Atlas of Hydroclimatic Vulnerability of the Amazon Region

ACTO
Amazon Cooperation Treaty Organization

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UN environment programme

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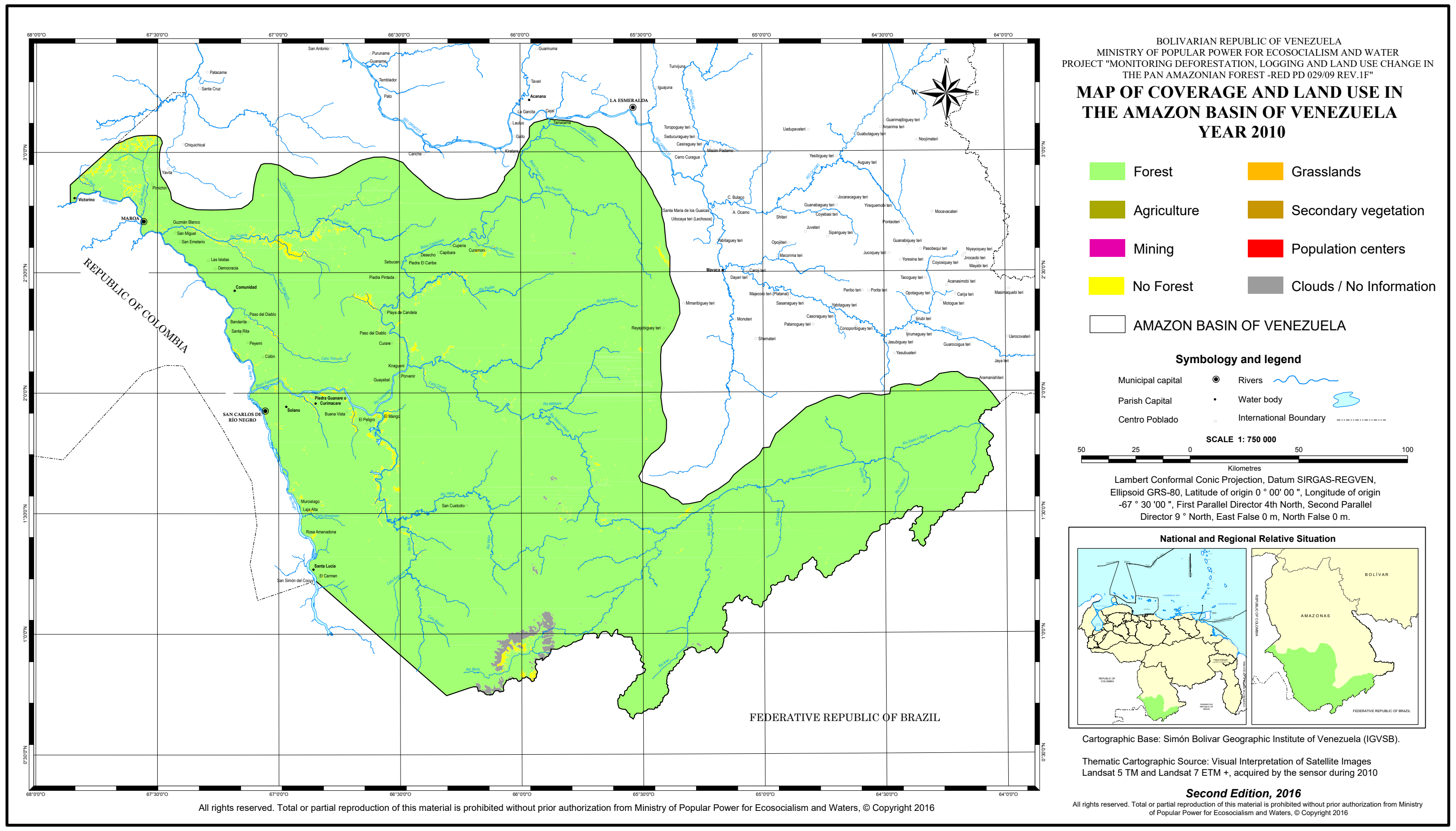
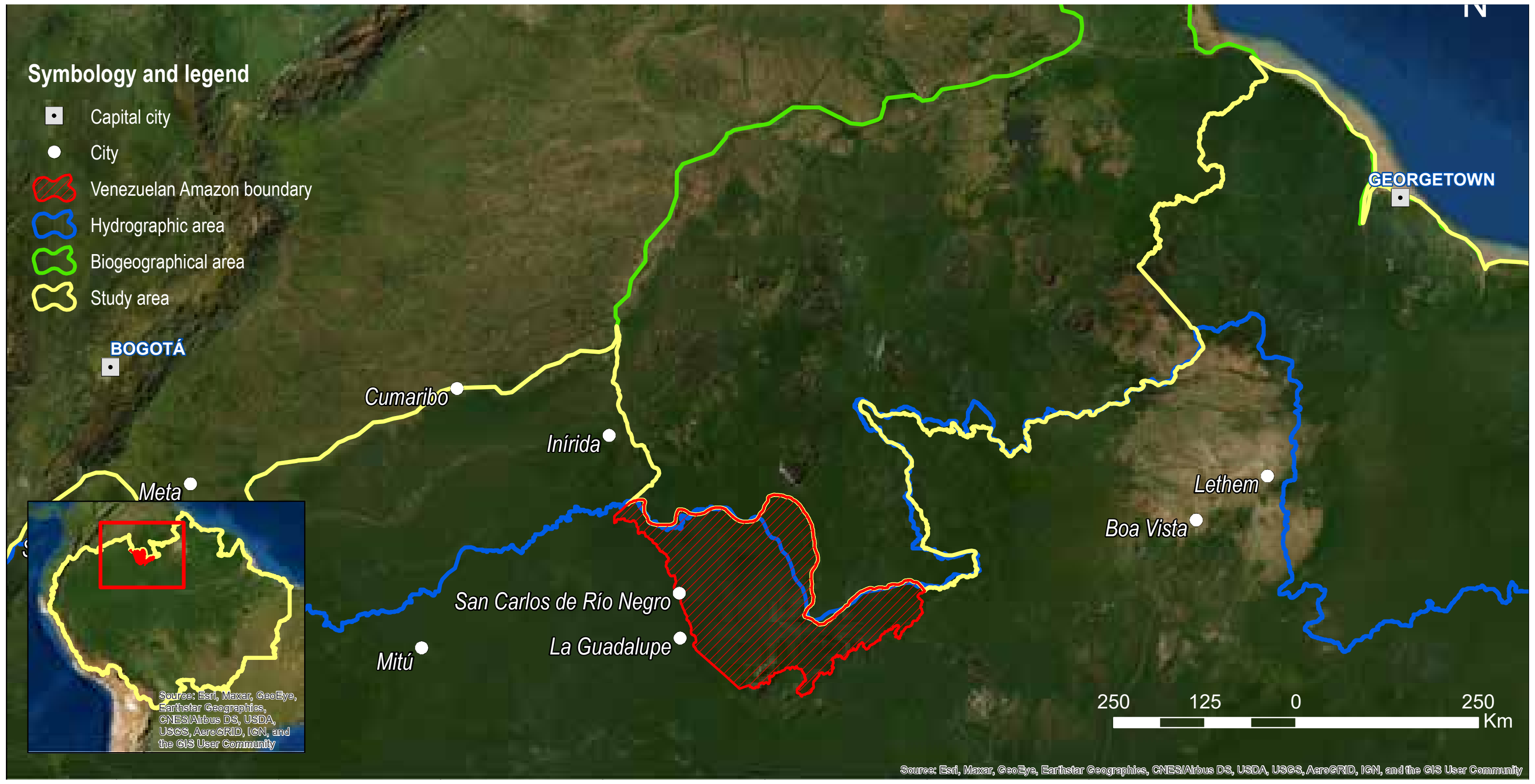




Note on Venezuela:

For the Bolivarian Republic of Venezuela, data on the Casiquiare and Negro River tributary in Venezuela's Amazon Region were taken into consideration.

Atlas of Hydroclimatic Vulnerability of the Amazon Region

This Atlas is the product of the ACTO/UNEP/GEF Amazon project "Integrated and Sustainable Management of Transboundary Water Resources of the Amazon Basin, Considering Climate Variability and Change."

It was produced under the executive direction of the **Amazon Cooperation Treaty Organization** (ACTO), through its Permanent Secretariat (PS), which coordinates actions within the framework of the Amazon Cooperation Treaty (ACT) and streamlines the implementation of its decisions. ACTO carries out studies and pilot projects on economic initiatives that have the potential to generate income and opportunities for the Amazon Region, thus contributing to effective cooperation and integration of the eight member countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela.

ACTO has a broad view and ample experience in South-South cooperation, working to strengthen the ability of these governments to build synergies with other actors, nations, multilateral organizations, development agencies, social movements, the scientific community, industrial sectors, and society as a whole. Its work is guided by the Amazon Strategic Cooperation Agenda (ASCA), with an eight-year medium-term plan for implementation, which was approved by the foreign ministers of the ACTO countries in 2010. This instrument reflects the priorities of the Amazon countries, in accordance with the political and social reality of the region.

The Atlas was produced with the participation of the **International Research Centre on El Niño (CIIFEN)**, whose mission is to promote, complement, and carry out scientific and applied research projects to improve understanding and provide early warnings about the El Niño Southern Oscillation (ENSO) and climate variability at the regional level. Its aim is to contribute to the reduction of socioeconomic impacts and provide solid foundations for the creation of sustainable development policies, in light of new climate scenarios.

This research was also done on behalf of the **UNEP**, also known as the **UN Environment Programme**, which was established in 1972 and speaks for the environment in the United Nations system. The UN Environment Programme acts as a catalyst, advocate, educator, and facilitator to promote the rational use and sustainable development of the global environment. Its mandate is to be the world's leading environmental authority, setting the global environmental agenda, promoting the coherent application of the environmental aspects of sustainable development within the United Nations system, and acting as an accredited global environmental advocate. Its mission is to provide leadership and encourage participation in caring for the environment by inspiring, informing, and providing nations and peoples with the means to improve their quality of life, without compromising that of future generations.

The Atlas also received support from the **Global Environment Facility** (**GEF**, known as **Fondo para el Medio Ambiente Mundial–FMAM**, in Spanish) which was established in 1991 with the purpose of providing donations and assistance to projects that contribute to the protection of "global environmental assets." Currently, 182 countries are members of the GEF, of which 39 are donor countries, financing projects in the fund's five focal areas: biodiversity, international waters, land loss, ozone, and persistent organic pollutants.

TABLE OF CONTENTS

PART I

TABLE OF CONTENTS

How to use the Atlas of Hydroclimatic Vulnerability of the Amazon Region

Welcome to the Atlas of Hydroclimatic Vulnerability of the Amazon Region (hereinafter the Atlas). It contains a collection of 60 thematic maps, created with validated information, intended for use by decision-makers in ACTO's member countries, academics, public and private institutions, and civil society.

Thumbnails of the maps appear at the start of the book, providing an overview of the maps, a visual summary that introduces the main issues in the region.

PART I explains how the Atlas was created. It begins with a general biogeophysical description of the Amazon Region. The next section presents the methodology that was used to develop the hydroclimatological maps, analyze the climatic threats and, thus, determine the vulnerability, sensitivity, and adaptive capacity of the ecosystems and human populations that are facing climate change.

PART II is the Atlas itself. Each thematic map is an explicit and clear technical and scientific information unit. The sequence from **MAP 1. LIMITS OF THE AMAZON REGION**, to **MAP 60. SPATIAL DISTRIBUTION OF INTEGRATED VULNERABILITY TO FLOODS IN THE AMAZON REGION**, provides a greater understanding of this region. The maps cover fundamental issues, such as the varied geographic relief, the soil, its suitability for agricultural, the rich vegetation, and the many climates. The journey through the maps also addresses the situation of the people of the Amazon Region, from their economic activity, to healthcare, education, and the road networks.

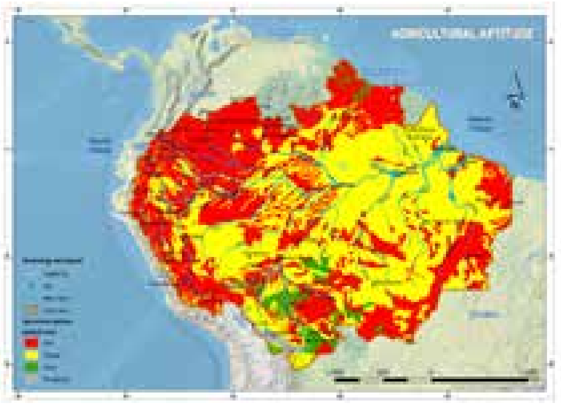
The Atlas looks at specific aspects of extreme hydroclimatic events that occur in the region, such as floods and droughts, and hydroclimatic vulnerability that results from the interaction between socioeconomic vulnerability and biophysical vulnerability, which is the main objective of this research project and the Atlas.

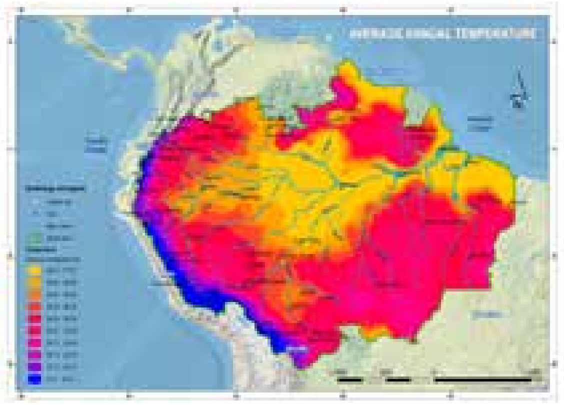
Finally, **PART III** lists the information sources consulted.

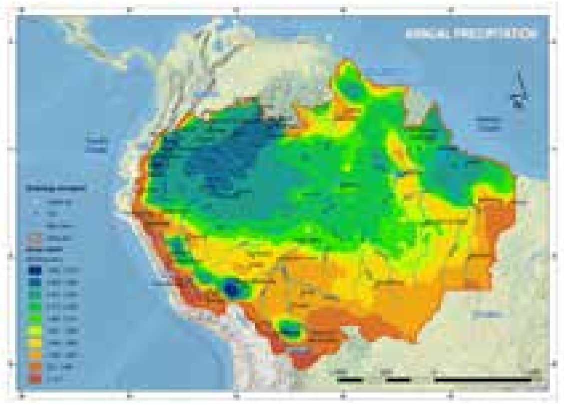
We hope that the Atlas, as a technical and scientific tool presented in an accessible way, will contribute to your understanding of the Amazon Region and increase your commitment to caring for it.

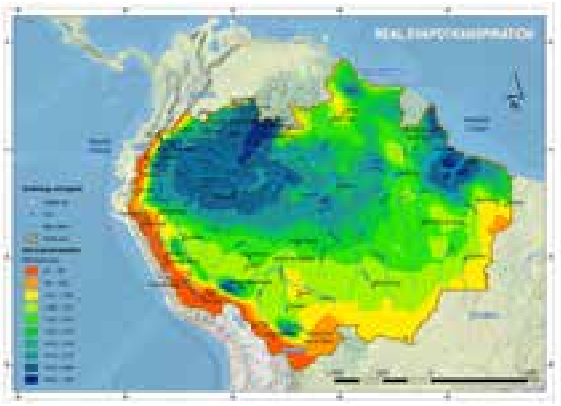
We also invite you to share this information for decision-making, and to use the Atlas as a starting point for further studies and actions for adaptation and mitigation of the impacts associated with floods and droughts in the region.

