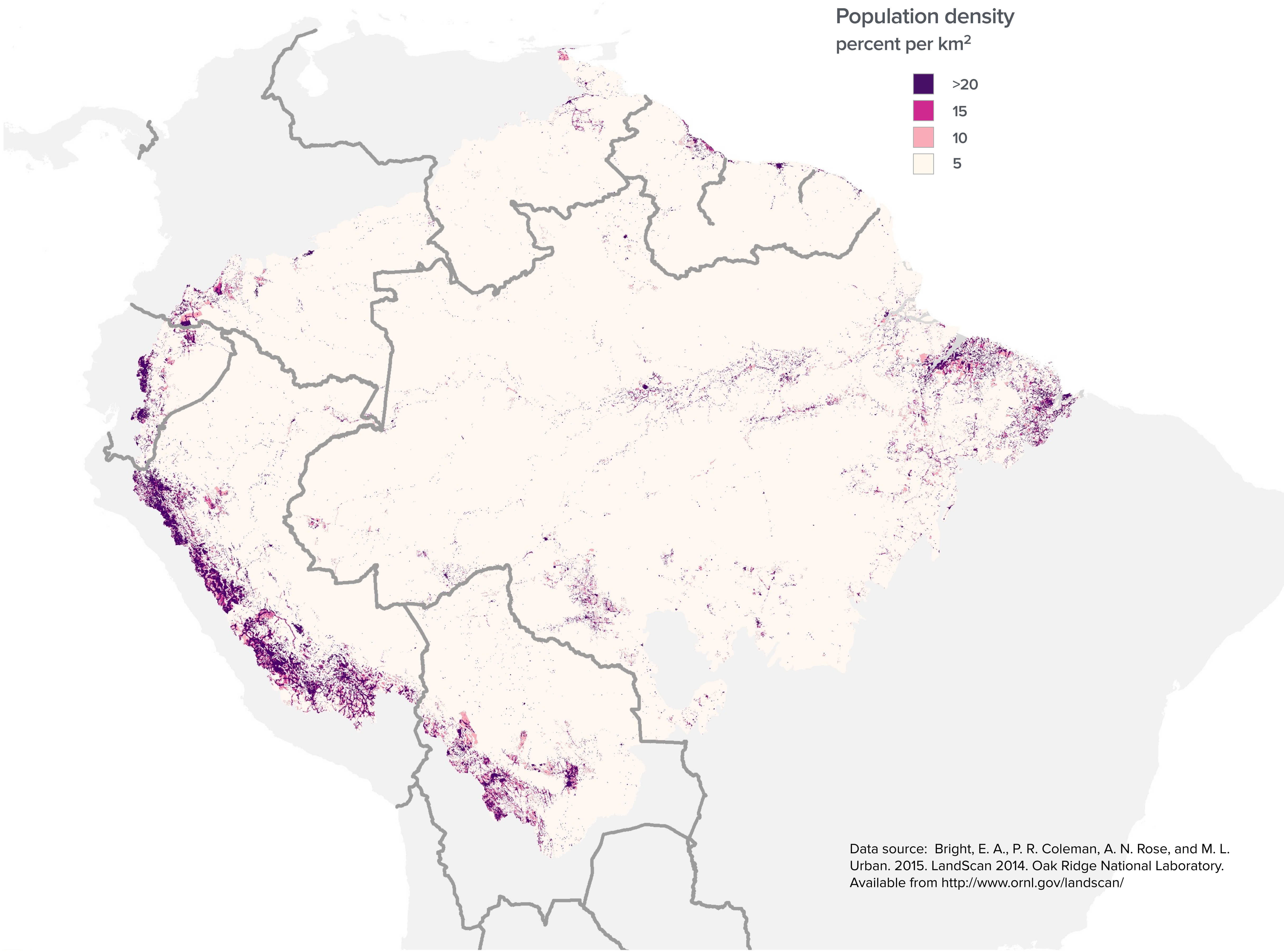
Change in water availability due to climate change



Data source: Conservation International 2015. Modeling based on WaterWorld model

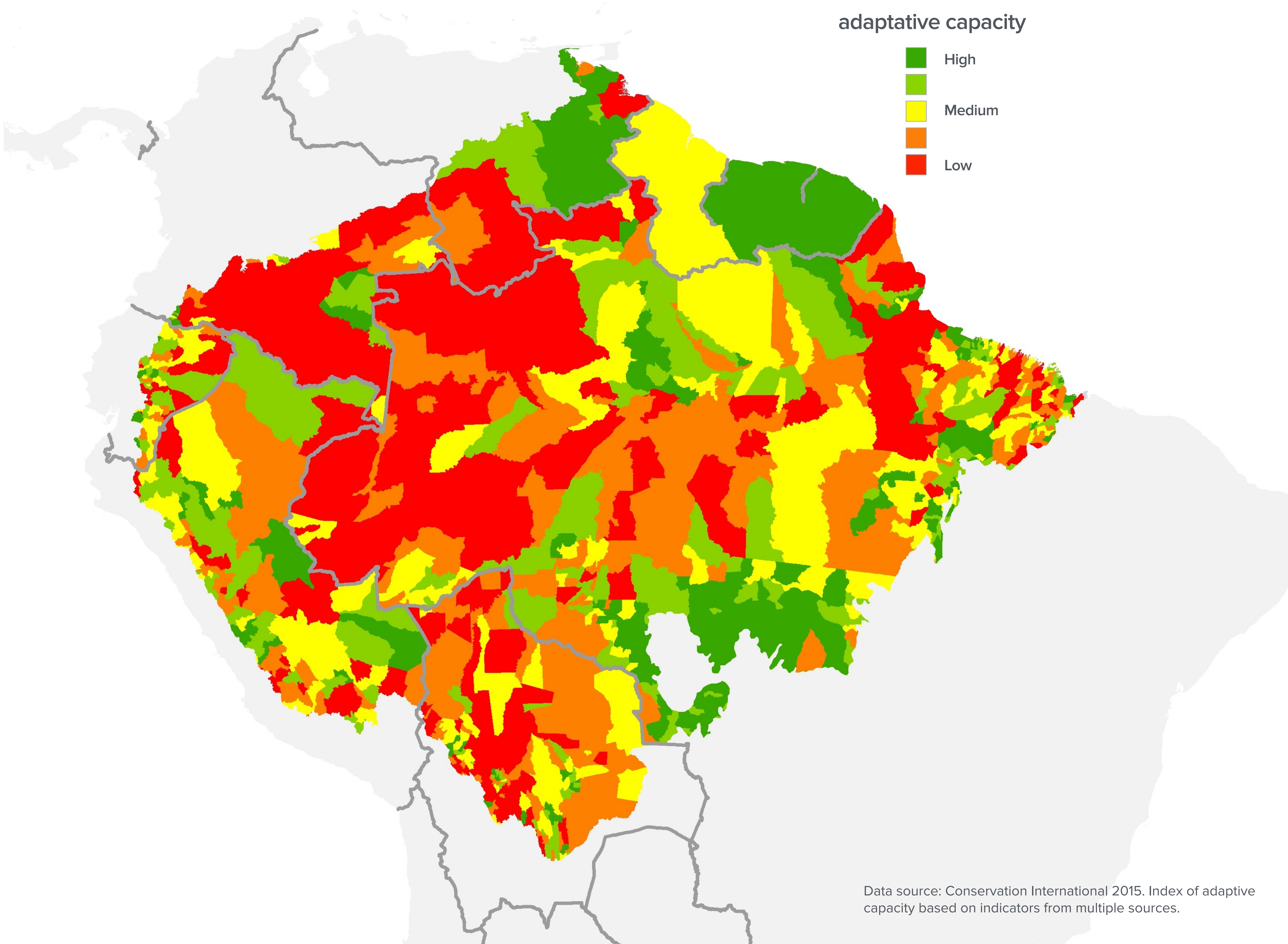
Mulligan, M. 2013. WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.

SENSITIVITY



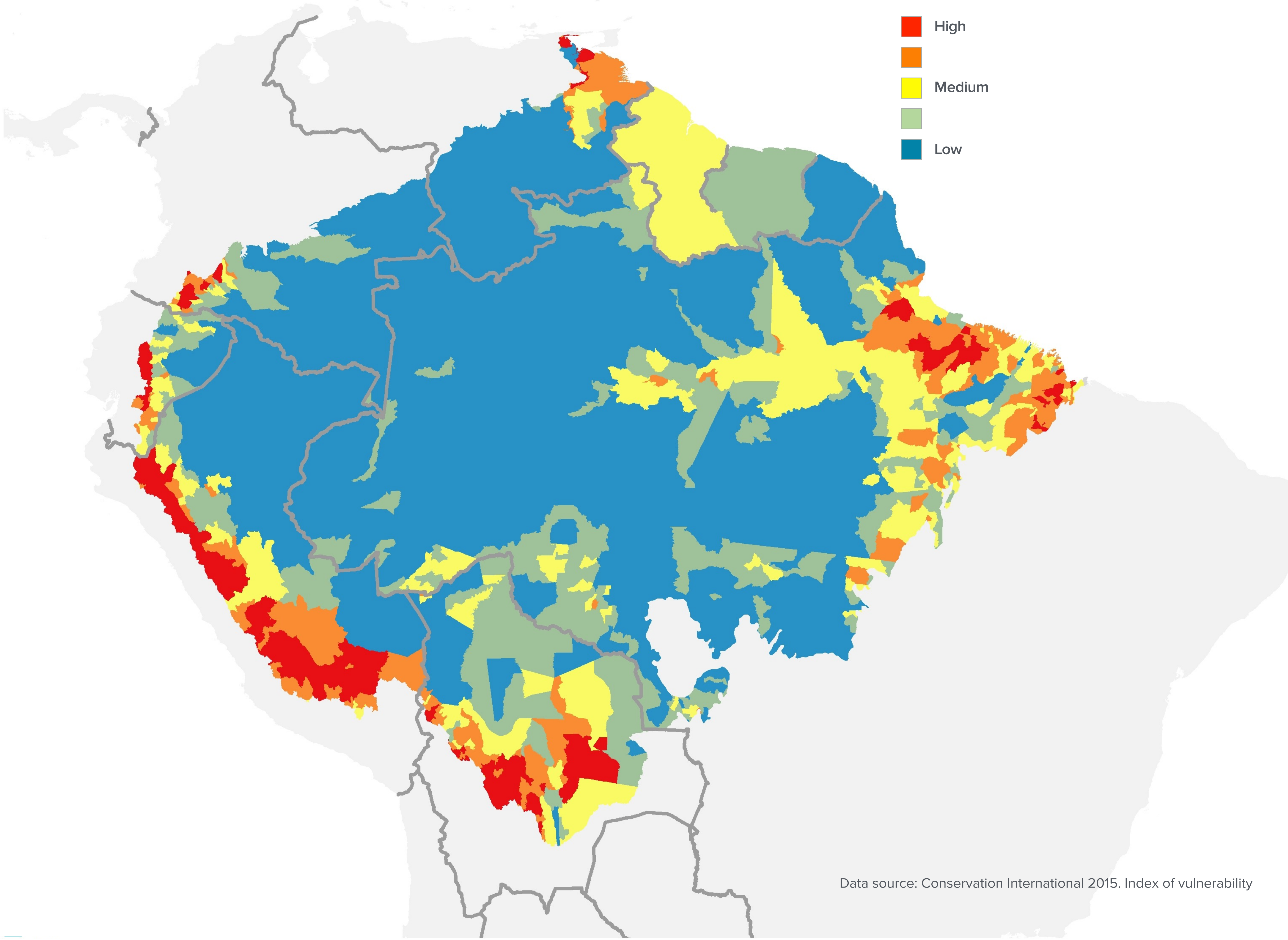
Data source: Bright, E. A., P. R. Coleman, A. N. Rose, and M. L. Urban. 2015. LandScan 2014. Oak Ridge National Laboratory. Available from http://www.ornl.gov/landscan/

HUMAN ADAPTIVE CAPACITY



Data source: Conservation International 2015. Index of adaptive capacity based on indicators from multiple sources.

VULNERABILITY = EXPOSURE X SENSITIVITY x (1 - ADAPTIVE CAPACITY)



Data source: Conservation International 2015. Index of vulnerability


ECOSYSTEMS CAN REDUCE HUMAN VULNERABILITY TO CLIMATE CHANGE, BY REGULATING LOCAL AND REGIONAL CLIMATE, ENSURING STABLE FLOWS OF FRESH WATER FOR DRINKING AND IRRIGATION, AND REDUCING IMPACTS FROM SEVERE DROUGHTS AND FLOODS.
© BENJAMIN DRUMMOND