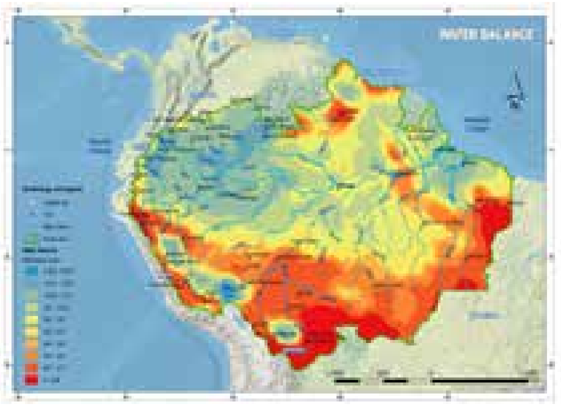
CARTOGRAPHIC INDEX

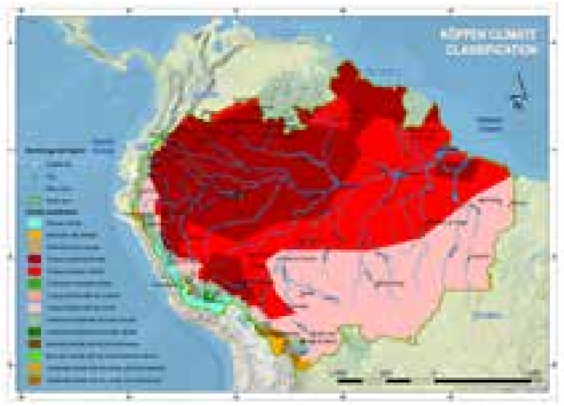


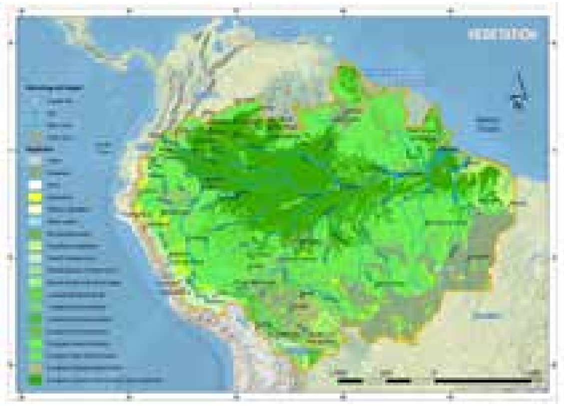


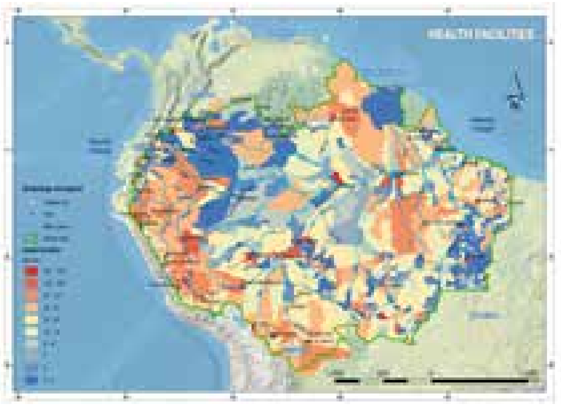


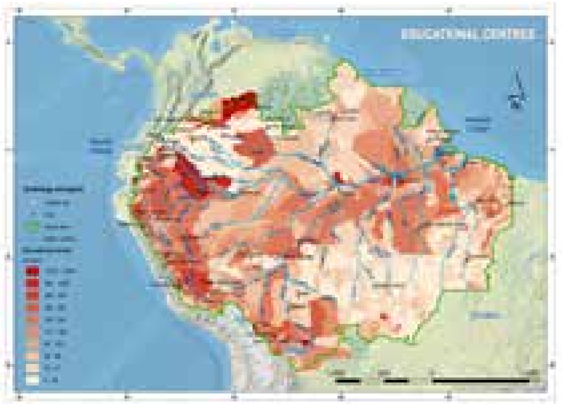


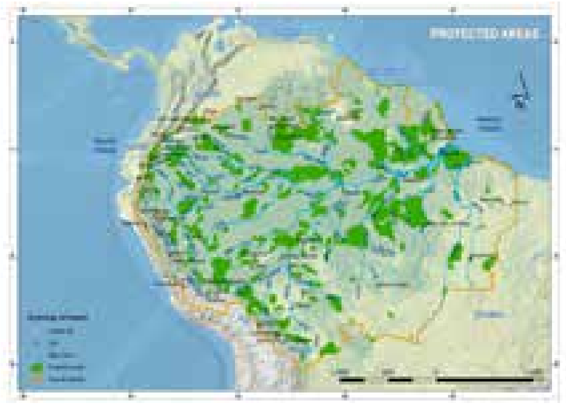


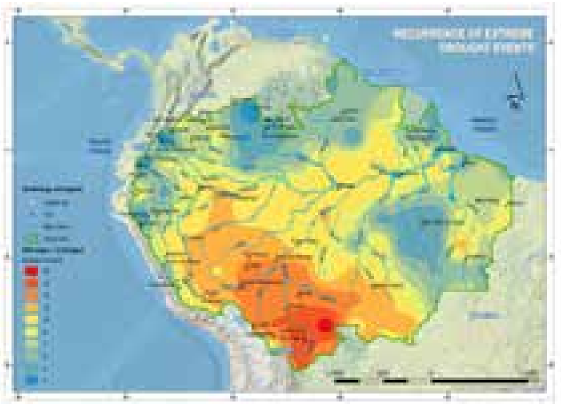


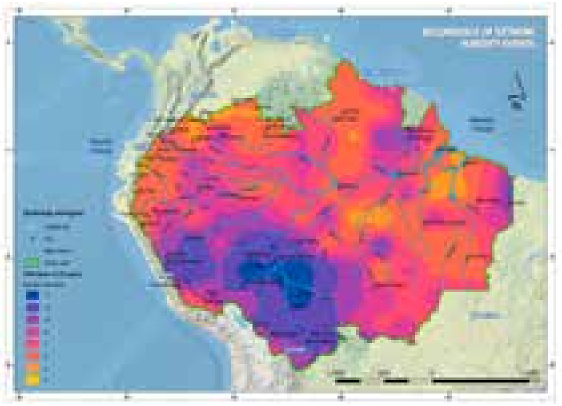


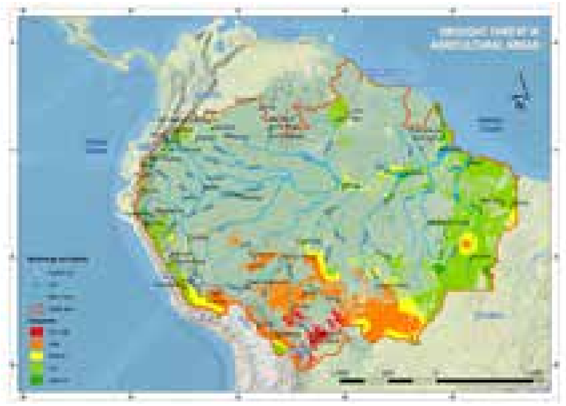


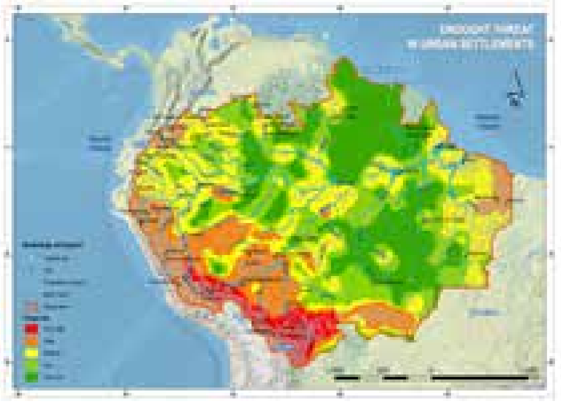


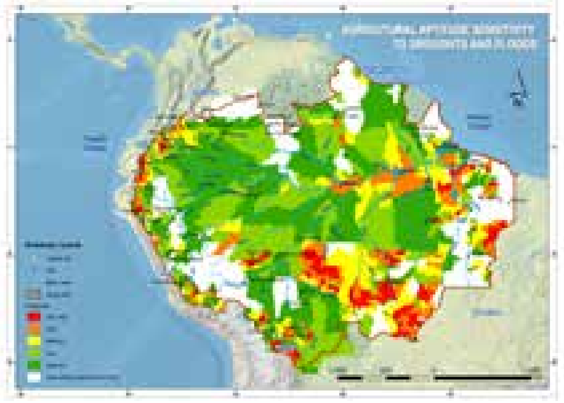


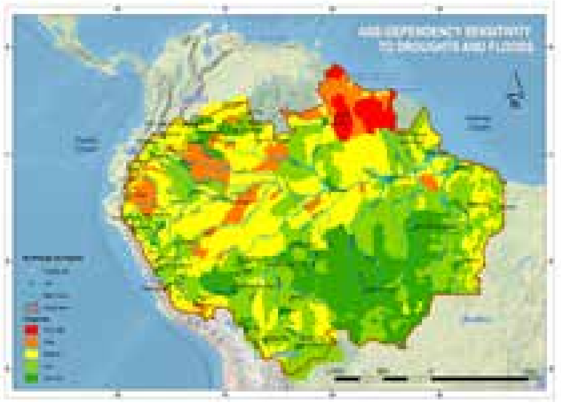


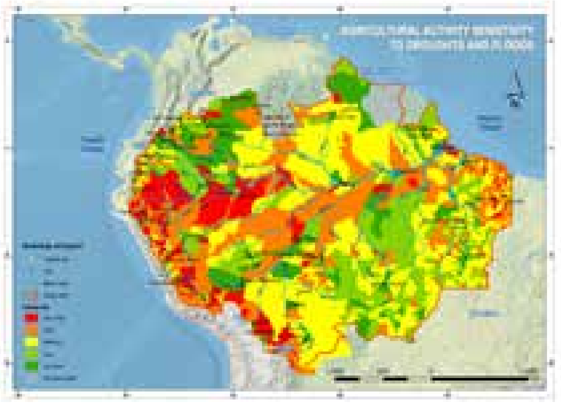


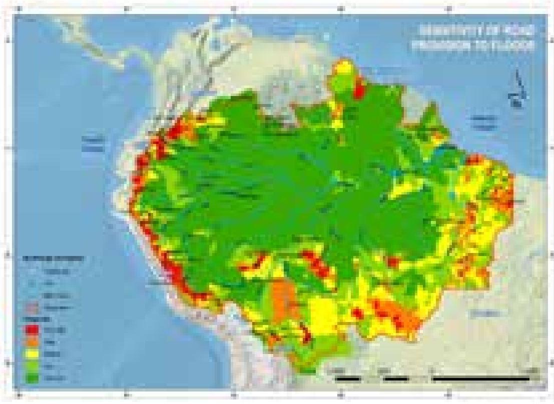


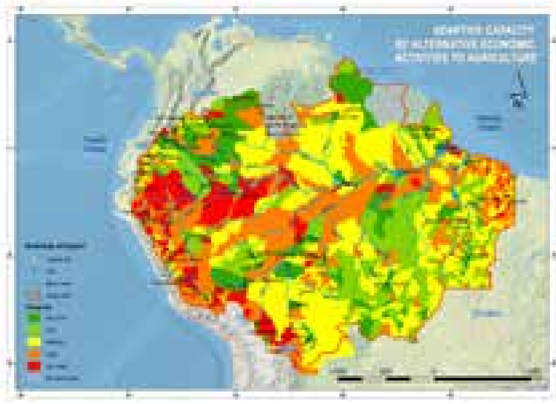


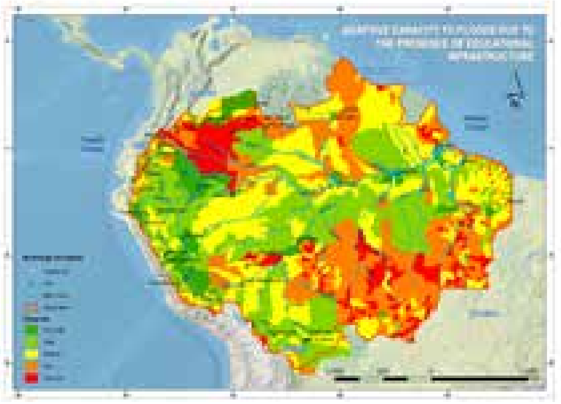


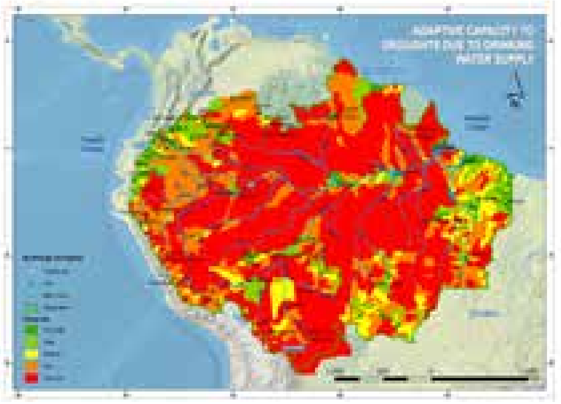


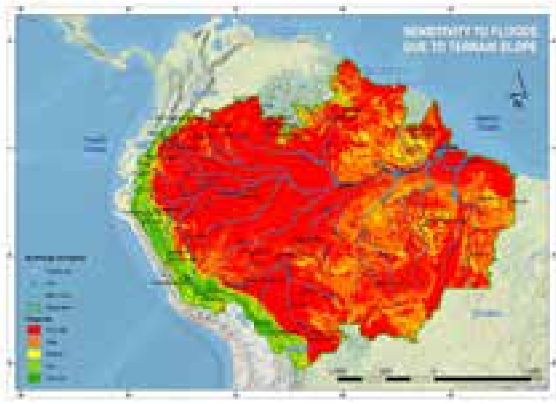


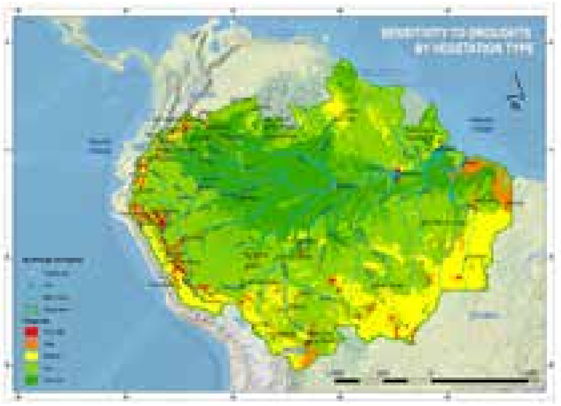


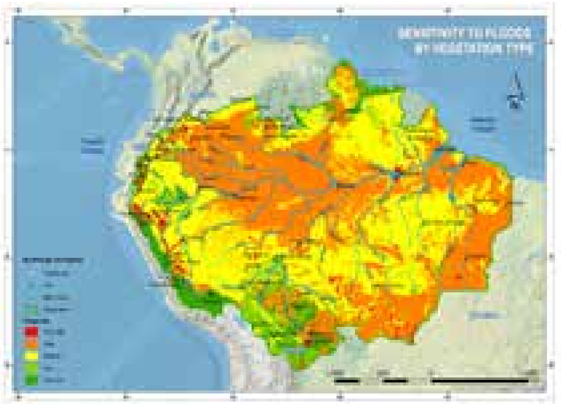


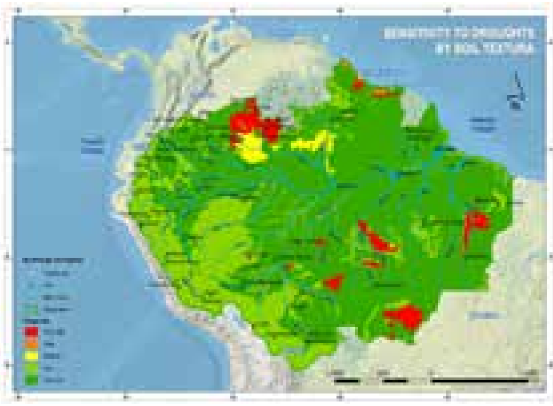


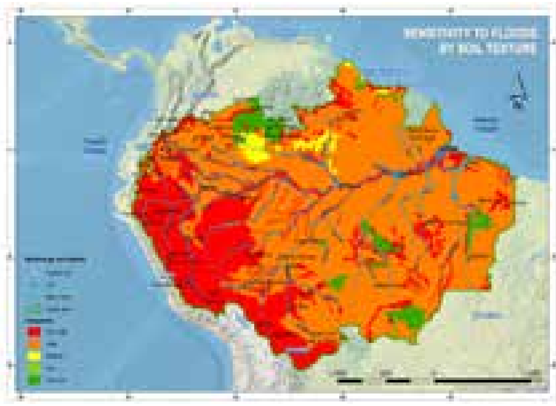


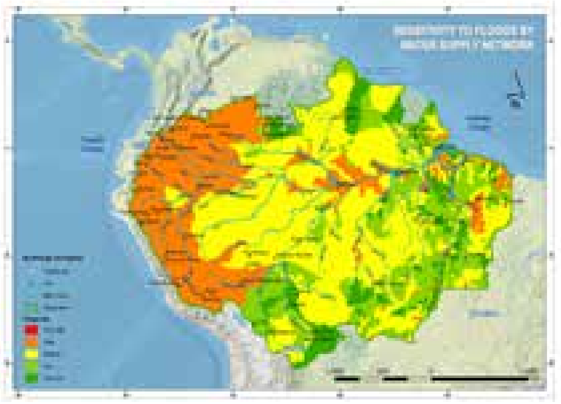


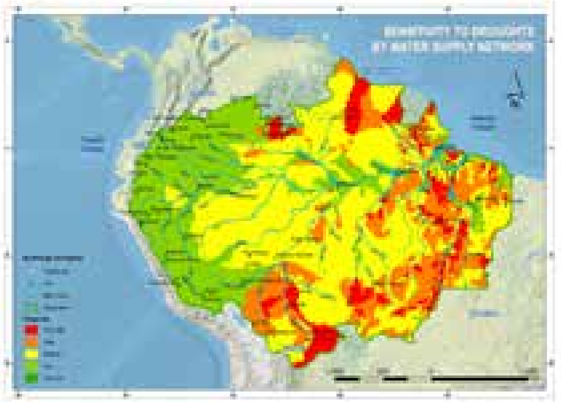


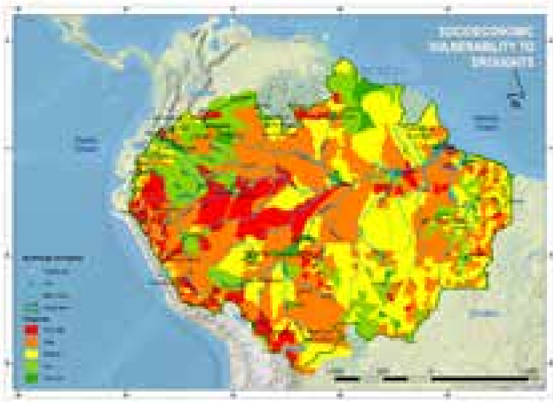


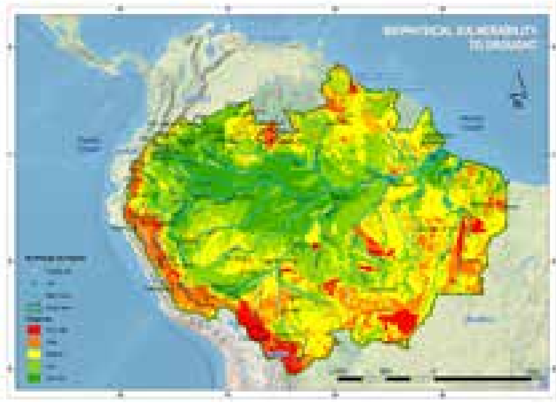


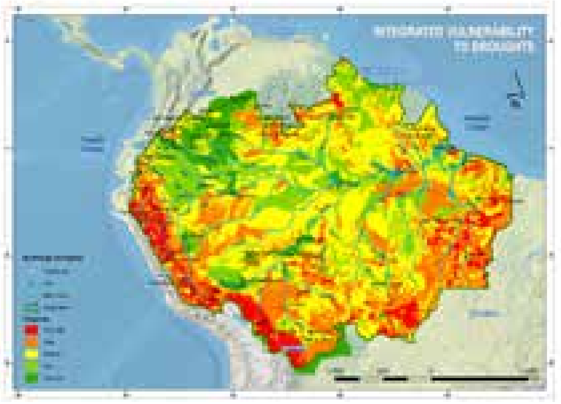


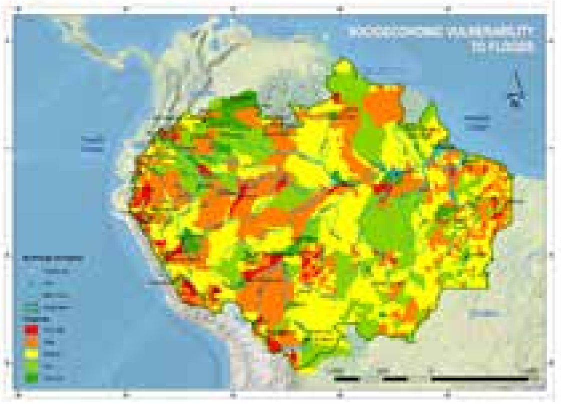


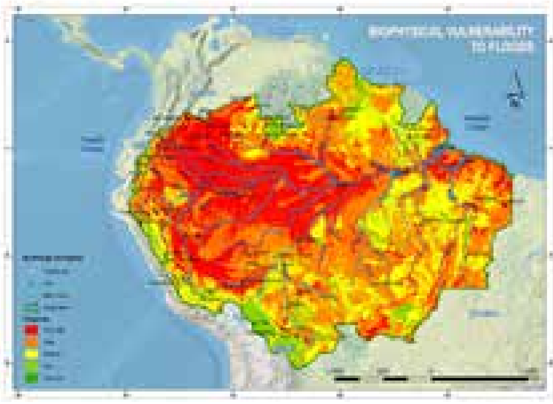


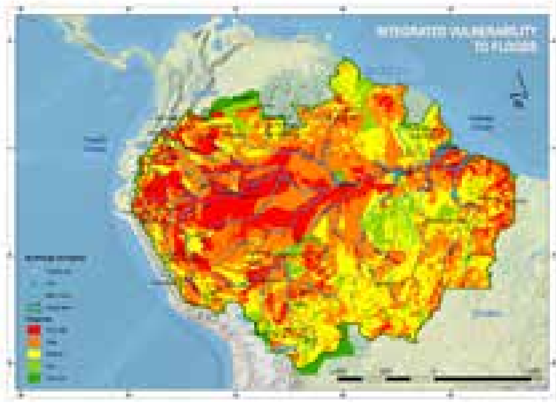












PART I

Technical studies leading to the production of the Atlas

Presentation

The main objective in producing this collection of 60 thematic maps that make up the Atlas of Hydroclimatic Vulnerability of the Amazon Region, is to contribute to knowledge and understanding of the Amazon, examining aspects related to the region's socioeconomic and physical vulnerability and exposure to extreme climatic events such as droughts and floods.