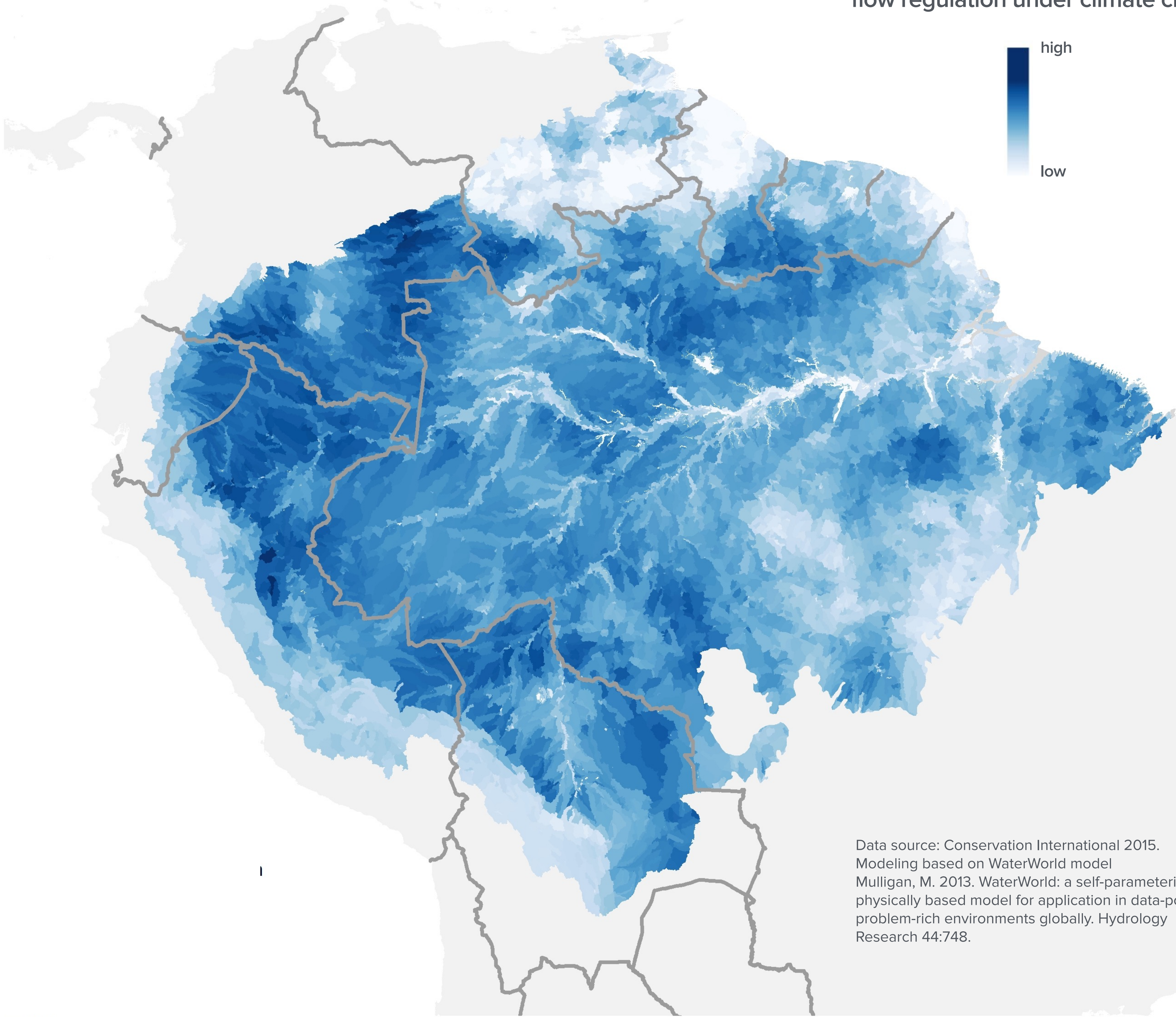
CLIMATE ADAPTATION

MAPPING ESSENTIAL NATURAL CAPITAL FOR CLIMATE ADAPTATION

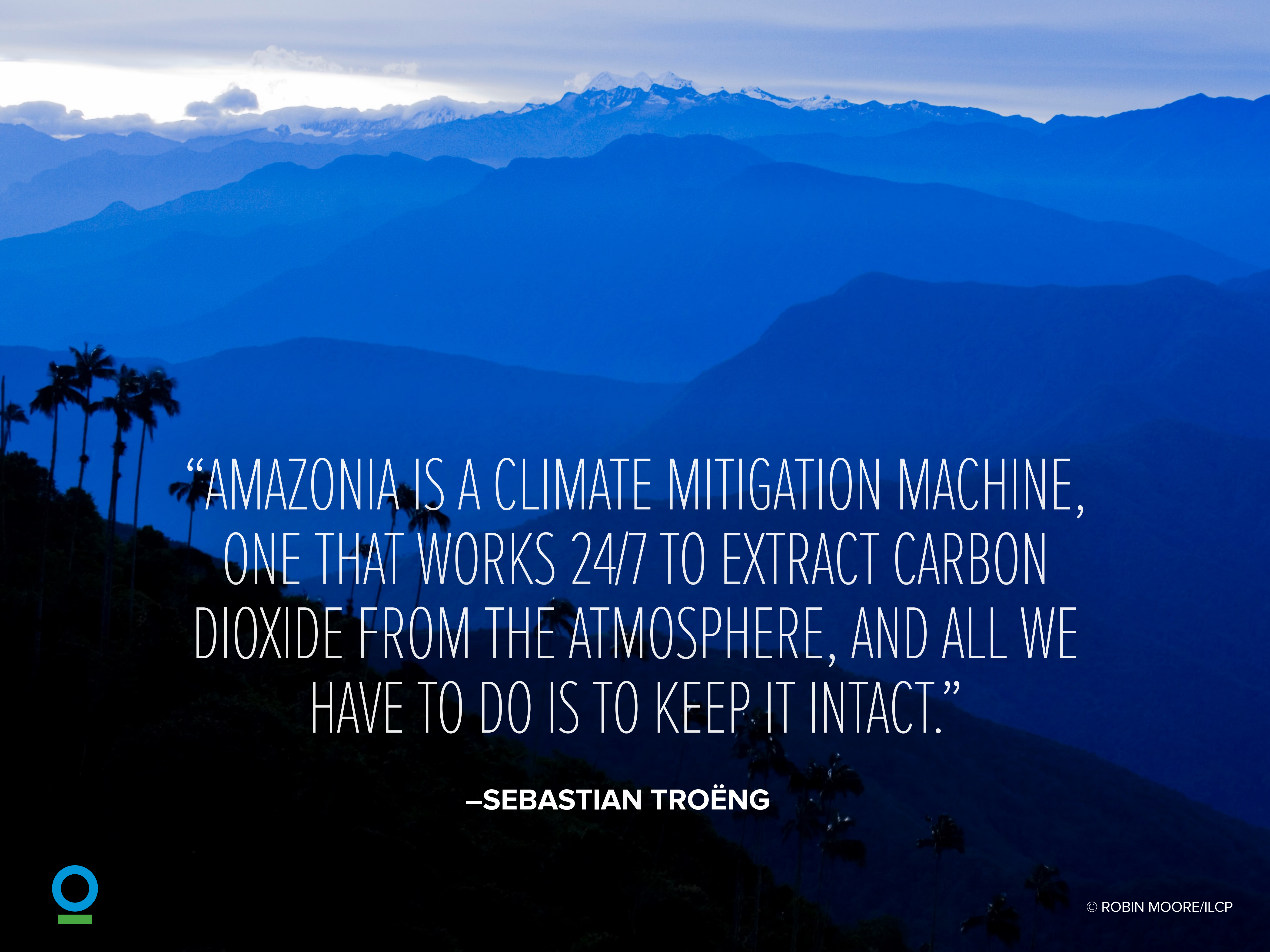
As described above, climate change is projected to increase exposure (defined as change in water balance) across northern and eastern Amazonia. This will likely result in increases in droughts and floods in the region. Natural capital, such as forests and wetlands, can reduce severe flooding by regulating fresh water flows. To map essential natural capital for flow regulation under climate change, we analyzed the role of ecosystems in mitigating changes in water availability, using climate change scenarios in WaterWorld. We did this by comparing flow regulation services provided by current land cover to a hypothetical drastic land use change scenario, in which all forest cover was converted to bare ground. This allowed us to analyze the role of ecosystems (specifically forests) in regulating water flows, under climate change scenarios. We found that areas in the Andean foothills and central Amazonia play an important role in flow regulation under climate change. Ecosystems from the northwest also play an important role in water regulation services under climate change, more so than under baseline conditions. These areas should be managed to maintain their natural forest cover, as they may provide even more critical flood protection services as the climate continues to change. We estimate that around 18% of essential natural capital for flow regulation under climate change is currently within protected areas, and 31% is within indigenous lands, totaling 46% (because there is some overlap between the two land use categories). This indicates that more than half of these critically important forests currently have no formal protection.