To create the Atlas, we worked primarily with data provided by the eight member countries of the Amazon Cooperation Treaty Organization (ACTO), Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Surinam, and Venezuela.

This document describes and analyzes biophysical and human systems in the Amazon Region, and identifies the main hydroclimatic threats, such as droughts and floods, and the locations where these occur.

Thirty of the thematic maps present the socioeconomic and biophysical characteristics of the region; each map addressing a specific variable. The biophysical maps show the land's relief and how this is related to the diverse climates, illustrating 21 types of soils, climate diversity, vegetation, and the enormous hydrographic network, among other topics.

The main socioeconomic indicators are represented in the maps, such as population, economic activities, infrastructure for healthcare, education, and energy, among others. One map shows the multimodal transport network, which runs from the Andean region to the mouth of the Amazon River on the Atlantic Ocean.

To estimate the vulnerability of the Amazon Region, theoretical formula were used to calculate vulnerability, exposure, sensitivity, and adaptive capacity, in addition to the IPCC methodology, thus producing 15 specific maps that present biophysical and socioeconomic sensitivity. Biophysical sensitivity maps were also produced according to vegetation type, soil texture, the hydrographic network, agricultural suitability, age dependency, agricultural activity, and the road network. Four maps were created that illustrate the threat of droughts and floods, revealing the extent of extreme hydroclimatic events.

One of the results was the observation that floods are responsible for 50% of the disasters in the region. Knowing this, vulnerability was studied and calculated to produce spatial maps of biophysical and socioeconomic vulnerability to floods in the region. Combining both of these vulnerabilities resulted in Map 60 (Spatial distribution of integrated vulnerability to floods in the Amazon Region). This map summarizes biophysical and socioeconomic vulnerability to flooding, which is the main problem that affects the region.

The thematic maps show how biophysical and socioeconomic elements have different levels of sensitivity to climate change, as well as their capacity to adapt. The information presented in the Atlas reveals the hydrological, environmental, social, and economic diversity of the Amazon Region, and identifies the locations where threats are concentrated.

Köppen's climate classification for the Amazon Region (Map 11) is an important contribution. It identifies 14 types of climates, showing how climate leads to different interrelationships between the physical environment and the presence of living organisms. This section includes an analysis of climate components, illustrated in the maps on temperature (Map 7), annual precipitation (Map 8), and real evapotranspiration in the region (Map 9), in addition to the influence of El Niño.

ACTO considers that this Atlas may be used as a tool for planning, and as a step toward more detailed and technical studies on different aspects of the Amazon Region. It is hoped that the Atlas will be an important reference tool for decision-makers, academics, and other groups that are interested in the countries referenced.

This Atlas allows us to view our region in a more informed way, to renew our commitment to the largest hydrographic basin on the planet.

Alexandra Moreira Lopez
Secretary General of PS/ACTO

Foreword

The Amazon Cooperation Treaty Organization (ACTO), with the support of the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF), carried out the project "Integrated and Sustainable Management of Transboundary Water Resources of the Amazon Basin, Considering Climate Variability and Change."

Under this project, ACTO's member countries — Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela — came together with the objective of strengthening the institutional framework for planning and implementing strategic actions for the protection and management of water resources in the Amazon Region, considering factors such as climate variability and change.

Toward achieving that objective, all of the countries agreed to systematize the existing information and create new knowledge that could be used for planning, integrating water resources management in the Amazon Region, disaster risk management, and to contribute to understanding in a relatively recent field: risk management related to climate change.

To this end, one of the priorities was to analyze vulnerability to extreme hydroclimatic events for ecosystems and human populations.

Thus, the Atlas of Hydroclimatic Vulnerability was conceived as a technical and scientific instrument to analyze the available data — which has been validated and officially recognized by ACTO's member countries — on extreme hydroclimatic events and their biophysical and socioeconomic impacts in the Amazon Region.

This is why the Atlas examines and analyzes socioeconomic and physical vulnerability to drought and flooding in the Amazon Region, as one of its major contributions to knowledge in the area of climatology and meteorology.

Climate change, which is the overarching reason why the Atlas was undertaken, is a cross-cutting issue that intersects with other disciplines that had to be considered in addressing the complex biogeophysical and socioeconomic reality of the region. As such, this research may be considered as a snapshot of the state of the ecosystems and human populations in the Amazon Region, and their sensitivity and capacity to adapt to hydroclimatic events.

The Atlas was developed in 2013, by compiling the information that was available. It was revised in 2018 and 2019. It was prepared using official information sources which sometimes corresponded to different years, depending on what was available as of 2012.

The Atlas was created in four stages: The first stage was the biogeophysical description, addressing more than 10 variables, such as topography, soil type, temperature, precipitation, evapotranspiration (evaporation from the land and transpiration by plants), and climate change, among others; plus a socioeconomic description of the region, its population and growth, including the main economic, agricultural and commercial activities. Outstanding results of this process include production of the maps of real evapotranspiration and the primary hydrographic network of the Amazon Region.

As may be seen, in this first stage a wide range of variables was taken into account in order to delimit and describe the complex characteristics of vulnerability in the region. It should be mentioned that although population censuses have been done in the countries since this research was completed, the official information analyzed included population data up to the year 2012 and information after that date has not been considered.

The second stage was the analysis of hydroclimatic threats, an issue that is fundamental for current and future actions in the region. According to the IPCC, a threat is when a system, or one of its parts, is exposed to the impact of an extreme hydroclimatic event, whose magnitude is assessed in terms of probability of loss or damage. The threats addressed in the Atlas are droughts and floods, considered by geographic region and magnitude of impact. During this stage of the analysis, climate change scenarios for the Amazon Region were reviewed as a complementary analysis. This was done based on the World Climate Research Programme's four CMIP5 models (Coupled Model Intercomparison Project-Phase 5).

The third stage of this process looked at sensitivity and adaptive capacity to climate change. The result was unprecedented information on vulnerability to extreme hydroclimatic events. The analysis identified hydroclimatic threats (droughts and floods), presented in 15 specialized maps representing sensitivity and adaptive capacity to climate change. These maps may now be used as inputs for the analysis of the region's socioeconomic and biophysical vulnerabilities.

In the fourth stage, the Atlas of Hydroclimatic Vulnerability of the Amazon Region was created with a scale of 1:1,000,000. The Atlas contributes to knowledge about the dynamics of climate variability in the region, and may be used as an input for regional planning, addressing periods of drought and flood, to improve integrated water resources management and disaster risk management.

Introduction

One main reason why the Amazon Region is outstanding, regionally and globally, is its wealth of water. The water of the Amazon plays an essential role in the global hydrological cycle. It helps regulate the global and regional climate. It is the most important resource for maintaining ecosystems and their biodiversity, as well as the functioning of the region's socioeconomic system.

The ecosystems and human populations of the Amazon Region depend on the availability of abundant water resources. Because of this dependence, communities have established a very particular relationship with the spatial and temporal (seasonal) availability of water.

It should be noted that this availability is regulated by climate, to a considerable extent. Extremes in water availability, which result in either excess or scarcity, cause conflicts in the relationship between water resources and the population. Any change in this relationship could lead to disaster.

A variety of extreme hydrometeorological and hydroclimatic events occur in the Amazon Region, which affect the region's socioeconomic systems. Sometimes disasters result because of exposure, vulnerability, and capacity for adaptation, all of which play a role in climate risk scenarios.

Of the many hydroclimatic events observed in the region, droughts and floods are the most important extreme events because of the extent of the areas they affect and the magnitude of their impacts on the region's population and socioeconomic systems. The term impacts, as employed by IPCC (2014), refers to the effects of events related to climate variability and change on natural systems (water resources, biodiversity, soil, etc.) and human activity (agriculture, health, tourism, etc.). Likewise, potential impacts are all the impacts that could occur as the result of a projected change in climate, without taking into account adaptive responses.

Droughts and floods result from extreme phases of climate variability; these phases might be annual or decade-long cycles.

In the Amazon, processes occurring in the tropical region of the Pacific and Atlantic Oceans are mainly responsible for climate variability. Some of the most intense droughts have been associated with climatic anomalies caused by El Niño, while others have been associated with abnormal conditions in the tropical Atlantic.

El Niño is a climate event that results from a change in water temperature, in this case the warming of the eastern equatorial Pacific Ocean, whereas La Niña is associated with cooling.

The warming and cooling pattern is known as the El Niño-Southern Oscillation or ENSO cycle, which may last between three and seven years. The cycle is not as regular as the seasons; it varies in intensity and duration, directly affecting the distribution of precipitation in the tropics and it can influence the climate elsewhere. El Niño and La Niña are the extreme phases of the ENSO cycle. To analyze warming requires reviewing precipitation and dry periods over a period of 0 to 100 years; ENSO changes the meteorological patterns in the long term and these vary by location in the region.

Some high impact floods have occurred during La Niña (cold phase), while others have been due to different specific situations, such as a difference in temperature between the tropical and subtropical sectors of the South Atlantic.

Climate variability entails the recurrence of extreme situations. Cyclical droughts and floods affect the region's communities, although the cycles do not necessarily have an exact periodicity. The socioeconomic impacts of these events depend on both the intensity and duration of the event, and the extent to which the communities are organized and prepared to face the critical event and recover.

Some communities, drawing on the experience of previous generations, have developed practices and ways to respond; others are only now starting to build their response capacity, and some have no organized systems to deal with critical events brought about by extreme phases of climate variability.

The disasters caused by these events are obstacles or impediments to sustainable human development in these communities, so it is necessary to work on strengthening the communities' capacity to respond to the negative impacts of extreme hydroclimatic events.

Climate change that is taking place today will become more evident in the coming decades.

This is why it is necessary to better understand what climate change means. According to IPCC (2014), climate change is the variation in the state of the climate, identifiable (e.g. by statistical testing) in the variations of the mean value or the variability of its properties, lasting for extended periods of time, usually decades or longer. Climate change may occur due to natural internal processes or external forces such as variations in the solar cycle, volcanic eruptions, or ongoing changes to the atmosphere's composition, or land use as the result of human activity.

Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC), defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC differentiates between climate change attributable to human activity that alters atmospheric composition and climate variability attributable to natural causes.

Climate change will modify the climate patterns that have given rise to regional socioeconomic processes. It is also expected that it will change the characteristics of the extreme phases of climate variability, altering the frequency and intensity of droughts and floods.

This is why it is important to determine the Amazon Region's vulnerability to extreme hydroclimatic events. In this sense, vulnerability means the propensity or predisposition of human and natural systems to be affected negatively by extreme hydroclimatic events. Vulnerability comprises a variety of concepts and elements, including sensitivity to damage and capacity to respond and adapt (IPCC, 2014). Analysis will make it possible to determine the vulnerability of socioeconomic and physical systems to drought and flooding, in order to contribute to making adaptations in response to the alterations implied by climate change.

This publication summarizes the methodology used to create the Atlas of Hydroclimatic Vulnerability of the Amazon Region, presents the main results and conclusions, and may be used as a basis for proposing actions aimed at improving the resilience of local communities to extreme hydroclimatic events in the region.

1

Conceptualization and Methodology

The Atlas is organized along the following themes: Climate Change, Climate Variability, and Climate Change Risk Management. The main sources consulted were the following: the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) by the Intergovernmental Panel on Climate Change (IPCC, 2012), the 2014 IPCC Fifth Assessment Report (AR5) by Working Group I on the Physical Science Basis, and the 2014 Report by Working Group II on Impacts, Adaptation and Vulnerability, among others.

The IPCC was established in 1988 to do comprehensive evaluations of the existing scientific, technical, and socioeconomic knowledge about climate change, its causes, potential impacts, and response strategies. Working groups produce its reports. Working Group I is the Physical Science Basis of climate change. Working Group II is on Impacts, Adaptation and Vulnerability to climate change, and Working Group III is on Mitigation of Climate Change. This Atlas draws mainly upon the reports prepared by Groups I and II.

1.1. Conceptual Basis

1.1.1. Climate, Climate Variability and Climate Change

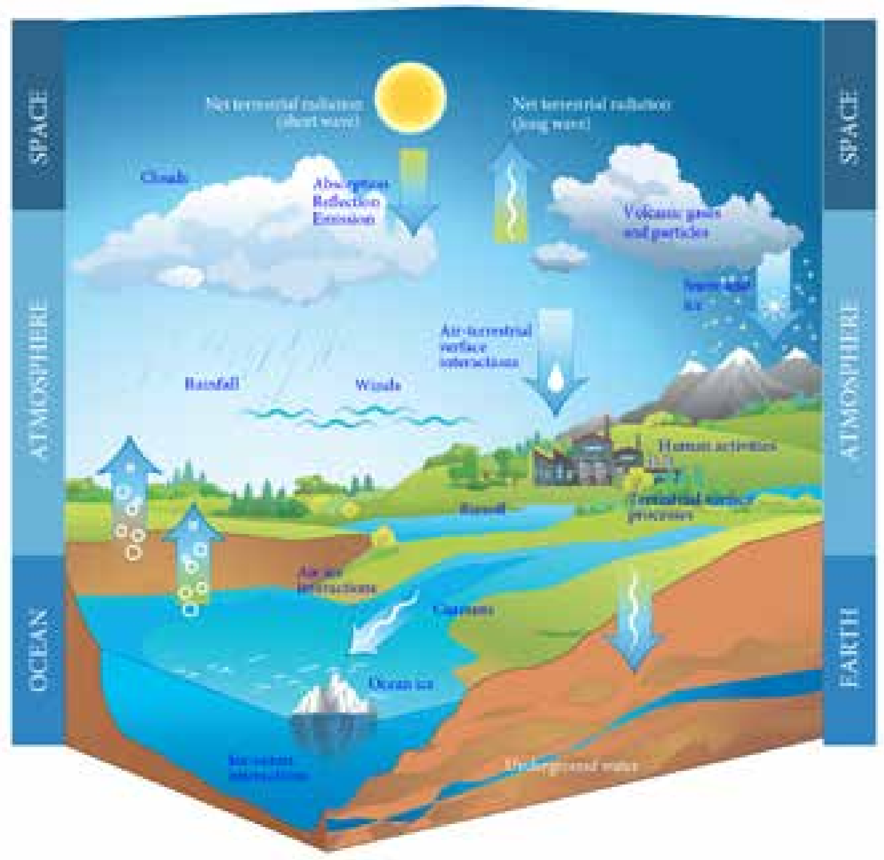
Atmospheric weather (henceforth referred to as weather) is the set of conditions, situations, and phenomena (wind, clouds, rain, storms, tornadoes, etc.) observed in the atmosphere within a short timeframe (moments, hours, a day). Conditions that last beyond a couple of days and predominate during a period (weeks, months, years) constitute what is referred to as climate. Thus, we say "rainy weather" when it rains in an afternoon and "rainy climate" for an area where the rains are very frequent.

In this way, we observe that:

- The weather is the state of the atmosphere at a given moment in time; it is expressed by the variety of meteorological conditions that are observed hour to hour or day to day.
- Climate is the set of atmospheric conditions predominant during a given period (months, years, thousands of years), a result not only of atmospheric dynamics, but also of the interaction between the different components (atmosphere, hydrosphere, biosphere, lithosphere, troposphere) of the Earth's system, as shown in **FIGURE 1**. (OMM, 2011. Oviedo, 2011).

In the Earth's natural system, climate is controlled by the solar energy that reaches the planet through the atmosphere and heats the surface of the water (ocean, lakes, and rivers) and the land on the continents. Climate is also impacted by the greenhouse effect, in which certain components in the air, both natural and manmade, absorb and release infrared radiation emitted from the land (IPCC, 2018).

FIGURE 1.
Illustration of the weather system.



SOURCE: Adapted from IPCC, Third Assessment Report - Climate Change 2001. (IPCC, 2001). https://www.ipcc.ch/site/assets/uploads/2018/03/wgi_tar_full_report.pdf

Atmospheric circulation — the global winds that produce waves and ocean currents — distributes heat and moisture from the air throughout the planet. Wind and the sun's heat also cause water masses to move, thus influencing ocean currents.

The climate of a place or region depends on its location within the global distribution of air mass (humidity or clouds) and energy (heat). This means, on the one hand, distance from the geodetic equator (equatorial line or parallel 0°), altitude above sea level, and orography (relief), and, on the other hand, the location in relation to the mountains and the influence of ocean currents and atmospheric circulation systems.

The solar rays that reach the Earth pass through the atmosphere, where they become weaker due to diffusion, reflection, and absorption by gas molecules and suspended particles. Of the total radiation present in the top level of the atmosphere, about half reaches the land and water of the Earth's surface. Some of the radiation is reflected and absorbed by the atmosphere, and some heats the Earth's surface (short wave). The Earth's surface reflects some of the radiation back into atmosphere and some of it is absorbed by greenhouse gases (long wave-infrared radiation). On the Earth's surface, this radiation is reflected or absorbed.

The amount of radiation absorbed by the surface is transformed into heat, which in turn is returned to the atmosphere as heat and long-wave radiation emitted by the Earth's surface.

Part of the long-wave radiation that the Earth's surface emits is absorbed by greenhouse gases in the atmosphere (water vapor, and gases such as carbon dioxide and methane, among others) and is re-emitted by them in different directions (sideways, upwards towards space, towards the Earth's surface), leaving part of the energy in the atmosphere and returning part of it to the surface.

Because of this property of the atmosphere, known as the greenhouse effect, global average air temperature near the Earth's surface is not below zero.