NATURAL CAPITAL FOR CLIMATE ADAPTATION:

Important areas for freshwater
flow regulation under climate change



Data source: Conservation International 2015.
Modeling based on WaterWorld model
Mulligan, M. 2013. WaterWorld: a self-parameterising, physically based model for application in data-poor but problem-rich environments globally. Hydrology Research 44:748.


"AMAZONIA IS A CLIMATE MITIGATION MACHINE, ONE THAT WORKS 24/7 TO EXTRACT CARBON DIOXIDE FROM THE ATMOSPHERE, AND ALL WE HAVE TO DO IS TO KEEP IT INTACT."
–SEBASTIAN TROËNG
© ROBIN MOORE/ILCP


INTEGRATING MAPS OF
NATURAL CAPITAL
©PETE OXFORD

INTEGRATING MAPS OF NATURAL CAPITAL

Understanding important areas for biodiversity, climate mitigation, fresh water, non-timber forest products, and climate adaptation is useful in and of itself. Combining maps of natural capital can yield insights into areas that are important for multiple benefits, as well as areas important for different types of natural capital. There are many ways to combine spatial data. For this analysis, we used two methods: an approach that relies on thresholding, and an additive approach.

Threshold-based approach

Targets or thresholds can be used to define the "most important" of important natural capital. Ideally, targets would be based on information about how much nature is actually needed in order to maintain human well-being or achieve effective biodiversity conservation in Amazonia. Unfortunately, this information is not available at the regional scale. It is currently unknown how much forest carbon is needed to maintain the local, regional, and global climate, or how much water is needed to meet demand of people and economic activities. Thus, for this analysis we defined arbitrary thresholds. We took the top 20% and the top 10% of pixels, by value, for each map. (A "pixel" is a unit of analysis, in this case each pixel is 1 square kilometer in size.) In some cases, it was not possible to identify exactly 20% (or 10%) of the pixels in the highest value category, due to many pixels having equal values, so we took all the pixels with the maximum value. We then combined the individual maps to identify a total extent of areas of essential natural capital.

These maps show both similarities and differences in the spatial patterns of different types of natural capital. Collectively, they identify large swaths of the region as important, including most of the Andean foothills and western Amazonian basin, large areas throughout the Guiana Shield, including the border of Venezuela and Guiana and most of French Guiana, and large areas along and south of the Amazon River in Brazil. Collectively, these areas should be the focus of ongoing conservation and sustainable management at the regional-scale.

Additive approach

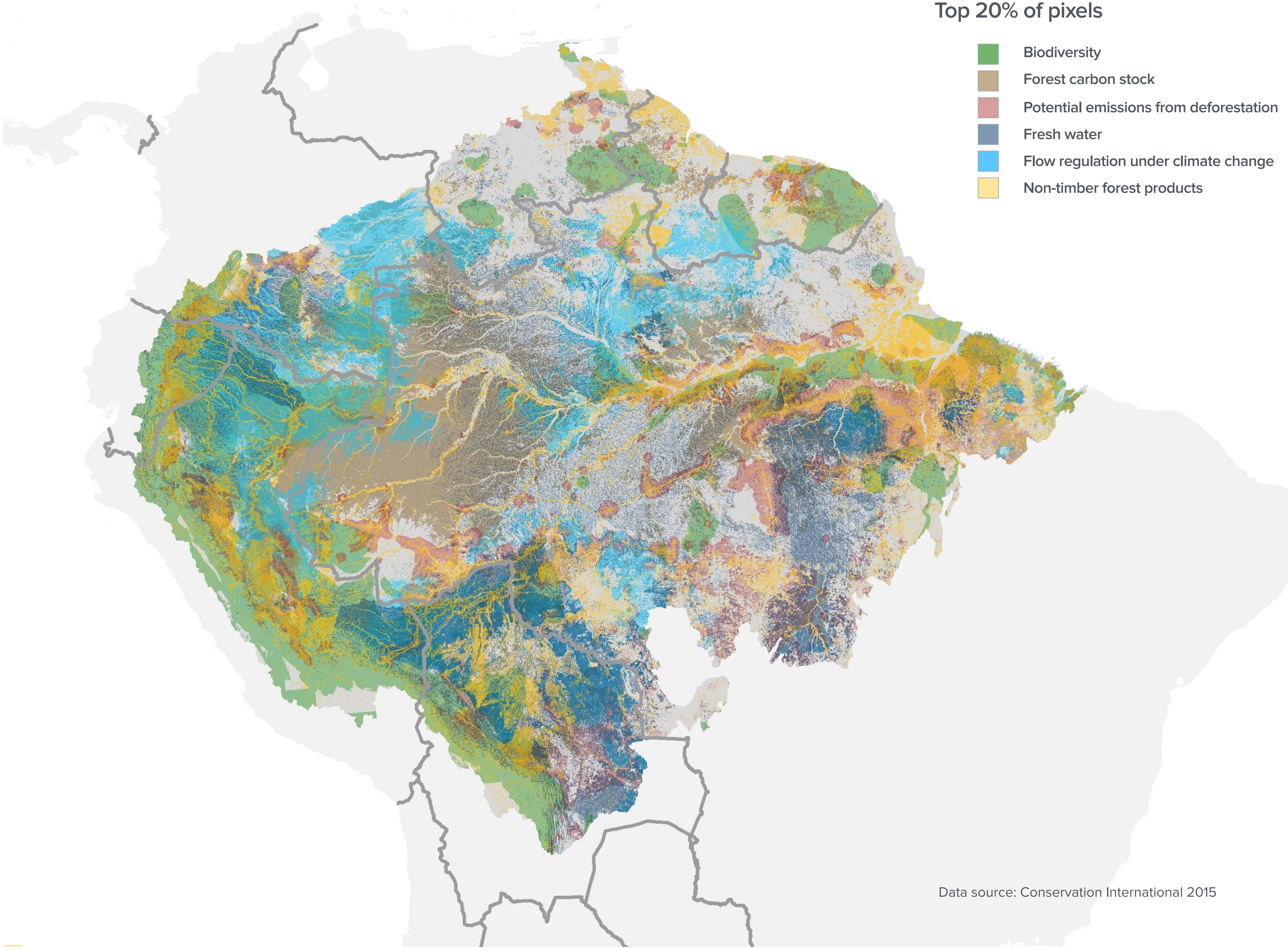
The above approach defines any area as "essential" if it is important for a single type of natural capital. We are also interested in identifying areas important for multiple types of natural capital. Therefore we conducted a second analysis using the continuous-scale (non-thresholded) maps. We scaled all the maps from 0-100 and summed their values, giving all maps equal weight . This results in a map that gives higher importance to areas important for multiple ecosystem services. Either approach could be useful depending on the interests of the users. While there are some local differences between this map and the preceeding maps, which are based on a thresholding approach, many of the overall spatial patterns are similar. Again, large areas of the Andes foothills and western Amazon basin show up as important, more limited areas in the Guiana shield, and large parts of the eastern Amazon basin in Brazil.