In the climate system, a role is played by each of the five components: I) the atmosphere, II) the hydrosphere, III) the biosphere, IV) the cryosphere, and V) the lithosphere, each of which also interacts with each other.

i] The atmosphere, with the greenhouse effect, has an important function in the planet's climate. Similarly, atmospheric circulation redistributes mass and energy, and thus generates a variety of climatic conditions in different parts of the world (WMO, 2011).

ii] The hydrosphere. The ocean, which is the largest container of water in the hydrosphere (bodies of water that are found on the surface of the Earth) plays a significant role in regulating the greenhouse effect, through its chemical, physical, and biological processes, as the main sink for carbon dioxide or the natural collector of the carbon it absorbs. In addition, the ocean reflects some of the radiation that strikes its surface; this is known as the albedo (measured as a percentage). Thus, the circulation of the ocean's tides regulates the balance of radiation and redistributes energy on the planet (IPCC, 2013).

iii] The biosphere is the relatively thin life-supporting stratum of the Earth's surface made up of land, water, and air in which living beings exist. It is an important regulator of radiation (the amount of solar radiation that enters the Earth in relation to the long wave radiation emitted by the Earth into space) because of its albedo properties and latent heat transmission from evapotranspiration. It also regulates the greenhouse effect because of its impact on variations in atmospheric carbon dioxide.

iv] The cryosphere consists of the mass of ice, snow, and permafrost (the layer of permanently frozen soil) on the planet. It makes a significant contribution to the regulation of the global climate through its influence on the flow of energy on the terrestrial surface, humidity, cloud formation, precipitation, hydrology and, in general, atmospheric and oceanic circulation.

v] The lithosphere consists of the continents and the ocean floor, excluding the surface layer of soil, which is sensitive to changes caused by atmospheric and oceanic phenomena. The lithosphere changes more slowly than the other elements in the climate system; its changes are imperceptible in the short and medium term. Its interactions with the atmosphere are important: these processes include mass exchange, dissipation of kinetic energy by friction of bodies with the Earth's surface, and the transfer of heat between the lithosphere and the atmosphere. There are also interactions between the lithosphere and the hydrosphere (continents-ocean) and between the lithosphere and the cryosphere (continents-glaciers).

In addition to the above-mentioned components of the climate system, there is the geographical and social environment in which humans exist and their activities take place. This is the anthroposphere, which refers to the aspects of the planet created by humans (for example, buildings, manufacturing, etc.) and those related to society. The anthroposphere's socioeconomic processes transform the terrestrial surface and modify the radiation balance. These changes may be attributed, among other things, to industrialization that produces gas emissions, which augments the greenhouse effect in the atmosphere and influences climate.

Within the climate system, there is an exchange of mass and energy through biogeochemical cycles, such as the water and carbon cycles, which produce variations in the chemical composition and physical properties of the system's components, particularly the amount of water vapor, carbon dioxide (CO_2) and methane (CH_4) in the atmosphere. These processes of mass and energy exchange also regulate the greenhouse effect and, consequently, climate.

In summary, climate is defined as the environmental factor that is evidenced in the prevailing atmospheric conditions during a determined period in a place, region, or planetwide, which are affected by the so-called radiative forcing factors (solar radiation and greenhouse effect) through the interaction of the different elements of the climatic system (atmosphere, ocean, biosphere, lithosphere, anthroposphere) and physical-geographic factors (latitude, altitude, continentality, orography, ocean currents, atmospheric circulation) that are characteristic of the specific place or region.

1.1.2. Global Climate Patterns

Given that the equatorial zone gets hotter than the poles, there are latitudinal differences in temperature (variations in temperature due to latitude), atmospheric pressure, and winds that change due to the contrast generated by the interaction of oceans and continents. Atmospheric circulation redistributes heat and humidity, resulting in different spatial patterns of air temperature, precipitation, wind, and climate type, as shown in **FIGURE 2**.

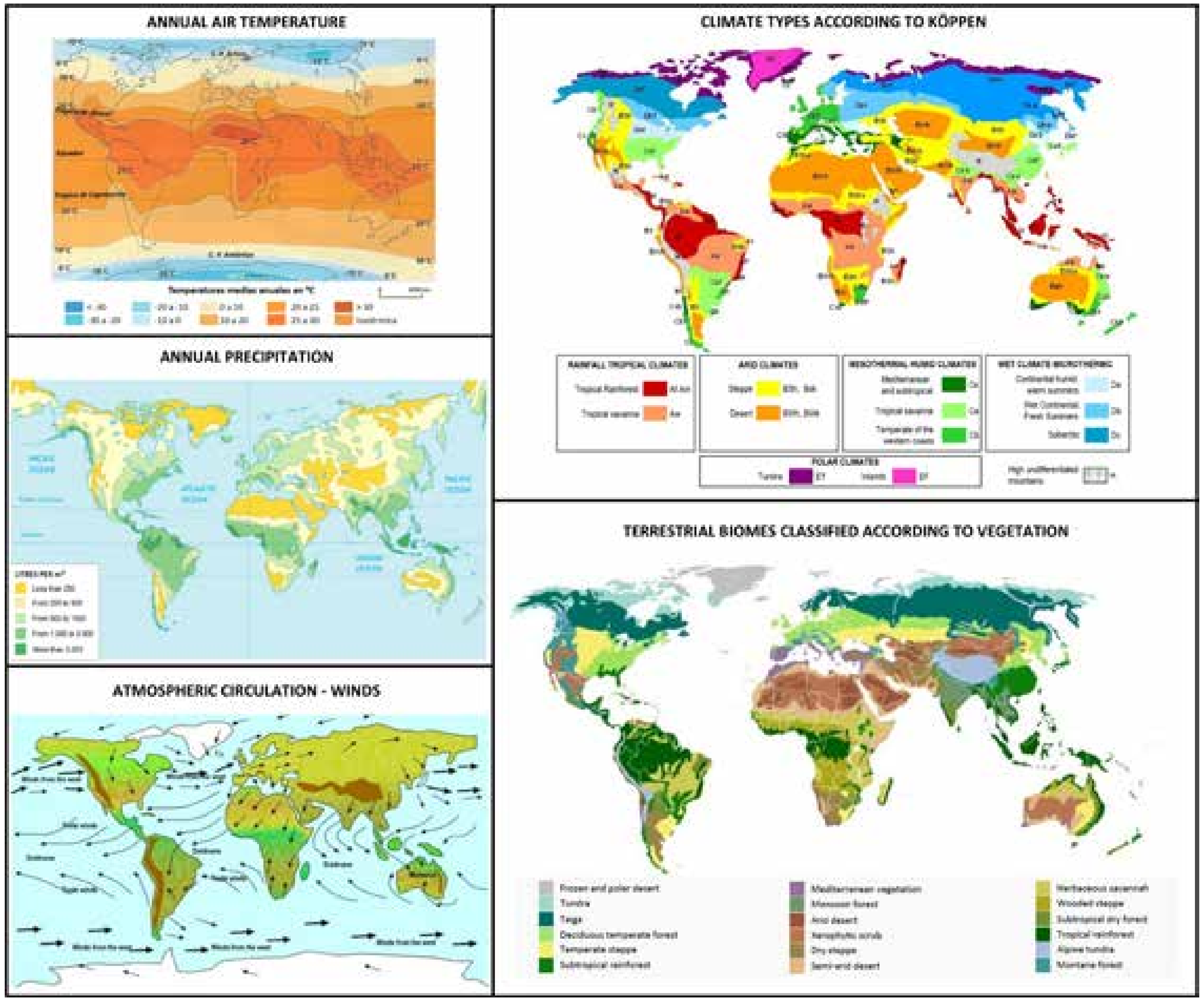
The global distribution of different types of climates is associated with the biosphere in the continents, flora, fauna, and ecosystems. Human activity has also adapted according to the climate's spatial distribution and seasonality.

The global distribution of climate diversity on the planet has led to the spatial organization of different types of human activities. Therefore, it is possible to find regions that are specialized in a type of crop, those that are characterized by certain cultural traits, or those that engage in different kinds of tourism. Trade patterns and even financial flows emerge among different regions of the planet as a result of this distribution of activities related to the production of goods and services.

Weather patterns may be repeatedly temporarily altered during phases of extreme climate variability, or they might be modified for long periods due to climate change. The alteration of these patterns can affect climate-ecosystem or climate-society relationships, resulting in potentially adverse socioeconomic effects.

FIGURE 2.

Global distribution of average annual temperature (top left), precipitation (center left), winds (bottom left), climates according to Köppen (top right) and terrestrial biomes according to vegetation (bottom right).



SOURCE: Taken from: https://los5oceanos.files.wordpress.com/2013/07/tempmediaanualesmundo.jpg (air temperature map) and https://agua.org.mx/wp-content/uploads/2017/02 Que-es-agua-mapa-mundial-precipitaciones.jpg (rainfall map); https://lageografia.com/wp-content/uploads/vientos-planeta-tierra.jpg(vientos),https://lostipos.net/wp-content/uploads/2018/03/K%C3%B6ppen-1_opt.jpg (Köppen weather) and De SirHenrry - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=49681202 (biomes according to vegetation).

1.1.3. Climate-Ecosystem and Climate-Society Relationship

Solar radiation plays a vital role in photosynthesis. The amount of solar energy that reaches the Earth's surface is regulated by climatic variables such as cloudiness which, in turn, is related to atmospheric pressure, wind, and precipitation.

Climatological variables affect the solar radiation energy available for photosynthesis. They also directly affect photosynthesis in the following way: air temperature regulates evaporation and plant transpiration (evapotranspiration); atmospheric pressure affects the rate of CO_2 exchange, and wind affects evapotranspiration. For this reason, there is a close relationship between climate and the different elements of the biotic medium (the biosphere), such as ecosystems.

The relationship between climate and biosphere is clearly evidenced in the relationship between climatic variables and vegetation. This relationship may easily be seen in **FIGURE 2**, by comparing precipitation distribution, climate types according to Köppen, and biomes. The different types of vegetation correspond to average annual temperature and humidity that leads to precipitation. Given that temperature varies latitudinally and altitudinally, and precipitation has geographic variations that can occur at the same latitude, there is a regional and altitudinal distribution of vegetation and biome types.

Due to the relationship between climate and vegetation, throughout the world, climates and biomes correspond closely. Different aspects of the biosphere may be considered to be interrelated. For example, in the humid tropical forest biome it is possible to find fungi, plants, and animals that live only in the humid or equatorial tropical climate.

Consequently, it should be noted that climate affects the development of human societies in the following ways:

- The climate-ecosystem relationship affects environmental functions/ecosystem services, which are resources or processes in natural ecosystems that benefit humans.
- Climate's influence on water availability affects flora and fauna (for hunting and fishing) and agricultural production, having a direct influence on food security.

- Climate creates conditions that affect human health or favor the abnormal proliferation of pests and carriers of human, animal, and plant diseases.
- Climate regulates the frequency of extreme weather events that can cause disasters.

The functioning of both ecosystems and human systems is related to established climatic conditions. Therefore, if the climate patterns change, it affects the climate-ecosystem-society relationship, which leads to impacts that can result in disasters.

These changes often appear in the form of climate anomalies, which is referred to as climate variability; whereas the modification of the predominant conditions is related to climate change.

Extreme phases of climate variability and climate change have varied impacts on ecosystems and society.

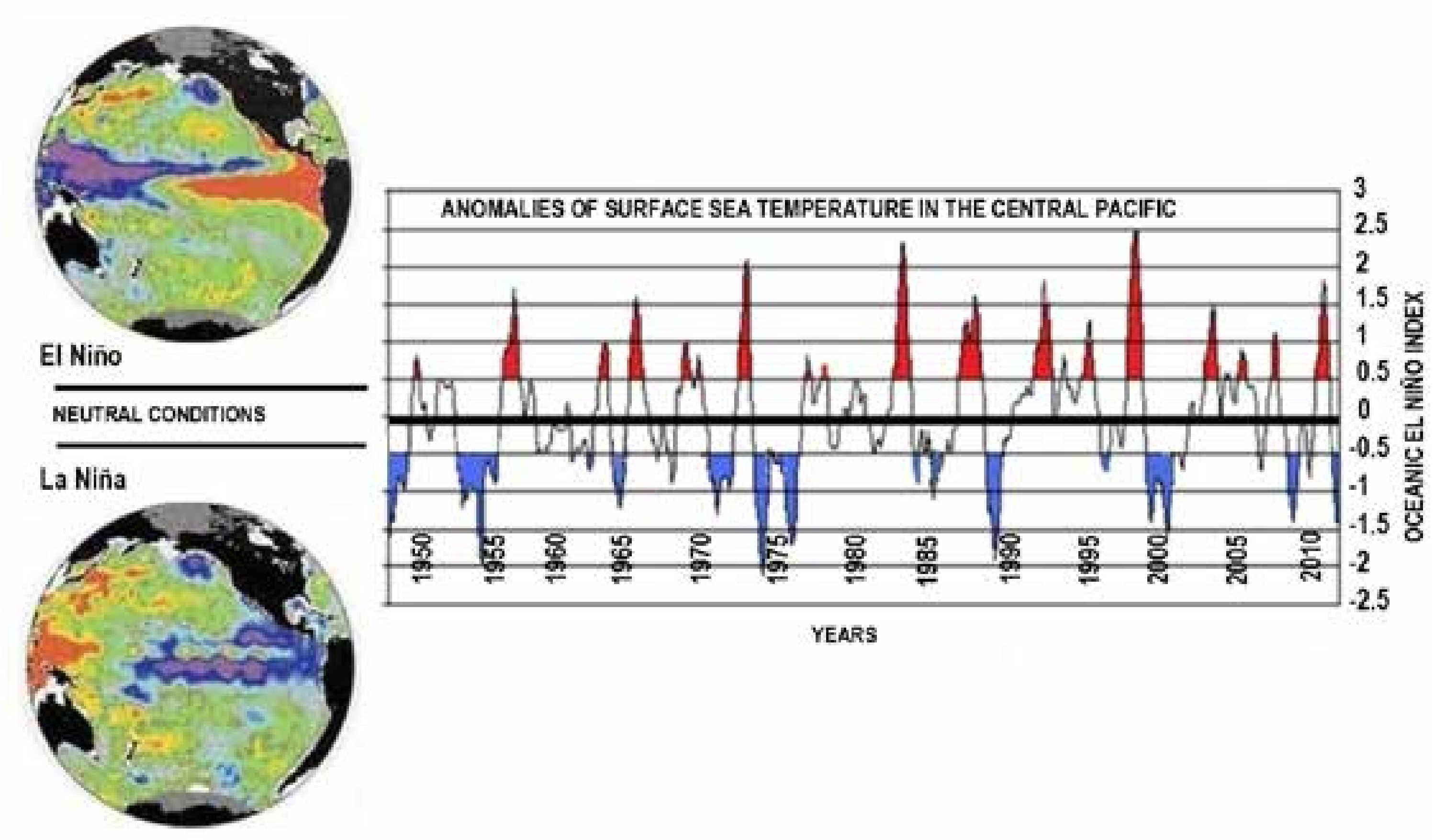
The magnitude of these impacts depends not only on the intensity of the hydroclimatic events, but also on the degree of preparedness or the capacity of the ecosystem or human system to cope with or withstand the crisis situation and recover, in other words, their degree of vulnerability to extreme events.

Therefore, to reduce the negative impacts of extreme hydroclimatic events, it is necessary to analyze the events themselves and also to assess the vulnerability of the human systems in the face of these events.

Given their different periodicities (extreme phases of climate variability recur in cycles of years or decades, whereas climate change is associated with slow changes, in cycles lasting centuries, millennia or even millions of years), the impacts generated by climate variability are different from those caused by climate change. For this reason, their analysis and the proposal of options to address them must be approached in different ways.

In this regard, it should be noted that impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure, due to the effects of climate change or dangerous climate events that take place during a specific period of time, and the vulnerability of the societies or systems that are exposed to these (IPCC, 2014).

FIGURE 3.
Distribution of surface temperature anomalies in the tropical Pacific Ocean during El Niño (top left) and La Niña (bottom left). Note: The right side shows the Oceanic Niño Index (ONI) for the period (1950-2010), illustrating the El Niño and La Niña phases that occurred during this timeframe (red indicates positive anomalies or temperatures above normal, blue and violet indicate negative anomalies or temperatures below normal).



SOURCE: Adapted by CIIFEN from information from the journal Ciencia y biología available at http://cienciaybiologia.com/biologia-marina/fenomeno-de-el-nino-y-la-nina

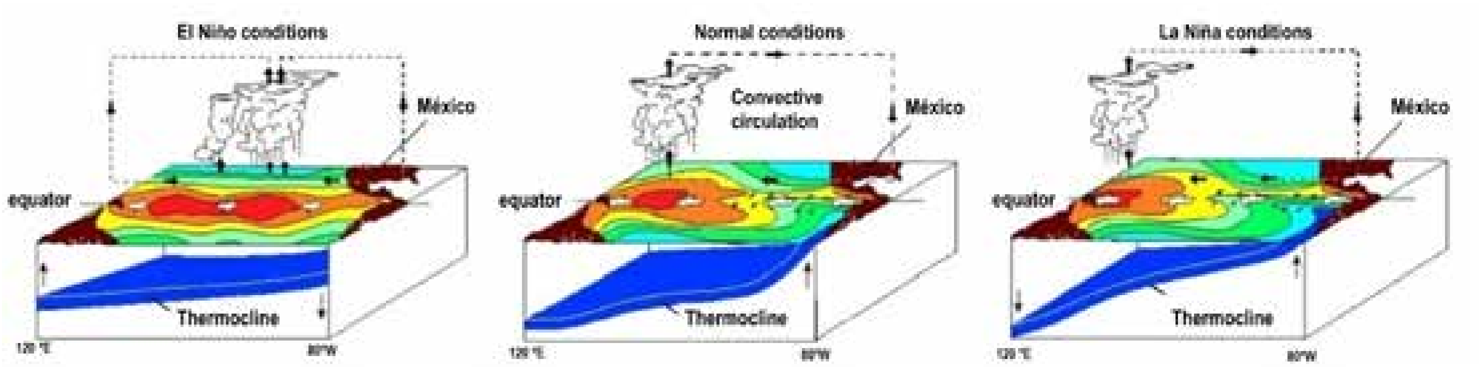
1.1.4. Climate Variability

Climate variability refers to fluctuations within the predominant climatic conditions observed over relatively short periods of time. These oscillations are observed in cycles of months (intra-seasonal climate variability), years (inter-annual climate variability), or decades (inter-decadal climate variability) and can reach extreme magnitudes that manifest in marked climatic anomalies in a region. It may easily be seen that, in a given year, if the rainy season brings almost no rain, drought is observed; whereas in other years the season might be very rainy, with frequent storms and disastrous floods. The repetition over time (recurrence) of these anomalies is known as climate variability **(FIGURE 3)**.

Variability may be evaluated quantitatively by comparing the current climate (monthly records of air temperature or precipitation, for example) with the predominant average (usually the average over 30 years).

By doing this comparison, climatic anomalies can be detected (in air temperature or precipitation, for example), indicating climate variability.

FIGURE 4.
Changes in atmospheric circulation over the Tropical Pacific and rainfall location due to El Niño (left), under normal conditions (center) and during La Niña (right).



SOURCE: Adapted by CIIFEN from information available at: http://www.eorc.jaxa.jp/trmm/about/result/earth/elnino_e.htm
(Note: The figure shows the thermocline: an imaginary line that separates two masses of water of different temperature.)

Fluctuations in the amount of solar energy reaching the planet are one cause of these climatic anomalies. Events that are taking place in different parts of the planet also have impact, such as the cycles known as El Niño and La Niña in the Pacific Ocean, as shown in **FIGURE 4**. Another cause of climatic anomalies is the Tropical Atlantic dipole, which refers to a pattern in sea surface temperature (SST) in the northern and southern Tropical Atlantic Ocean.

When one phase or the other of these processes occurs, the climate of any given region of the planet exhibits anomalies, for example, it might receive more rainfall or less rainfall than normal (depending on the region).

The Tropical Atlantic sea surface temperature (SST) dipole is an ocean phenomenon that sometimes causes the North Tropical Atlantic Ocean to be warmer than normal and the South Tropical and Equatorial Atlantic to be cooler than normal, whereas at other times the situation is reversed. This ocean phenomenon has particularly significant impacts in South America and Africa **(FIGURE 5)**.

As takes place with El Niño and La Niña in the Tropical Pacific, the extreme phases of the Tropical Atlantic dipole affect atmospheric pressure and circulation and, in this way, they cause anomalies in air temperature and precipitation in different regions.

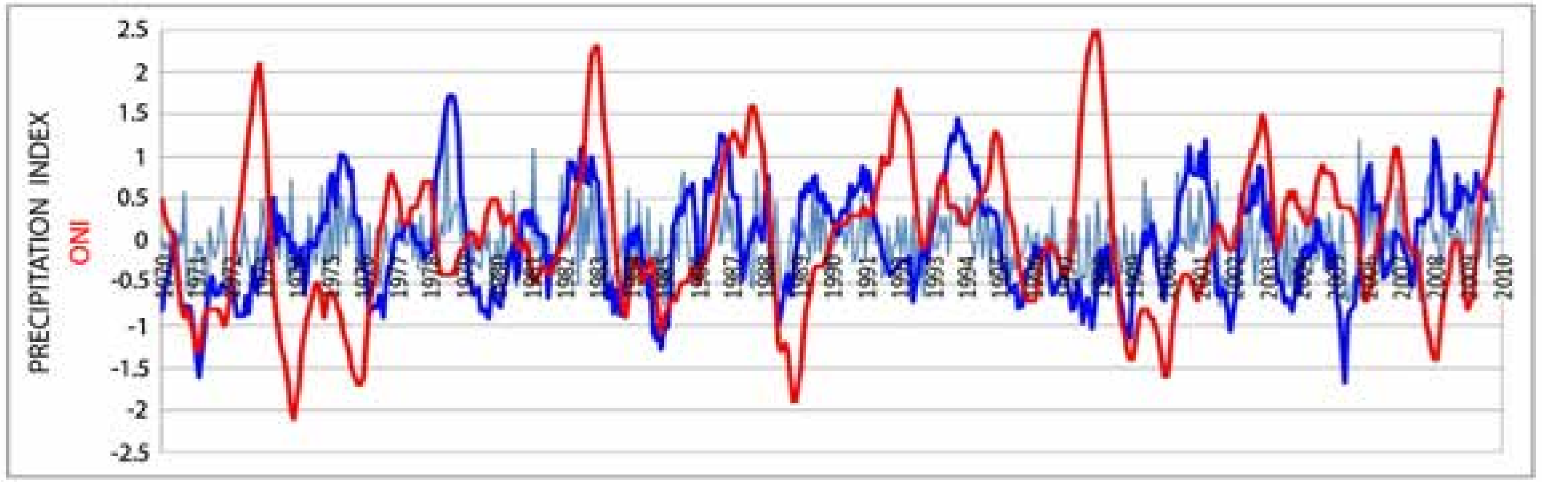
In summary, different recurrent (or cyclical, but not necessarily periodic) phenomena take place in the climate system, which generate anomalies that–when reaching certain magnitudes–affect the ecosystems and the socioeconomic system of the regions, in varying ways and degrees.

1.1.5. Climate Change

As defined above, climate change is when the predominant conditions change over a long timeframe (centuries, millennia, etc.). An example of such a change is the long-lasting glacial–interglacial cycles that have occurred during the evolution of the planet: very cold periods (glacial phases) lasting thousands of years followed by warm periods (interglacial phases) of similar duration.

FIGURE 5.

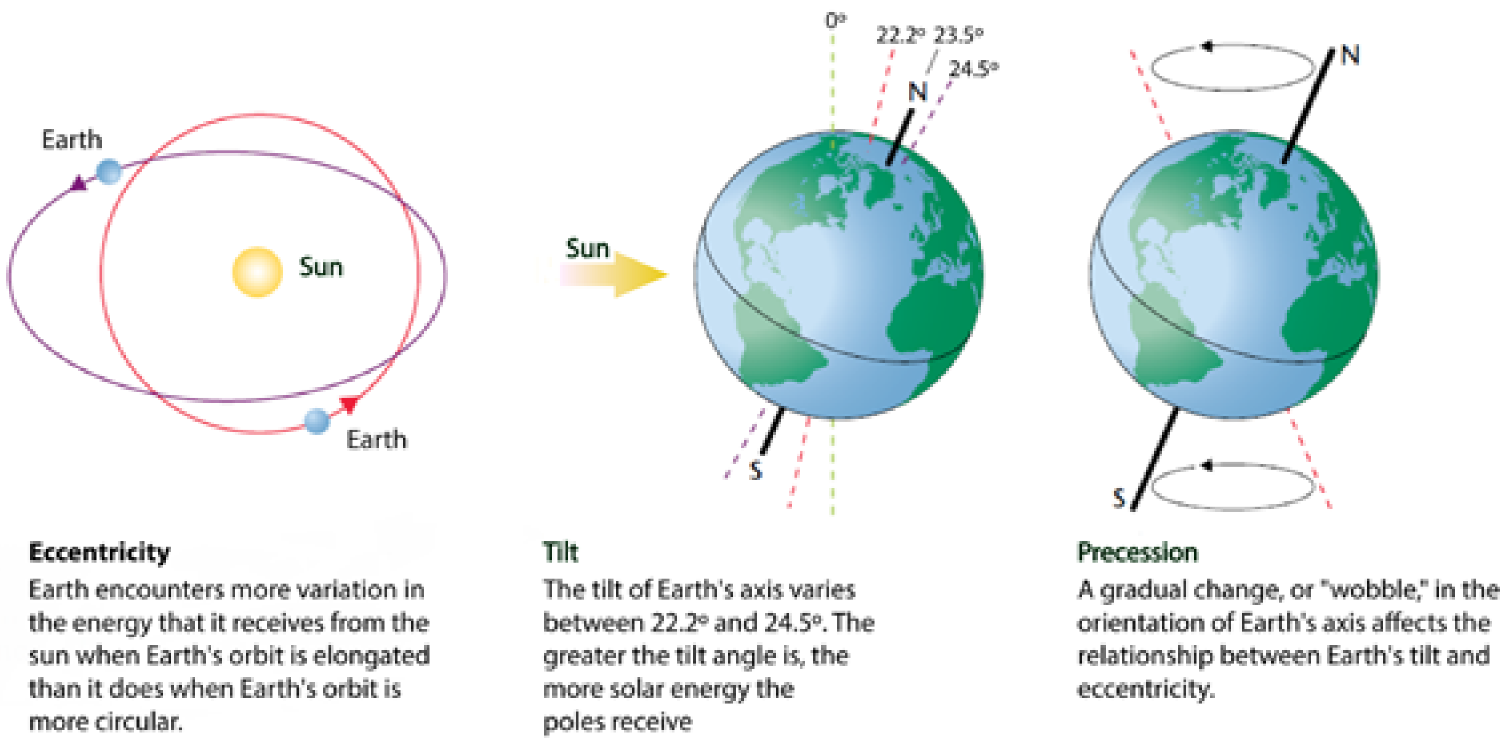
Phases of the Oceanic Niño Index (ONI) compared with precipitation anomalies recorded in Leticia (Colombia), in the western part of the Amazon Region.



PRODUCED BY: CIIFEN. **SOURCE:** IDEAM climatological data (2014).

FIGURE 6.

Milankovitch's theory that explains cycles of global climate change according to changes in the geometry of the Earth's orbit or the angle of the sun's rays on the planet.



SOURCE: Pabón (2011) and http://1.bp.blogspot.com/- AXtAZgfRRaM/UoeieH18pMI/AAAAAAAABQ0/M5zL0WdKEts/s1600/milankovitch_cycles+origin+grahamhancock+origin.png.

What processes cause these changes? They occur as a result of external factors, such as impacts by meteorites, long-lasting solar cycles, changes in the geometry of the Earth's orbit, and the angle that the sun's rays hit the Earth's surface, as illustrated by the Milanković theory in **FIGURE 6**. They also result from internal factors, such as continental drift (movements of the tectonic plates that support the continents), changes in atmospheric composition, interactions between components of the Earth's system, and anthropic processes.

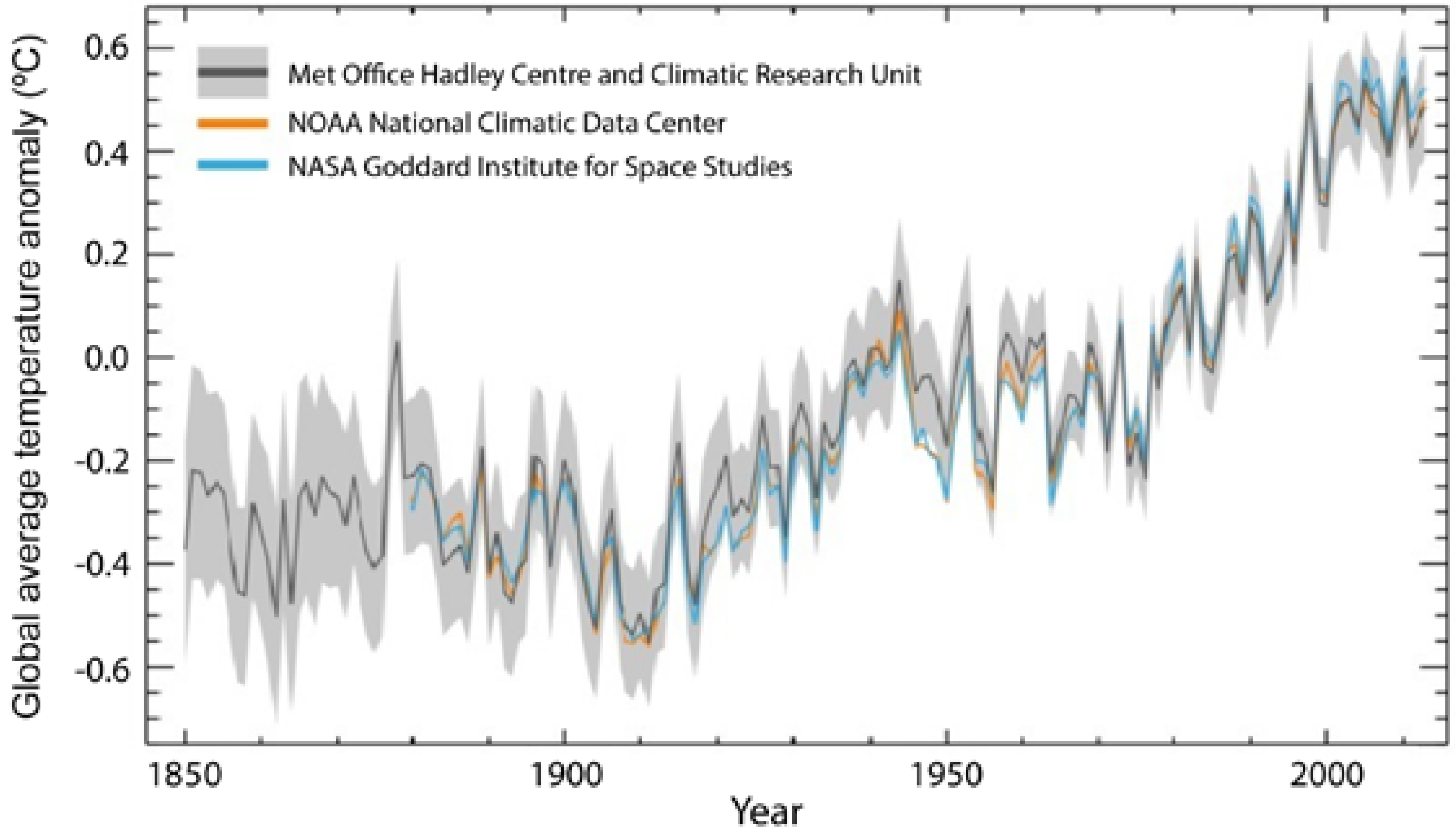
The engine that drives the climate is the solar energy that enters the Earth's system. Cycles in solar activity create corresponding cycles in the planet's climate. Milanković's[1] cycles explain how the Earth's position determines the planet's global climate. Changes come about as the result of the amount of energy that the Earth's surface receives. These were responsible for the glacial–interglacial periods recorded in the past, which occurred over periods of tens of thousands of years.

There are also climatic changes that have occurred over shorter periods of time (500-1,000 years) such as those that took place during the Holocene, the post-glacial period that began about 10,000 years ago, with the appearance of man, and is the era in which we are currently living. During the past 10,000 years, it is possible to see fluctuations that stand out in the context of the overall long-term cycle. For example, there was a cooling period that occurred around 10,500 years ago, a short warming period between about 10,000 and 9,000 years ago, and another cooling period about 8,000 years ago.

The amount of energy that reaches the planet is also regulated by long-term cycles of solar activity that are not as long-lasting, which generate cycles of shorter duration in the climate. Thus, for example, between the 10th and 12th centuries, there was high solar activity that caused the medieval warming period. In the period of the 15th to 18th centuries, there was low activity, which produced the cooling known as the Little Ice Age.

1. Serbian civil engineer, astronomer, mathematician, geophysicist, and developer of mathematical models on the Earth's orbital variations and the relationship with the distribution and seasonality of solar irradiance.

FIGURE 7.
Global annual average temperature anomalies for 1850-2015 (relative to 1961-1990).



SOURCE: The Global Climate in 2011–2015, World Meteorological Organization, 2016; **FIGURE 1**, page 6. https://public.wmo.int/en/resources/library/global-climate-2011%E2%80%932015.

When the number of solid particles suspended in the atmosphere increases, these intercept more radiation. The layer in which these particles are found heats up, and cooling simultaneously takes place on the Earth's surface. In addition, if marine currents change their average course over a long period, this also causes changes in the climate.

In short, various causes of climate change have been occurring naturally throughout the planet's history. Human beings appeared on Earth relatively recently; in the last 10,000 years, the period known as the Holocene. In that short time, they have managed to organize as a society and create a new sphere: the anthroposphere.

The need for space, food, and energy means that, as society develops, it transforms the environment because human activity affects the radiation balance that underlies the planet's climate. Human activity, which affects global climate, is a new factor within the planet's ecosystem. This activity is causing signs of climate change that historically have not occurred in the Earth's evolutionary process, and it is taking place in addition to the other factors that cause changes.

Over the last three centuries, human activity has intensified and its effect on the climate has increased. The burning of fossil fuels for energy and the transformation of the Earth's surface are causing changes in the composition of the atmosphere by increasing greenhouse gases (carbon dioxide and methane) and aerosols, which alter the radiation balance of the Earth–atmosphere system. Due to the increase in greenhouse gases, the atmosphere is warming worldwide, in addition to the warming that has been occurring since the end of the 19th century.

Between 1906 and 2005, the global average air temperature increased by almost 0.74 °C (a range between 0.56 and 0.92 °C). Over the last 50 years, the rate of increase has accelerated and is now almost twice what it was 100 years ago **(FIGURE 7)**. It is also possible to state that the last 12 years have been the hottest years on record since 1850, when this measuring began. The 2007 Climate Change Report by the Intergovernmental Panel on Climate Change (IPCC) determined that this warming has been greatest on the continents, at middle and high latitudes.

Changes in precipitation trends have been recorded across different parts of the world. For example, between 1990 and 2005, a significant increase was detected in the eastern parts of North and South America, northern Europe, and northern and central Asia; whereas during the same period a decrease was observed in the Sahel region, the Mediterranean, southern Africa, and parts of southern Asia. An increase in heavy rainfall events was also noted in several regions of the world, while in others there has been a decrease in rainfall.

Looking at different projections for future scenarios, IPCC (2013) estimates that towards the end of the 21st century (2090-2099), the global average air temperature will be 1.8 to 4.0 °C higher than what was observed at the end of the 20th century (1980-1999). Precipitation will be very likely to increase at high and middle latitudes and decrease in the subtropical zone. These changes would have a direct impact on the regions and their socioeconomic sectors.

FIGURE 8.
Classification of extreme meteorological and hydroclimatic events.

TIMEFRAME		
minutes-hours-days	months-years	centuries-millennia
WEATHER Extreme meteorological events	**CLIMATE** Extreme hydroclimatic events	**PLANET-WIDE** Long-term events
METEOROLOGICAL Intense rainstorms, hailstorms, windstorms, lightning, fog, tornados, cyclones, tropical storms, hurricanes **HYDROMETEOROLOGICAL** Flashfloods, overflows **HYDRO-GEOMPHOLOGICAL** Landslides, dust storms, sandstorms **METEOMARINE** Swells, storm tides **METEO-PYROECOLOGICAL** Wildfires	**CLIMATOLOGICAL** Long-term droughts, floods Extreme phases of climatic variability	**GLOBAL CHANGES** Atmospheric warming Ocean warming Ocean acidification Rising sea level Climate change Changes in vegetation cover
METEOROLOGY	**CLIMATOLOGY**	**INTEGRATED EARTH SCIENCES**

SOURCE: IPCC (2012a) and Pabón 2012).