It is important to note that, while these maps might be useful for regional-scale prioritization, finer-scale analyses would be necessary for prioritization at the national or sub-national level.

ALL NATURAL CAPITAL

Threshold-based approach:
Top 20% of pixels

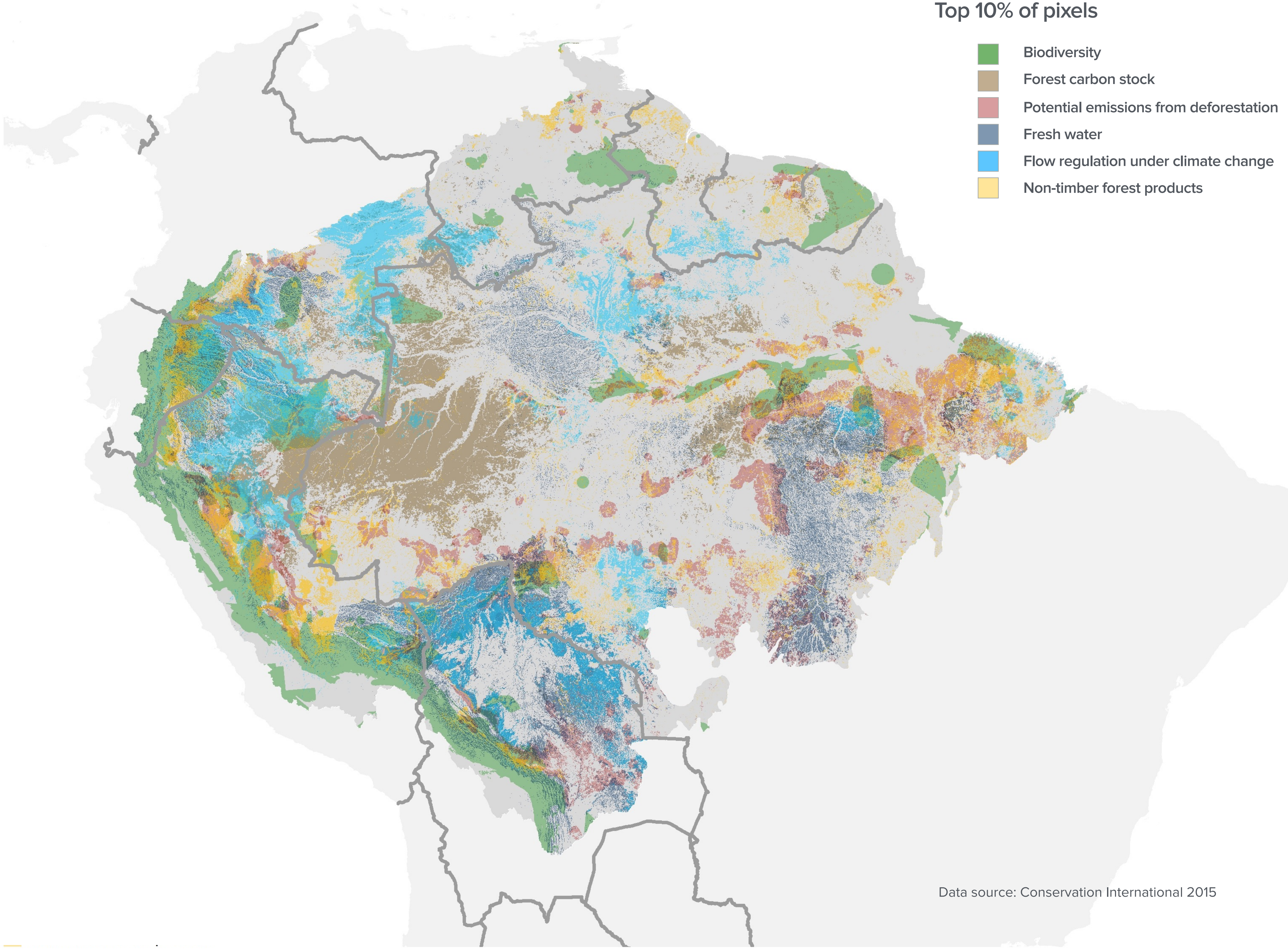
- Biodiversity
- Forest carbon stock
- Potential emissions from deforestation
- Fresh water
- Flow regulation under climate change
- Non-timber forest products



Data source: Conservation International 2015

ALL NATURAL CAPITAL

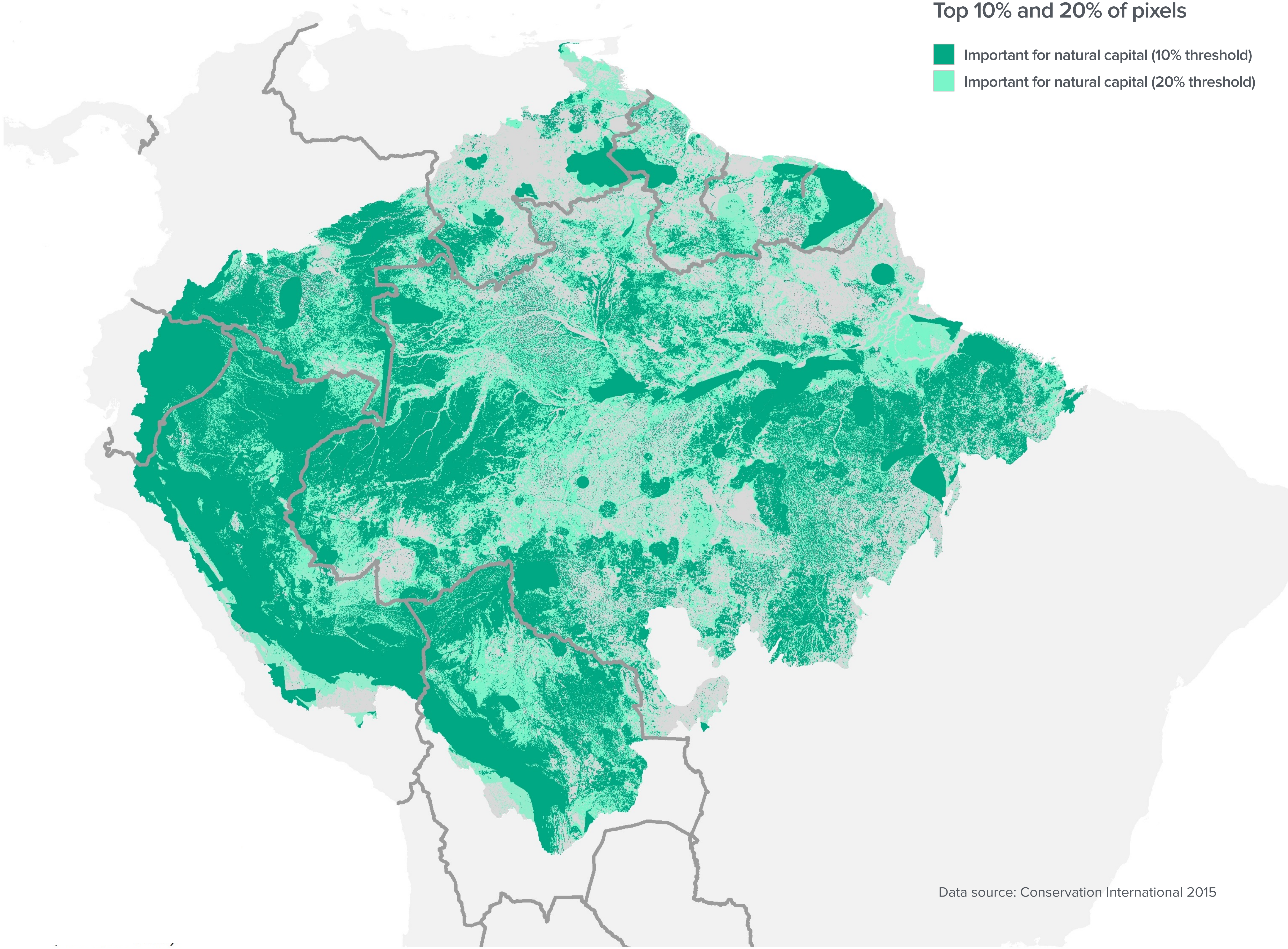
Threshold-based approach: Top 10% of pixels



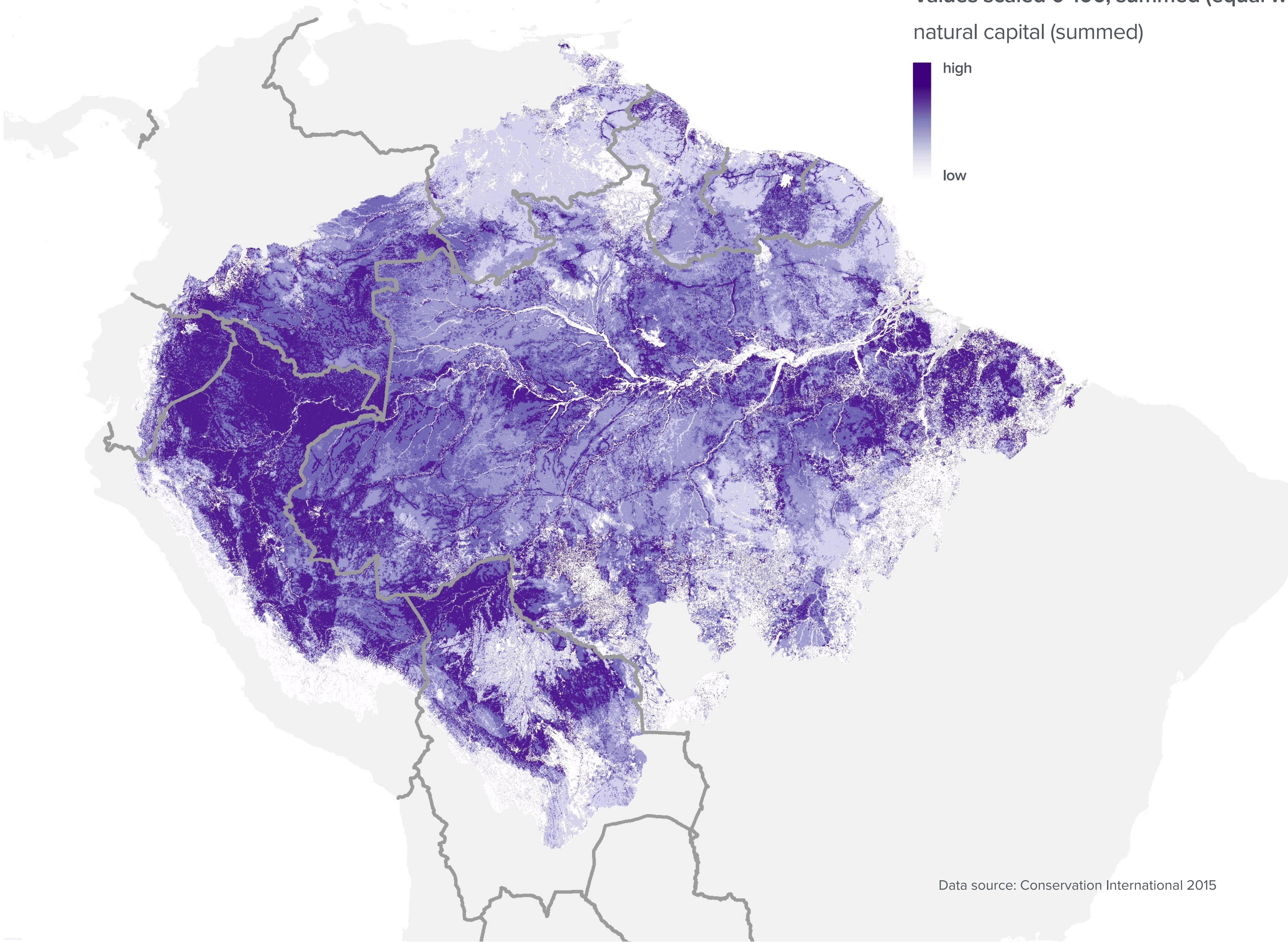
Data source: Conservation International 2015