1.1.6. Threats, Vulnerability, and Risk Associated with Extreme Meteorological and Hydroclimatic Events

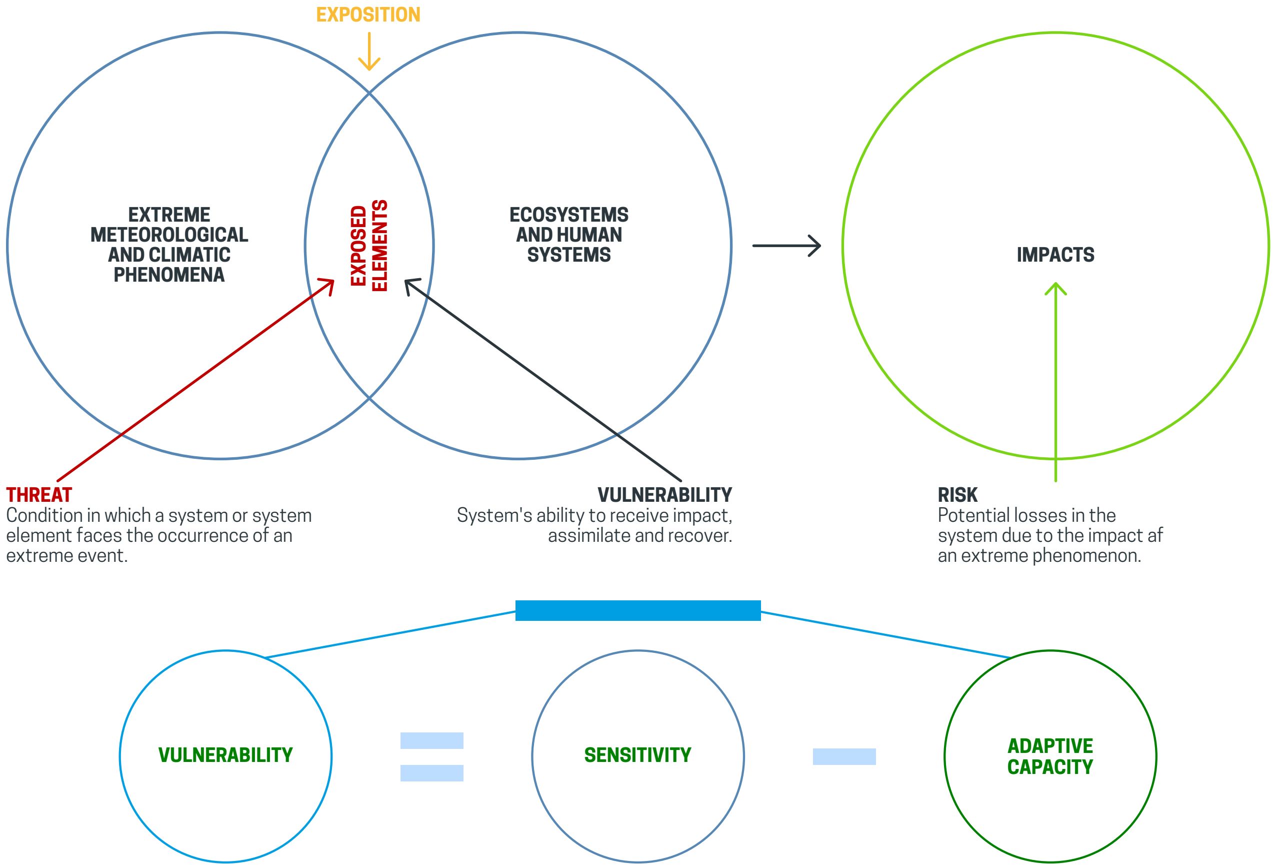
Atmospheric and climatic processes occasionally produce extreme events. Although these extreme events are interrelated, given the difference between weather and climate, detailed analysis is required to determine whether an event should be classified as a meteorological event or a climatological event. **FIGURE 8** presents the classification of extreme meteorological and hydroclimatic events. The differences of scale between the events makes clear the need for different strategies when analyzing and responding to them.

In the interrelationship between meteorological and climatological categories, climate defines the type of meteorological events that occur in a specific location or region during a certain time of the year. For this reason, there are regions where the characteristics of the climate lead to a very particular annual cycle because of the frequency of certain extreme meteorological events. It is also possible to observe that, in some years, certain extreme events are more frequent than normal (more frequent than the average annual cycle), while in other years, said frequency is lower.

In recent decades, changes in climate have impacted natural and human systems on all the continents and oceans (IPCC, 2014). Extreme weather and climate events and climate change can have negative impacts on human and natural systems. These impacts result from the interaction of dangerous climatic events in a given period of time, and the vulnerability of the systems exposed to them. When extreme events take place in a region, they impact the elements that exist in that region and can give rise to disasters. **(FIGURE 9)**.

Currently, the conceptual framework of climate disaster risk theory is being used to analyze the event–impacted system–disaster sequence. Developments in this theory have led to the establishment of the concepts of threat, exposure, and vulnerability, which may be used theoretically and conceptually to describe situations involving negative impacts and disasters.

FIGURE 9.
Illustration of the extreme event-impacted system-disaster sequence, its conceptualization for analysis, and breakdown of the concept of vulnerability.



SOURCE: IPCC (2012a) and Pabón (2012).

FIGURE 9 shows the interaction between the factors that constitute risk: threat, exposure, sensitivity, and vulnerability.

This conceptual framework describes the concepts represented in **FIGURE 9**. Risk is considered as the potential negative impact that an extreme event could cause, which is measured in terms of probability of loss or damage.

"Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems" (IPCC, 2014).

"The term hazard usually refers to climate-related physical events or trends or their physical impacts." In the context of climate, it is related to extreme weather and climatic events, and climate change (IPCC, 2014).

Exposure refers to the "presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" (IPCC, 2014).

Vulnerability refers to the intrinsic characteristics of a system or its elements that give it the propensity or predisposition to be adversely affected. Its definition encompasses sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Sensitivity is the "degree to which a system is affected, either adversely or beneficially, by climate variability or climate change" (IPCC, 2014).

Adaptive capacity refers to the "ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014).

1.2. Methodology

1.2.1. Study Area

The study area covers the Amazonian territory[2] of the eight Amazon Cooperation Treaty Organization (ACTO) member countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela.[3]

Historically, a variety of options have been used, with different justifications, to delimit the Amazon Region, as may be seen in different documents and existing bibliographical sources. In its maps, the Atlas uses the administrative limits established by the ACTO member countries, as well as the geographical, ecological, and biological characteristics seen in the tropical biome, the Guiana shield, the Brazilian shield, and the Amazonian plains.

The study area was delimited by combining the set of boundaries seen in the bibliographic sources related to the Amazonian biome (biogeographic limits[4]), the Amazon River basin (hydrographic limits[5]), and the political-administrative area defined by each country (Amazon Region[6]) See **MAP 1. LIMITS OF THE AMAZON REGION**.

According to the unified criteria, the Amazon Region covers an area of 7,918,682.31 km² located between 9°N and 21°S and 44°W and 80°E in the northern and central part of South America. Its altitude ranges from 5,597 meters above sea level (masl) in the Andes to 0 masl at the mouth of the Amazon River on the Atlantic Ocean.

2. The definition of the study area for the Atlas of Hydroclimatic Vulnerability of the Amazon Region follows the criteria set forth in article 2 of the Amazon Cooperation Treaty (ACT), including the territory corresponding to the Casiquiare-Negro River tributary (53,311.16 km²) in the Bolivarian Republic of Venezuela.

3. Part of the Amazon biome is in French Guiana, but that country is not a member of ACTO.

4. Amazon Geo-referenced Socio-environmental Information System, RAISG, https://www.amazoniasocioambiental.org/en/maps/

5. SO HYBAM (https://hybam.obs-mip.fr/); Brazil. National Water Agency; Peru. National Water Authority and Ministry of Agricultural Development and Irrigation of Peru.

6. National contact groups in Brazil, Colombia, Ecuador, Guyana, Peru, and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Venezuela: Simon Bolivar Geographic Institute (http://www.igvsb.gob.ve).

The Amazon River Basin strictly speaking (shown in blue on **MAP 1**), covers an area of 6,118,000 km², according to the results presented in the Strategic Action Program, by the ACTO/UNEP/GEF Amazon-Water Resources and Climate Change Project, which has been validated by ACTO's member countries.

MAP 2. LIMITS OF THE STUDY AREA (INCLUDING THE AMAZON HYDROGRAPHIC NETWORK).

1.2.2. Methodological Aspects of Producing the Atlas

The Atlas was produced in four phases:

1] Biogeophysical description, which includes the characteristics of the biological, geographical, and physical environment of the Amazon Region.

2] Analysis of hydroclimatic threats.

3] Assessment of vulnerability to extreme hydroclimatic events: sensitivity and adaptive capacity; assessment and analysis of vulnerability.

4] Creation of the Atlas of Hydroclimatic Vulnerability of the Amazon Region.

In the description phase, bibliographic and cartographic information was collected in order to develop a biophysical and socioeconomic description to determine the current state of the Amazon Region.[7]

To analyze the threats, the most frequent hydroclimatic events in the Amazon Region, which affect ecosystems, populations, and their activities, were identified.

7. The information was provided by ACTO's national contact groups in Brazil, Colombia, Ecuador, Guyana, Peru, and Suriname, plus Bolivia: GeoBolivia (http://geo.gob.bo/) and Venezuela: Simon Bolivar Geographic Institute (http://www.igvsb.gob.ve).

Having identified the hydroclimatic threats, the populations, livelihoods, and biophysical conditions of the Amazon Region were defined for consideration as subjects of analysis or exposed elements to study. Indicators of sensitivity and adaptive capacity were then developed to assess socioeconomic and biophysical vulnerability to hydroclimatic events (CIIFEN, 2018).

Finally, maps were prepared, illustrating the characteristics of the Amazon Region, analyzing hydroclimatic threats, showing socioeconomic sensitivity and adaptive capacity, and the results of the vulnerability analysis.

FIGURE 10 illustrates the process that was followed in this study.

FIGURE 10.
Workflow for the creation of the Atlas of Hydroclimatic Vulnerability of the Amazon Region.

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: CIIFEN, 2018.

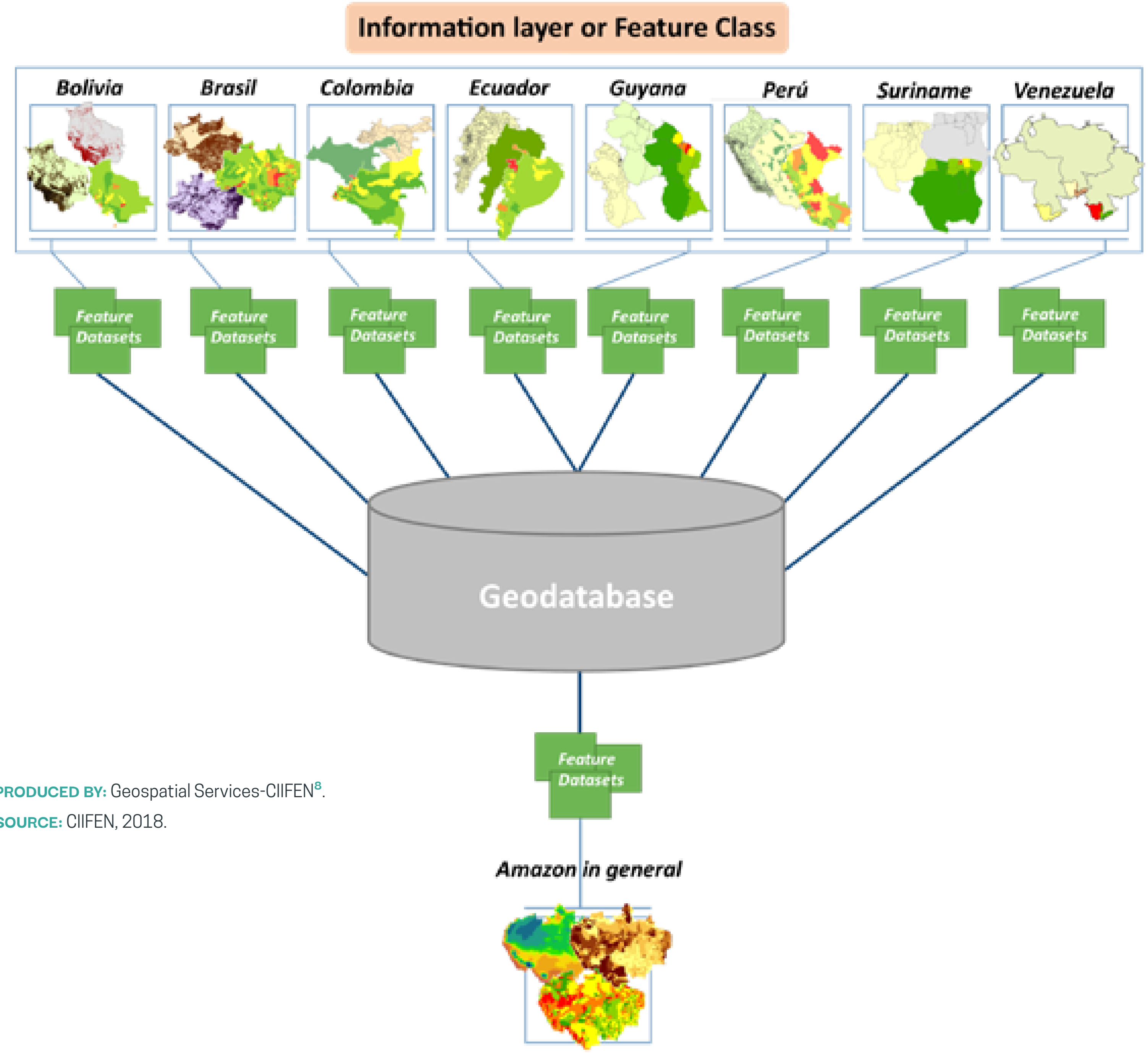
1.2.3. Socioeconomic and Biophysical Description

1.2.3.1. Compilation of the Information and Creation of the Geodatabase

The bibliographic information used to analyze the Amazon Region came mainly from studies done in the region concerning climatic variability, risk of disasters from adverse events, human dynamics in the region, and biophysical characteristics. Much of the information used had a regional context, although some hydroclimatic studies referred to individual countries or the entire Amazon Region.

The information used in the socioeconomic and biophysical description included climatological data, basic cartography, and statistics on different subjects, gathered from different sources, such as: geoportals of state institutions, free access websites, as well as contributions from the project's contact groups in each country, and CIIFEN's cartographic information. Statistical information from the census data for each country was obtained in table format using REDATAM software, (developed by ECLAC for local and regional analysis and mapping of census and polling data), and later linked to each country's census cartography.

FIGURE 11.
Geodatabase Structure.



PRODUCED BY: Geospatial Services-CIIFEN[8].
SOURCE: CIIFEN, 2018.

The cartographic information was organized and saved in a geographic database through ArcGIS (program for creating and managing Geographic Information Systems). The units of measurement and the projection for each file were then assigned using the open source program PostGreSQL.

FIGURE 11 shows how the geodatabase (geographic database) for the Atlas was created.

8. Note on Venezuela: For the Bolivarian Republic of Venezuela, data on the Casiquiare and Negro River tributary in Venezuela's Amazon Region were taken into consideration.

1.2.3.2. Spatial Analysis Unit

The spatial analysis unit is the smallest unit or territorial division used in the data on which this study is based and therefore, to which the results on vulnerability refer.

For each country, mid-level political-administrative districts were used as the units for the socioeconomic description and vulnerability analysis of the Amazon Region, as presented in **TABLE 1**.

For the biophysical description, the spatial unit was the basin or hydrographic unit, according to Pfafstetter, Level 4 (CAN, 2008).

TABLE 1.

Political-administrative divisions used in the Atlas.

Country	Political-administrative division
Bolivia	Province
Brazil	Municipality
Colombia	Municipality
Ecuador	Canton
Guyana	Neighbourhood Council
Peru	Province
Suriname	District
Venezuela*	Municipality

PRODUCED BY: Geospatial Services-CIIFEN.

SOURCE: Geospatial information provided by: ACTO's national contact groups.[9]

1.2.3.3. Construction of the Socioeconomic Maps

Socioeconomic maps were constructed with census information from the websites of the official statistics and census institutes[10] of each ACTO member country. Data was downloaded as Excel or database tables, and then linked to the geographic area or unit of analysis for each country.

It should be mentioned that socioeconomic data for each country were taken from the most recent population and housing census that was available in 2012. This made it possible to do a qualitative analysis, given that the censuses were not taken or published during the same years, as shown in the following table:

TABLE 2.

Last census year for ACTO member countries.

Country	Census
Bolivia	2012
Brazil	2010
Colombia	2005
Ecuador	2010
Guyana	2012
Peru	2007
Suriname	2012
Venezuela	2011

PRODUCED BY: Geospatial Services-CIIFEN

SOURCE: Geospatial information provided by ACTO's national contact groups.[11]

The population characteristics analyzed were:

- Total population
- Population density
- Indigenous population
- Population growth (last two censuses)
- Population by age group
- Age dependency index
- Illiteracy rate
- Poverty due to Unsatisfied Basic Needs -UBN
- Economic activities
- Economically Active Population (EAP) working in farming
- Economically Active Population (EAP) with alternatives to farming

9. ACTO contacts in: Brazil, Ecuador, Colombia, Guyana, Peru, and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Venezuela: Simon Bolivar Geographic Institute (http://www.igvsb.gob.ve) and CIIFEN database.

* For the Bolivarian Republic of Venezuela, data on the Casiquiare and Negro River tributary in Venezuela's Amazon Region were taken into consideration.

10. Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

11. ACTO contacts in: Brazil, Ecuador, Colombia, Guyana, Peru, and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Venezuela: Simon Bolivar Geographic Institute (http://www.igvsb.gob.ve) and CIIFEN database.

* For the Bolivarian Republic of Venezuela, data on the Casiquiare and Negro River tributary in Venezuela's Amazon Region were taken into consideration.

Information on other types of social infrastructure, such as:

- Healthcare facilities
- Educational establishments
- Main and secondary roads
- Waterways
- Electrical Infrastructure

1.2.3.4. Construction of the Biophysical Maps

The biophysical maps were constructed from basic cartography and thematic maps provided by ACTO's contact groups, in addition to information found on the official portals of state institutions in some countries.[12]

The biophysical characteristics analyzed were:

- Relief
- Soil taxonomy
- Soil texture
- Soil suitability for agriculture
- Mean annual temperature
- Annual precipitation
- Real evapotranspiration
- Water balance
- Köppen's Climate Classification
- Vegetation type
- Ecoregions
- Main hydrographic network
- Level 4 hydrographic units

12. Bolivia: GeoBolivia (https://geo.gob.bo/portal/); Brazil: National Water Agency (https://www.ana.gov.br), Ministry of the Environment (https://www.mma.gov.br/); Ecuador: Military Geographic Institute (www.igm.gob.ec), National Information System (https://sni.gob.ec), Ministry of Public Works (https://www.obraspublicas.gob.ec), Water Secretariat (https://www.agua.gob.ec); Venezuela: Simon Bolivar Geographic Institute of Venezuela.

Maps were constructed with climate information, such as: mean annual temperature, annual precipitation, real evapotranspiration, and water balance, using historical data on temperature and precipitation.

1.2.3.5. Construction of the Climate Maps

To create the climate maps, data from meteorological stations on precipitation and average temperature[13] were used. The data were optimized using global models, such as the average precipitation map. In the case of temperature, the values used were adjusted with Digital Elevation Model (DEM) data.

1.2.3.5.1. Annual Precipitation

Average precipitation data were obtained from meteorological stations operated by the meteorological and hydrological services in the region, and complemented with information from the Tropical Rainfall Measurement Mission (TRMM)[14] databases (NASA, 2013). For this purpose, a grid was created of 11,125 points, showing precipitation in millimeters, with a resolution of 30 km (distance between points). Previously selected climatological stations were added to this grid, for a total of 11,276 points. The kriging geostatistical interpolation method was applied, with a spatial resolution of 500 m, resulting in the final monthly and annual precipitation maps for the Amazon Region.