ALL NATURAL CAPITAL

Threshold-based approach:
Top 10% and 20% of pixels



Data source: Conservation International 2015



ALL NATURAL CAPITAL

Additive approach:
Values scaled 0-100, summed (equal weight)

natural capital (summed)

Data source: Conservation International 2015


"THE AREA DEFORESTED IN THE AMAZON FROM 2011 TO 2014 IS LARGER THAN THE COUNTRY OF BELIZE"
–MAX WRIGHT
© PETE OXFORD/ILCP

INTEGRATING MAPS OF NATURAL CAPITAL: PROTECTED AREAS, INDIGENOUS LANDS, AND VULNERABILITY TO DEFORESTATION

INTEGRATING MAPS OF NATURAL CAPITAL: PROTECTED AREAS, INDIGENOUS LANDS, AND VULNERABILITY TO DEFORESTATION

Combined maps of natural capital can be used to ask questions such as, "how much important natural capital in Amazonia is contained within protected areas and indigenous lands?" For illustration purposes, we used one of the threshold-based maps (top 10% of values), and overlaid both protected areas (PAs) and indigenous lands (ILs), and calculated how much of the area is contained within each category. Based on these analyses, we calculated that 22% of essential natural capital (defined as the top 10% of pixels) is contained within protected areas, 24% is contained within indigenous lands, and 43% is contained in either category (note there is some overlap between protected areas and indigenous lands). When we used the top 20% of pixels as the threshold (map not shown), these percentages changed, but only slightly: 24% falls within protected areas, 23% within indigenous lands, and 44% falls within either category.

It is also possible to overlay a map of vulnerability to deforestation, in order to identify areas that are important for natural capital and also are highly threatened. These areas might be considered as priorities for conservation, as they are currently forested but are at risk of being lost. These areas include places along roads, rivers, and agricultural frontiers.

Conclusion

All of Amazonia's natural capital is important. The region contains globally important biodiversity values, plays a critical role in regulating the climate, produces flows of fresh water for cities and hydropower, and sustains the food security and livelihoods of people throughout South America. The many maps presented above highlight the "most important", or essential, natural capital within this important region.

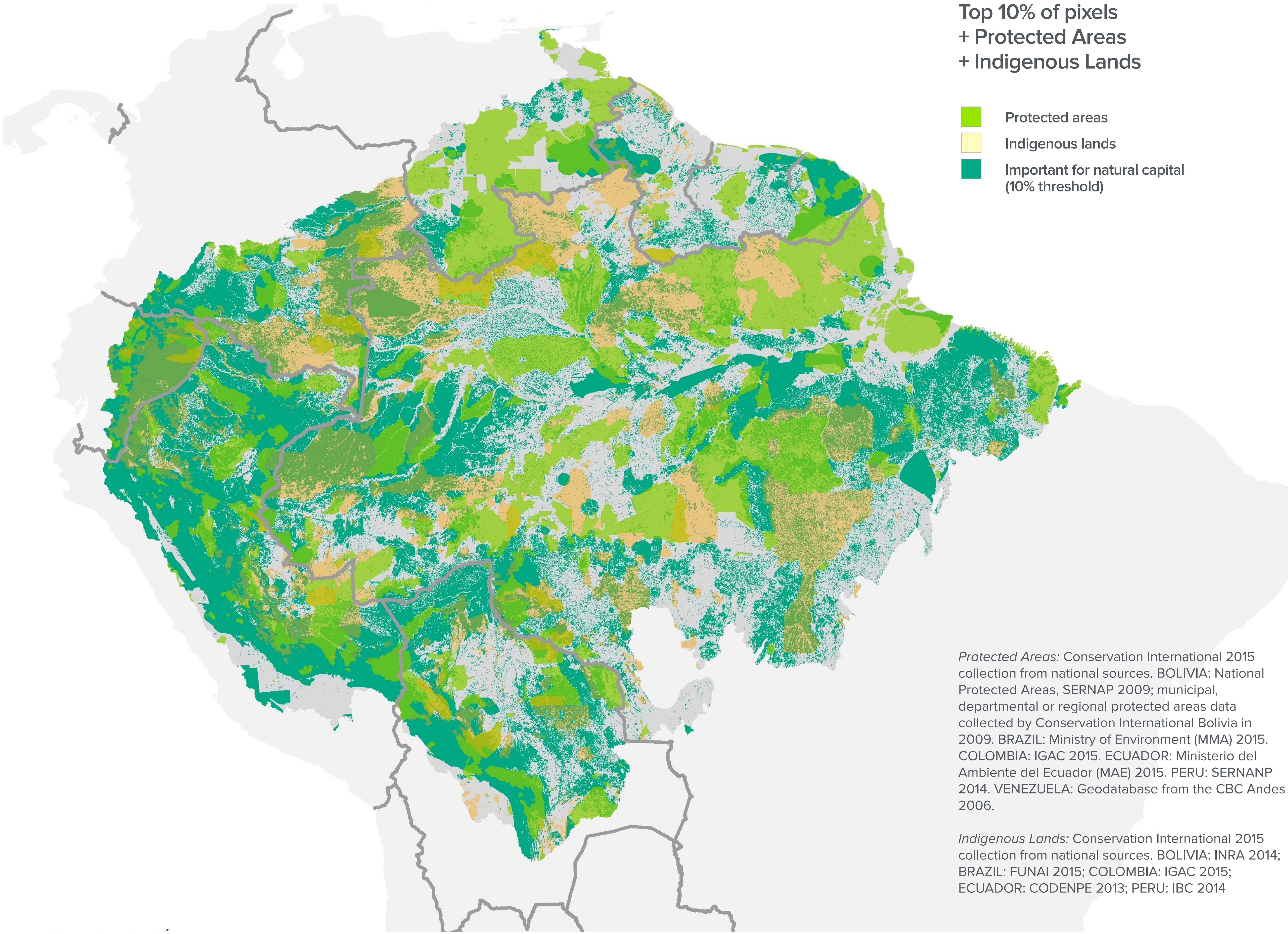
The analysis of protected areas and indigenous lands show that a considerable percentage of Amazonia's essential natural capital is already under some kind of legal designation. However, deforestation continues to threaten the region, including within protected areas and indigenous lands.

The information on biodiversity and ecosystem benefits shown in the maps could be useful to inform public and private policies aiming at reconciling conservation and development, such as efforts to develop and monitor progress towards meeting national Sustainable Development Goals (SDG) targets, measuring performance towards the Convention on Biological Diversity Aichi targets, efforts to develop National Adaptation Plans of Action to address impacts from climate change, efforts to meet avoided deforestation commitments, and other policy goals.