TRMM precipitation data are given in mm/h, which required conversion to obtain the data in mm/month. The following conversion was applied:

$$P._{monthly} = P._{hour} * h * d$$

Where:

$P._{monthly}$ = monthly precipitation

$P._{hour}$ = precipitation in millimeters per hour

h = number of hours per day

d = average number of days per month

13. In this first study, neither the deforestation rate nor the land use rate has been considered. These are relevant variables that will be addressed in a future edition of the Atlas.

14. https://pmm.nasa.gov/trmm.

1.2.3.5.2. Mean Annual Temperature

The mean annual temperature was obtained from the average of the mean temperatures recorded for each month of the year (Spain. National Geographic Institute, 2020). The mean temperature was calculated using the maximum and minimum temperatures recorded at the weather stations operated by the meteorological and hydrological services in the area of study (CIIFEN, 2014). After obtaining the mean temperature value for each station, the mean temperature estimate based on the Shuttle Radar Topography Mission (SRTM) of 500 m (pixel size) was added, from which the final mean monthly and annual temperature maps were generated for the Amazon Region.

The calculation was done by applying a correlation model and regression equation between the existing mean temperature information for each station, its altitude, and the DEM (Alarcón and Pabón, 2013). The following equation was used:

$$T°C = \frac{h-a}{b}$$

Where:

$T°C$ = average temperature in degrees centigrade

h = elevation above sea level (DEM)

a = axis ratio (temperature and elevation)

b = intersection of the slope (temperature and elevation)

1.2.3.5.3. Real Evapotranspiration

Evapotranspiration was calculated using the method proposed by Turc (Sánchez San Román, 2001), applying the following formula with spatial information:

$$ETR = \frac{P}{\sqrt{0.9 + \left(\frac{P^2}{L^2}\right)}}$$

Where:

ETR = real evapotranspiration

P = precipitation (mm)

L = $300 + 25T + 0.05T^3$

T = temperature in °C

1.2.3.5.4. Water Balance

Water balance was calculated using annual precipitation and real evapotranspiration, applying the following formula (UNESCO, 1981):

$$P_a - ETR$$

Where:

P_a = annual precipitation

ETR = real evapotranspiration

1.2.4. Methodology for the Analysis of Hydroclimatic Threats

Extreme hydroclimatic events were identified by calculating the Standard Precipitation Index (SPI), then counting the frequency of events that surpassed the established thresholds, qualifying them as extreme.

The SPI is based on the analysis of the difference between the standard deviation and the average in a large set of precipitation data. Most SPI values range from -3.0 to 3.0, where negative values indicate a precipitation deficit compared with normal volumes for the region, and positive values indicate excesses. Therefore, lows and highs on this index indicate extreme drought and precipitation events. This index has become important for analyzing climatic extremes in the region, and has been widely used to study drought (Vicente-Serrano et al., 2012; Edwards and McKee, 1993). It can also be used to analyze the opposite extreme phase, periods of heavy rainfall, allowing inferences to be drawn about flooding; in the latter case the flood zone map was also used.

Given that extreme hydroclimatic events are anomalies that occur over a prolonged period, lasting longer than the rainy or dry season, SPI was calculated at six-month intervals (SPI6), using data from the period 1979-2014, downloaded from the library of the International Research Institute for Climate and Society (IRI, 2014), located at Columbia University, USA.

A historical analysis of hydroclimatic disasters in the Amazon Region, based on the countries' records from different sources, made it possible to identify the most common hydroclimatic events in the region, and which socioeconomic and biophysical elements were affected most strongly. What this study found, as shown below, is that droughts and floods have caused the biggest and most frequent disasters.

The extreme events identified were then classified into zones, showing the spatial distribution of event frequency in the Amazon Region. Having classified the events and exposed elements into zones, threat maps were produced for droughts and floods.

1.2.5. Methodology To Determine Vulnerability

Vulnerability was determined based on the definition used in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), in which vulnerability is understood as the capacity of a system to cope with the adverse effects of climate change, climate variability, and extremes, depending on its exposure, sensitivity, and adaptive capacity. The following formula was used:

Vulnerability = (Exposure + Sensitivity) - Adaptive Capacity

In the Atlas, exposure is considered to be separate from vulnerability, in keeping with IPCC's definitions. It is directly related to threat, in the sense that exposure and vulnerability to weather and climate events determine the impact and probability of disaster (disaster risk) (IPCC, 2012). In other words:

Risk = Threats X Exposure X Vulnerability

In producing the Atlas, the recommendation of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) was used, which considers that vulnerability is a function of sensitivity and adaptive capacity, as follows:

Vulnerability (V) = Sensitivity (S) - Adaptive Capacity (AC)

Sensitivity corresponds to the extent to which a system or species may be adversely or beneficially affected by climate variability or change. Adaptive capacity, in contrast, refers to all the factors that strengthen systems or species against the impacts of extreme events (IPCC, 2014).

Based on the above, two subjects of analysis (meaning, key elements to be studied) were identified, to determine the vulnerability of the Amazon Region. These subjects were: the socioeconomic system and the biophysical system.

1.2.5.1. Determining Vulnerability in the Amazon Region

Conceptual Aspects

The study examines vulnerability from a comprehensive perspective in which hydroclimatic vulnerability results from the combination of socioeconomic vulnerability and physical vulnerability, which makes it possible to establish the biophysical limitations of the territory in relation to the socioeconomic dynamics of the population. This was done by quantifying and establishing levels of vulnerability.

Vulnerability was examined, taking into account sensitivity and adaptive capacity, as mentioned above, considering the hydroclimatic events of floods and droughts, as presented in **TABLE 3**.

To calculate vulnerability to droughts or floods, all the sensitivity and adaptive capacity indicators were added together. This resulted in quantified vulnerability to droughts or floods for the socioeconomic and biophysical systems. The result was standardized and classified into five levels of socioeconomic and biophysical vulnerability.

This made it possible to produce maps showing the spatial distribution of socioeconomic and biophysical vulnerability to droughts and floods. The concept of integrated vulnerability was applied to produce the map of spatial distribution of integrated vulnerability to floods in the Amazon Region.

Technical Aspects

Indicators were selected from a list of approximately 50 variables. These were then summarized into 29 variables, according to the availability and consistency of spatial-statistical information from the ACTO member countries.

In order to use the indicators in the vulnerability formula, they were classified by the events being considered, that is to say as indicators of sensitivity or adaptive capacity to droughts or floods.

In order to standardize the data to make them comparable, they were put through a normalization process by applying the "min-max" method using the following formula (Hudrliková, 2013):

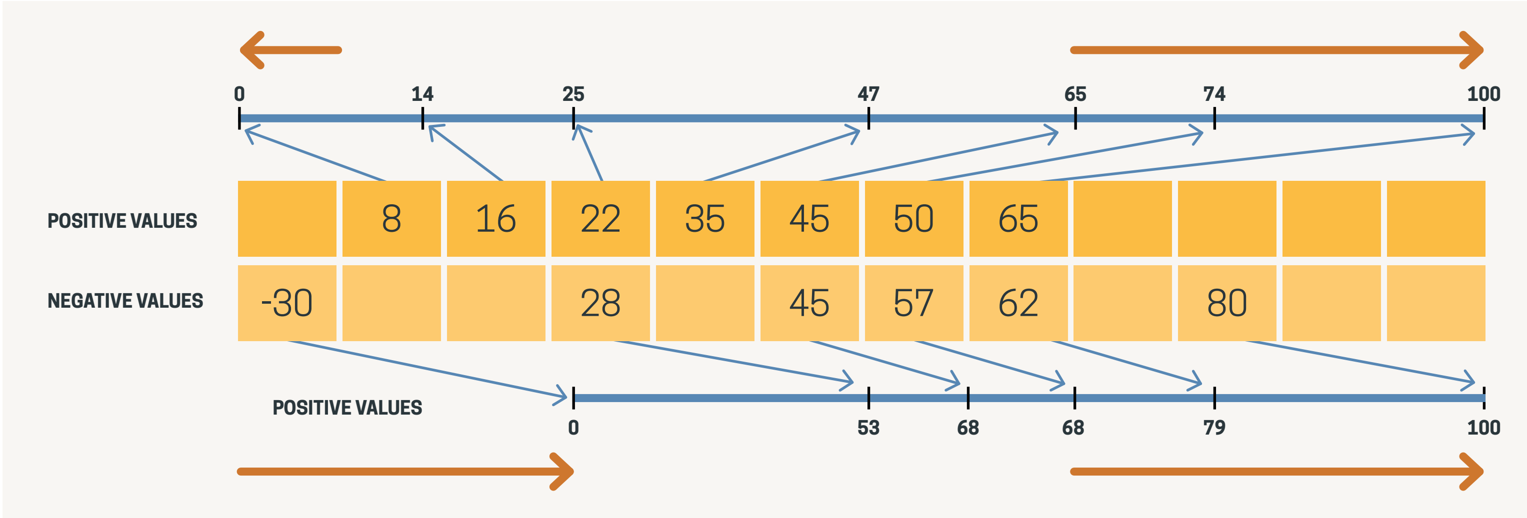
$$Val_N = \frac{Val_i - Val_{min}}{Val_{max} - Val_{min}}$$

Where:

Val_N = normalized value
Val_i = indicator value
Val_{min} = minimum indicator value
Val_{max} = maximum indicator value

In the min-max method, the minimum and maximum values in the dataset are set at 0 and 1, respectively, then the formula is used to rescale the rest of the data into the range [0.1]. In our process, data from the indicators was converted into a range from 0 to 100, where the lowest data value was assigned 0 and the highest data value was assigned 100. (FIGURE 12)

FIGURE 12.
Normalization of the Indicators



PRODUCED BY: Geospatial Services-CIIFEN. **SOURCE:** (CIIFEN, 2018).

1.2.5.1.1. Construction of Vulnerability Indicators for Socioeconomic Systems

The socioeconomic vulnerability indicators were constructed taking into account the sensitivity and adaptive capacity indicators listed in **TABLE 3**.

TABLE 3.
Types of vulnerability: variables and indicators for floods and droughts

Types	Variables	Indicators	Floods	Droughts
Vulnerability of socioeconomic systems	Sensitivity	Age dependency	X	X
		Agricultural activity	X	X
		Agricultural suitability	X	X
		Road network	X	
	Adaptive capacity	Presence of healthcare infrastructure	X	X
		Presence of educational infrastructure	X	
		Economic alternatives to agriculture	X	X
				X
Biophysical vulnerability	Sensitivity	Hydrographic network	X	X
		Terrain slope	X	X
		Soil texture	X	X
		Vegetation type	X	X

PRODUCED BY: ACTO. **SOURCE:** Geospatial Services-CIIFEN.

Sensitivity Indicators

Sensitivity Due to Age Dependency

The age dependency ratio was calculated from population data by age groups. This ratio relates the economically dependent population (under 14 and over 65) to the non-dependent population (between 15 and 64), which is considered economically active (Saad et al., 2008). To obtain the indicator, the following equation was applied:

AD = DP - NDP

Where:

AD = Age dependency
DP = Dependent Population
NDP = Non-Dependent Population

The age dependency indicator was assigned a vulnerability scale of 0 to 100, considering that the administrative districts with the largest numbers of dependents will be more sensitive to extreme hydroclimatic events than those where this number is lower. The following assessment was considered (**TABLE 4**).

TABLE 4.
Assessing sensitivity to droughts and floods due to age dependency.

Normalized value	Sensitivity to droughts	Sensitivity to floods
100 ↑ 0	Higher ↑ Lower	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

The indicator shows that the higher the age dependency index, the greater the burden that the dependent population exerts on the economically active population. The same assessment was considered for droughts and floods.

Sensitivity Due to Agricultural Activity

The economically active population (EAP) involved in agricultural activities is an indicator that affects the economic sensitivity of the region, given that agriculture is one of the most common activities practiced by the population of the Amazon Region. Thus, the more people who are involved in agricultural activities, the greater their level of sensitivity to the occurrence of an extreme event.

To calculate this measure, statistical, demographic, and economic databases from each country were consulted, from which data were extracted about the economically active population by occupation. Thus, the percentage of the population dedicated to agricultural activities was calculated with respect to the total EAP. The percentage was normalized between 0 and 100 to use in the vulnerability formula (**TABLE 5**).

TABLE 5.
Assessing sensitivity to droughts and floods due to agricultural activity.

Normalized value	Sensitivity to droughts	Sensitivity to floods
100 ↑ 0	Higher ↑ Lower	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN (2014).
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Sensitivity Due to Soil Suitability for Agriculture

Sensitivity due to the soil's suitability for agriculture was obtained based on the information about soil suitability and agricultural areas in the region.

The categories used in each country to rate soil suitability for agriculture were unified to create values between 1 and 4, as shown in **TABLE 6**.

TABLE 6.
Assessing soil suitability for agriculture.

Category	Assessment
Poor	4
Moderate	3
Good	2
Not suitable	1

PRODUCED BY: Geospatial Services-CIIFEN (2014).
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Based on each country's information on land use, areas with short-term crops, perennials, pasture, and forestry were identified. A general overlay of cultivated areas was generated, information that was later crossed with the abovementioned agricultural suitability overlay; thus obtaining the classification of the agricultural zones according to soil suitability by activity.

The assessment of sensitivity of agricultural areas was the same for droughts and floods, assuming that agricultural production is affected in both cases (**TABLE 7**).

TABLE 7.
Assessing sensitivity to droughts and floods by agricultural suitability

Normalized value	Sensitivity to droughts	Sensitivity to floods
100 ↑ 0	Higher ↑ Lower	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN (2014).
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Sensitivity Due to Road Infrastructure

This refers to the proportion of primary and secondary roads in relation to the area of the corresponding administrative districts. In order to calculate this measure, the length of the roads was added up, and that figure was multiplied by a factor assigned to the road's classification (2 for primary, 1 for secondary roads). Finally, the values obtained were added together for each administrative district. These values indicated vulnerability in the administrative district.

The indicator was applied to evaluate sensitivity to floods, considering that administrative districts with more roads have higher sensitivity in terms of road infrastructure exposure. Values were normalized between 0 and 100 **(TABLE 8)**.

TABLE 8.
Assessing sensitivity to floods by road infrastructure

Normalized value	Sensitivity to floods
100 ↑ 0	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Indicators of Adaptive Capacity

Adaptive Capacity Due to the Presence of Healthcare Infrastructure

The number of healthcare centers in a given region was considered an indicator of adaptive capacity. Values representing the number of healthcare centers were normalized between 0 and 100 to use in the vulnerability formula **(TABLE 9)**.

TABLE 9.
Assessing adaptive capacity to droughts and floods due to healthcare infrastructure

Normalized value	Adaptive capacity to droughts	Adaptive capacity to floods
100 ↑ 0	Higher ↑ Lower	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

This indicator was applied to both droughts and floods, using the same values for both.

Adaptive Capacity Due to the Presence of Educational Infrastructure

In emergency situations, schools are often used as shelters for people affected by floods (ISDR, 2008; ISDR/UN, 2004). In this sense, school infrastructure can be considered a means of adaptation to floods. For this reason, the number of schools was counted in each of the administrative districts.

The greater the number of educational establishments in a given location, the greater the capacity to adapt to floods. Values corresponding to the number of educational establishments were normalized between 0 and 100 to use in the vulnerability formula **(TABLE 10)**.

TABLE 10.
Assessing adaptive capacity to droughts and floods due to educational infrastructure

Normalized value	Adaptive capacity to floods
100 ↑ 0	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Adaptive Capacity Due to Economic Alternatives to Agriculture

Alternative economic activities were considered as a measure that demonstrates the population's ability to shift to other economic activities that do not depend on agriculture, as a means of subsistence in case of extreme hydroclimatic events (IPCC, 2012).

Some of the alternative economic activities considered were construction, trade, manufacturing, automotive, and administration, among others.

The assessment considered that the administrative districts with the greatest diversity of economic activities are those with higher capacity for adaptation. This value was normalized from 0 to 100 to use in the vulnerability formula **(TABLE 11)**. This indicator was applied for both droughts and floods.

TABLE 11.
Assessing adaptive capacity to droughts and floods due to alternative economic activities

Normalized value	Adaptive capacity to droughts	Adaptive capacity to floods
100 ↑ 0	Higher ↑ Lower	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Adaptive Capacity Due to Drinking Water Supply

Access to drinking water is one of the indicators in the Human Development Index (UNDP, 2014) and one of the main goals of the Sustainable Development Agenda 2030. Access to this resource is also considered to be a critical factor that supports adaptation to climate change, as a means of reducing vulnerability and increasing resilience (IPCC, 2014; UNDP, 2014).

Some sources of water are wells, waterholes, marshes, etc., but their storage capacity is susceptible to decreases due to the effects of droughts (FAO, 2013). Therefore, in order to determine the Amazon population's adaptive capacity to this event, access to drinking water was used as an indicator, based on the percentage of homes connected to the public water supply in each country's Amazon Region. This was examined in the administrative divisions for each country.

Adaptive capacity was assessed based on the criterion that areas with the highest number of dwellings connected to the public water supply have greater capacity for adaptation. The data obtained were normalized between 0 and 100 to use in the vulnerability formula (**TABLE 12**).

TABLE 12.
Assessing adaptive capacity to droughts due to public drinking water supply

Normalized value	Adaptive capacity to droughts
100 ↑ 0	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

1.2.5.1.2. Construction of Vulnerability Indicators for Biophysical Characteristics

The biophysical vulnerability indicators were constructed, taking into account the biophysical sensitivity indicators, as follows.

Sensitivity Indicators

Sensitivity of the Hydrographic Network

The result for each hydrographic unit was normalized between 0 and 100 to use in the vulnerability equation. The highest value (100) corresponds to the most sensitive hydrographic units, which are those that have a high density hydrographic network, which increases their sensitivity to flooding; while the lowest value (0) corresponds to those with less sensitivity.

When assessing the case of droughts, the opposite may be seen, indicating that hydrographic units with greater water supply have lower sensitivity to droughts than those with less water supply. **(TABLE 13)**.

TABLE 13.
Assessing sensitivity to droughts and floods due to water density

Normalized value	Sensitivity to floods	Normalized value	Sensitivity to droughts
100 ↑ 0	Higher ↑ Lower	0 ↓ 100	Higher ↑ Lower

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Soil sensitivity due to terrain slope is different for droughts and floods. In the case of droughts, steeper terrains are more sensitive as they have less capacity to retain water. In the case of floods, flatter terrains are more sensitive as they are more prone to flooding (FAO, 2009).

The assessments for each slope category, considering sensitivity to droughts and floods, are presented in **TABLE 15**.

The value was normalized between 0 and 100 to use in the vulnerability formula.