Beyond these existing goals, the approaches developed in this project could help to build a regionally-integrated vision for Amazonia's sustainable development. The use of these region-wide results will be essential to maintain the coherence of policies developed nationally and sub-nationally. After all, recognizing that this is a connected region, and that nature has no political boundaries, is key to the success of sustainable development in Amazonia.

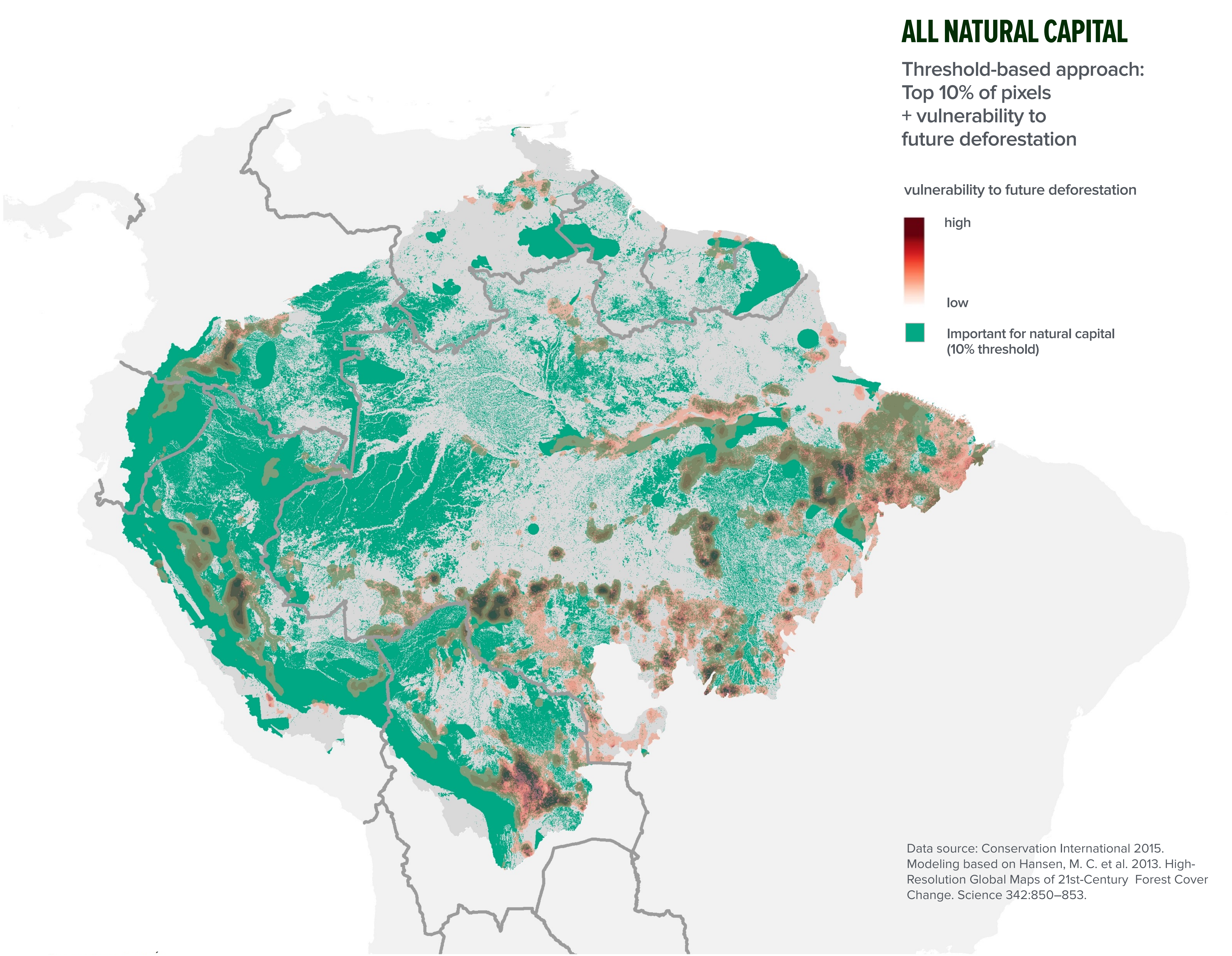
ALL NATURAL CAPITAL

Threshold-based approach:
Top 10% of pixels
+ Protected Areas
+ Indigenous Lands



Protected Areas: Conservation International 2015 collection from national sources. BOLIVIA: National Protected Areas, SERNAP 2009; municipal, departmental or regional protected areas data collected by Conservation International Bolivia in 2009. BRAZIL: Ministry of Environment (MMA) 2015. COLOMBIA: IGAC 2015. ECUADOR: Ministerio del Ambiente del Ecuador (MAE) 2015. PERU: SERNANP 2014. VENEZUELA: Geodatabase from the CBC Andes 2006.

Indigenous Lands: Conservation International 2015 collection from national sources. BOLIVIA: INRA 2014; BRAZIL: FUNAI 2015; COLOMBIA: IGAC 2015; ECUADOR: CODENPE 2013; PERU: IBC 2014


ALL NATURAL CAPITAL
Threshold-based approach:
Top 10% of pixels
+ vulnerability to
future deforestation
vulnerability to future deforestation
high
low
Important for natural capital
(10% threshold)
Data source: Conservation International 2015.
Modeling based on Hansen, M. C. et al. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342:850–853.

DATA SOURCES

Land cover: Chen, Jun, Jin Chen, et al. 2014. Global Land Cover Mapping at 30m Resolution: a POK-based Operational Approach, ISPRS Journal of P&RS, doi: 10.1016/j.isprsjprs.2014.09.002.

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Protected Areas: Conservation International 2015 collection from national sources. Bolivia: National Protected Areas, SERNAP 2009; municipal, departmental or regional protected areas data collected by Conservation International Bolivia in 2009. *Brazil:* Ministry of Environment (MMA) 2015. *Colombia:* IGAC 2015. *Ecuador:* Ministerio del Ambiente del Ecuador (MAE) 2015. Pe*ru:* SERNANP 2014. *Venezuela:* Geodatabase from the CBC Andes 2006.

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*Non-timber forest products model: P*orro, R. et al. 2008. Challenges to Managing Ecosystems Sustainably for Poverty Alleviation: Securing Well-Being in the Andes/Amazon. Situation Analysis prepared for the ESPA Program. Amazon Initiative Consortium,. ESPA-AA, Belém, Brazil. http://www.mtnforum.org/sites/default/files/publication/files/4579.pdf. Model developed by Manuel Peralvo, CONDESAN.

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For a more detailed description of the maps and analyses presented in this document, please refer to the accompanying technical report:

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