Sensitivity Due to Terrain Slope

The terrain slope (in percentage) was calculated by using the Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM), with a resolution of 500 meters. With this data, the terrain slope was calculated using Geographic Information Systems (GIS) (ESRI, 2014). Slope percentages were classified according to their gradient, considering the classes proposed by FAO (2009) in its soil description guide, used in studies of vegetation, erosion, irrigation, and drainage **(TABLE 14)**.

TABLE 14.
Classification of slopes gradients

Class	Description	%
01	Flat, level, and nearly level	0 – 1
02	Very slightly sloped	1.0 – 2.0
03	Slightly sloped	2 – 5
04	Sloped	5 – 10
05	Strongly sloped	10 – 15
06	Moderately steep	15 – 30
07	Steep	30 – 60
08	Very steep	> 60

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Adapted from FAO (2009).

TABLE 15.
Assessing sensitivity to droughts and floods due to terrain slope

Description	%	Droughts	Floods
Flat, level, and nearly level	0 – 1	1	8
Very slightly sloped	1.0 – 2.0	2	7
Slightly sloped	2 – 5	3	6
Sloped	5 – 10	4	5
Strongly sloped	10 – 15	5	4
Moderately steep	15 – 30	6	3
Steep	30 – 60	7	2
Very steep	> 60	8	1

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Sensitivity Due to Soil Texture

Based on the global classification of soils, sensitivity due to soil texture was assessed to determine vulnerability to droughts and floods (Batjes, 2011). The IPCC categories are presented in **TABLE 16**.

TABLE 16.
Soil texture categories in the Amazon Region

Texture
High-activity clayey soils
Low-activity clayey soils
Spodic soils (coarse texture)
Sandy soils
Volcanic soils
Wetland soils
Water

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Batjes (2011).

TABLE 17 shows the assessment of sensitivity to droughts and floods due to soil texture. It is assumed that soil texture is one of the factors that determines water filtration into the soil. Soils with finer textures (clayey) have higher water retention capacity because they are more plastic, and they make the terrain more prone to flooding. The opposite occurs with sandy soils that, having a thicker texture, allow water to drain more quickly into the soil (Gardi et al., 2014). This favors the occurrence of droughts due to the soil's lower capacity to retain water.

The values assigned to each category were normalized between 0 and 100 to use in the sensitivity formula.

Sensitivity Due to Vegetation Type

Vegetation was classified according to the vegetation's sensitivity to potential drought and flood events. The vegetation was categorized using the classification proposed by Sierra (1999), which is based on a synthesis of methodologies published for the classification of vegetation worldwide.

In the case of droughts, the farming sector, rainforests, and alluvial vegetation are the most sensitive because of their high water requirements and, therefore, have values between 4 and 5; bush vegetation and dry forests are ecosystems adapted to low rainfall patterns and, therefore, were assigned a value of 1 (**TABLE 18**).

TABLE 17.
Assessing sensitivity droughts and floods due to soil texture

Texture	Drought assessment	Flood assessment
High-activity clayey soils	2	5
Low-activity clayey soils	1	4
Spodic soils	3	3
Sandy soils	4	1
Volcanic soils	2	2
Wetland soils	1	5
Water	0	0

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

For floods, the highest sensitivity value is also found in the farming sector, as well as lowland deciduous forests and rainforests (TABLE 18).

The assessment considered the vegetation's sensitivity to droughts and floods.

1.2.5.2. Calculation of Vulnerability

Overall vulnerability was calculated by adding together the normalized values for the indicators of socioeconomic and biophysical sensitivity, minus adaptive capacity. The following formula was applied:

TABLE 18.
Assessing sensitivity to droughts and floods due to vegetation type

Vegetation by class	Assessment		Normalization	
	Drought	Flood	Drought	Flood
Farm land	5	5	100	100
Deciduous/dry lowland forest	2	4	40	80
Humid evergreen lowland forest (rainforest)	1	4	20	80
Semi-deciduous montane forest	3	2	60	40
Evergreen lowland forest	2	3	40	60
Evergreen lowland floodplain forest	2	1	40	20
Evergreen high montane forest	3	1	60	20
Evergreen lowland forest	3	2	60	40
Evergreen foothill forest	4	2	80	40
Bodies of water	0	0	0	0
Herbaceous lacustrine lowland	2	3	40	60
Humid lowland scrub	2	3	40	60
Humid montane scrub	3	1	60	20
Dry montane scrub	3	2	60	40
Snow-covered	0	0	0	0
Savanna	3	4	60	80
No vegetation	0	0	0	0
Urban	0	0	0	0
Vegetation in transition	4	4	80	80

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Vulnerability (V) = Sensitivity (S) - Adaptive Capacity (AC)

The results obtained for both drought and flood events were classified into five categories of vulnerability, ranging from very high to very low. Sensitivity and adaptive capacity were classified in the same way.

1.2.5.2.1. Calculation of the Vulnerability of Socioeconomic Systems

To calculate the vulnerability of the socioeconomic systems, the indicators on sensitivity to droughts and floods were used.

Floods

The formula for calculating total sensitivity of socioeconomic systems to floods was:

TSSSf = SADf + SFf + SASf + SRIf

Where:

- **TSSSf** = Total sensitivity of socioeconomic systems to floods
- **SADf** = Sensitivity due to age dependency, for floods
- **SFf** = Sensitivity due to farming, for floods
- **SASf** = Sensitivity due to agricultural suitability, for floods
- **SRIf** = Sensitivity due to road infrastructure, for floods

The formula for calculating total adaptive capacity of socioeconomic systems to floods was:

TACSSf = ACHIf + ACEIf + ACEAAf

Where:

- **TACSSf** = Total adaptive capacity of socioeconomic systems to floods
- **ACHIf** = Adaptive capacity due to healthcare infrastructure, for floods
- **ACEIf** = Adaptive capacity due to educational infrastructure, for floods
- **ACEAAf** = Adaptive capacity due to economic alternatives to agriculture, for floods

Droughts

The formula for calculating total sensitivity of socioeconomic systems to droughts was:

TSSSd = SADd + SFd + SASd

Where:

TSSSd	= Total sensitivity of socioeconomic systems to droughts
SADd	= Sensitivity due to age dependency, for droughts
SFd	= Sensitivity due to farming, for drought
SASd	= Sensitivity due to agricultural suitability, for droughts

The formula for calculating total adaptive capacity of socioeconomic systems to droughts was:

TACSSd = ACHId + ACEId + ACEAAd + ACDWSd

Where:

TACSSd	= Total adaptive capacity of socioeconomic systems to droughts
ACHId	= Adaptive capacity due to healthcare infrastructure, for droughts
ACEId	= Adaptive capacity due to educational infrastructure, for droughts
ACEAAd	= Adaptive capacity due to economic alternatives to agriculture, for droughts
ACDWSd	= Adaptive capacity due to drinking water supply, for droughts

Once sensitivity and total adaptive capacity were calculated, the latter was subtracted from the former.

A. Vulnerability of socioeconomic systems to floods

The formula for calculating the vulnerability of socioeconomic systems to floods was:

VSSf = TSSSf – TACSSf

Where:

VSSf	= Vulnerability of socioeconomic systems to floods
TSSSf	= Total sensitivity of socioeconomic systems to floods
TACSSf	= Total adaptive capacity of socioeconomic systems to floods

B. Vulnerability of socioeconomic systems to droughts

The formula for calculating the vulnerability of socioeconomic systems to droughts was:

VSSd = TSSSd – TACSSd

Where:

VSSd	= Vulnerability of socioeconomic systems to droughts
TSSSd	= Total sensitivity of socioeconomic systems to droughts
TACSSd	= Total adaptive capacity of socioeconomic systems to droughts

The result was normalized and classified into five levels of vulnerability, applying the Jenks natural breaks optimization method available in Geographic Information Systems (ArcGis).

1.2.5.2.2. Calculation of Biophysical Vulnerability

To calculate biophysical vulnerability, all of the biophysical indicators of sensitivity to droughts and floods of the Amazon Region were considered. This methodological approach considers sensitivity as an integral part of vulnerability, and that adaptive capacity is another characteristic of the natural environment (IPCC, 2014).

Floods

The formula for calculating total biophysical sensitivity to floods was:

TSBPf = SWHNf + STSf + SSTf + SVTf

Where:

TSBPf	= Total biophysical sensitivity, for floods
SWHNf	= Sensitivity due to hydrographic network, for floods
STSf	= Sensitivity due to terrain slope, for floods
SSTf	= Sensitivity due to soil texture, for floods
SVTf	= Sensitivity due to vegetation type, for floods

Droughts

The formula for calculating total biophysical sensitivity to droughts is:

TSBPd = SWHNd + STSd + SSTd + SVTd

Where:

TSBPd = Total biophysical sensitivity, for droughts
SWHNd = Sensitivity due to hydrographic network, for droughts
STSd = Sensitivity due to terrain slope, for droughts
SSTd = Sensitivity due to soil texture, for droughts
SVTd = Sensitivity due to vegetation type, for droughts

The result was normalized and classified into five levels of vulnerability, applying the Jenks natural breaks optimization method available in Geographic Information Systems (ArcGis).

1.2.5.3. Representing Vulnerability, Sensitivity, and Adaptive Capacity

The degree of vulnerability, sensitivity, and adaptive capacity was ranked on a scale of 1–5, according to the categorization established by CIIFEN (2018), and represented visually by a color scale, from red (very high) to green (very low), as shown in **FIGURE 13** (for vulnerability and sensitivity) and in **FIGURE 14** (for adaptive capacity).

FIGURE 13.
Color scale representing vulnerability and sensitivity

Value	Scale representing vulnerability and sensitivity	Color
5	Very high	
4	High	
3	Moderate	
2	Low	
1	Very low	

PRODUCED BY: Geospatial Services-CIIFEN. **SOURCE:** (CIIFEN, 2018).

FIGURE 14.
Color scale representing adaptive capacity

Value	Scale representing adaptive capacity	Color
5	Very high	
4	High	
3	Moderate	
2	Low	
1	Very low	

PRODUCED BY: Geospatial Services-CIIFEN. **SOURCE:** (CIIFEN, 2018).

2

Description of the Amazon Region

2.1. Biogeophysical aspects

The Amazon Region is home to biomes of global importance, such as tropical forests and rainforests, savannas, and alluvial forests, where there is great biodiversity of flora and fauna species. It also contains one of the biggest water systems on the planet, and acts as a sink for large amounts of carbon dioxide (CO_2). Additionally, it has great capacity to return oxygen (O_2) to the atmosphere, which is fundamental for life on Earth.

2.1.1. Relief (Orography)

The Amazon Region is dominated topographically by two plateaus of Precambrian origin (the longest era in the Earth's history): the Guiana shield, located in the northern hemisphere of the region, between Venezuela, Colombia, Guyana, and Brazil; and the Brazilian shield to the south, which serves as Brazil's border with Paraguay and Bolivia. On the western side, the Amazon is bordered by the watershed of the Andean peaks in Colombia, Ecuador, Peru, and Bolivia.

These shields are the oldest geological formations from the planet's Precambrian era. They are sedimentary in origin and made of rocky material broken down by erosion (Revista Geográfica Digital, 2013). They have enormous biodiversity, great cliffs like Angel Falls in the Guiana Shield (Venezuela), and cloud forests surrounded by valleys and savannas (Ibáñez, 2008).

The Guiana shield has a maximum altitude of 2,800 m, while the Brazilian shield or plateau has an average maximum altitude of 1,200 m. In between these formations, there are plains and valleys that extend from the mouth of the Amazon River at 0 m to an altitude of 200 m. These low-lying areas are home to the largest expanse of tropical forests on the planet.

The action of high-energy river flows has given rise to geomorphological structures related to this dynamic, such as hills, depressions, flood plains, and plains, which are below 200 masl. These plains and valleys stretch from Colombia and Venezuela, cross the Amazon, and extend into the El Chaco region in Bolivia. **SEE MAP 3**. Relief of the Amazon Region.

2.1.2. Soils

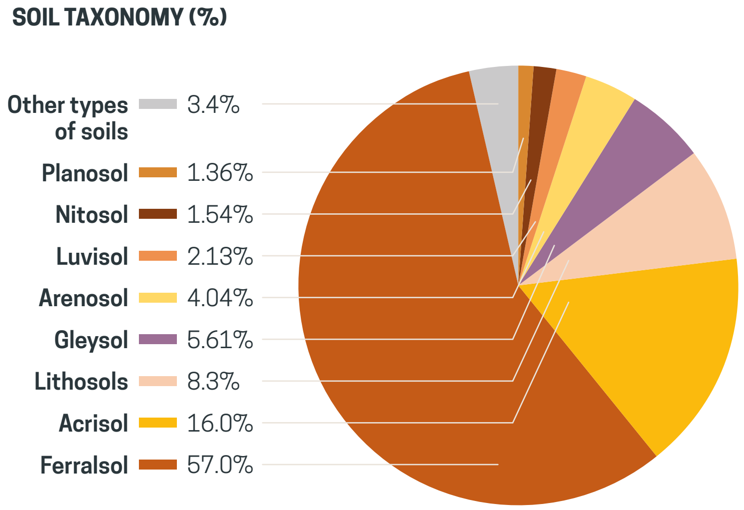
The soil is the natural environment in which plants grow. It is composed of solid compounds such as organic matter, minerals, and some liquids and gases. The proportion of these elements determines the type and texture of the soil.

Soils are formed, in different layers or horizons, depending on their thickness, and have different chemical or mineral components that give them their characteristics. Matter and energy interact within soils, and soils provide a natural support for plants with roots (USDA-NRCS, 2010). The type of vegetation that grows in the soil depends on the climate and conditions, in addition to topographical characteristics. The soil has a maximum depth of 2 meters. It forms on top of the bedrock, as a result of the interaction of factors such as climate, water, microorganisms, topography, and weather (USDA, 2014).

2.1.2.1. Classification by Soil Type

In the Amazon Region, there are approximately 21 soil classes, according to their taxonomic properties, among which the most predominant are ferralsols (iron-rich soils, 57%), found mainly in the Amazon plains, acrisols (acid soils, 16%), found in the area of the Brazilian shield, and lithosols (8.3%) found in the Cordillera Real mountain range, as shown in **FIGURE 15**.

FIGURE 15.
Percentages of soil types in the Amazon Region by taxonomic classification.



PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: International Soil Reference and Information Centre, ISRIC (2011). Soil taxonomic classification. (https://www.isric.org/).

Other less common types of soils in the Amazon Region are: gleysol (5.61%), arenosol (4.04%), luvisol (2.13%), nitosol (1.54%), planosol (1.36%), found in the alluvial plains, and a small percentage (3.4%) of other soil types which are found in scattered pockets in the eastern part of the Atlantic coast and the western region at the source of the Amazon River in the Andes (Batjes, 2011). **SEE MAP 4. TAXONOMIC CLASSIFICATION OF THE SOIL OF THE AMAZON REGION**.

Ferralsols are the most common soils, typically found on plains and sometimes hills. They are usually well drained, with horizons at least 30 cm thick. For tropical forests to grow, these soils are a necessary requirement, in addition to other particular characteristics such as climate type (tropical) and relief (Batjes, 2011).

The second most common soils are acrisols, which account for approximately 16% of the total Amazon soil. Found in forests that have mostly been cleared, these are acid soils with low organic matter content and little vegetation cover. Under their vegetation, these soils tend to be very porous. Because of their sparse vegetation, the soil weakens and degrades easily, forming an impermeable crust.

Acrisols are usually characteristic of terrains with undulating and low relief, which are periodically saturated with water (Gardi et al., 2014). In the Amazon Region, this type of soil is found mainly in the Bolivian and Brazilian floodplains, the lowlands of Peru and Ecuador, the drainage areas of the Amazon River, and the plains adjacent to the Guiana and Brazilian shields **(SEE MAP 4)**.

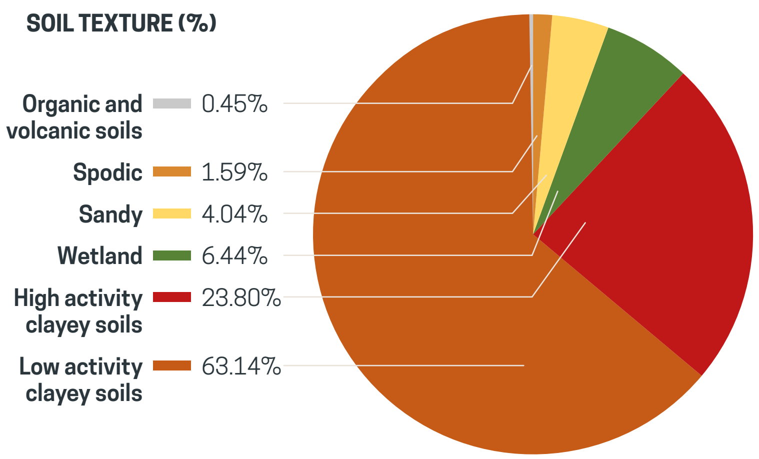
2.1.2.2. Classification of the Soils of the Amazon Region by Texture

Texture is one of the physical properties of the soil, and it refers to mineral particles in the soil according to particle size. According to the FAO (2006b), soil texture is classified as: clay (<0.002 mm), silt (0.002-0.63 mm), and sand (0.063-2.0 mm) (Gardi et al., 2014). The type of texture is determined by the predominance of particle types (Hernández Jiménez et al., 2006).

In the Amazon Region, there are clayey, sandy, spodic (plastic), organic, and volcanic soils, of which clayey soils are the most common in the region. Clayey soils are classified as: low activity soils, which make up 63.14%, and high activity soils, 23.8% (Batjes, 2010). Low activity clayey soils are characterized by having low cation exchange capacity (positive charge) and low content of bases, which means that this type of soil has little capacity to supply nutrients for plants (Casanova Olivo, 2005). In contrast, high activity soils are mainly found in areas with hilly or undulating topography, located in tropical, humid, and sub-humid climates. Such soils are commonly acidic. They are susceptible to erosion because of their shallow depth and fertility. Therefore, crops grown in this type of soil must have surface roots, which make them sensitive to water stress during the dry season (FAO, 2007).

FIGURE 16 shows the percentages of soil types by texture in the region.

FIGURE 16.
Percentages of soil types by texture in the Amazon Region



PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Regional classification of soil texture, Batjes (2010).

Less common types of soil, such as wetland and sandy soils, are found in lowland areas bordering riverbanks (wetland soils) and in flat savannas (sandy soils), as may be seen in **MAP 5. SOIL TEXTURE OF THE AMAZON REGION**. Other less common types of soils include those with high organic matter content, such as spodic, and soils of volcanic origin. (Batjes, 2010).

2.1.2.3. Soil Suitability in the Amazon Region

The agricultural suitability of most of the soils is moderate to poor, due to their acidity and shallowness, which is typical of soil with tropical vegetation, as shown in **MAP 6. AGRICULTURAL SUITABILITY OF THE SOIL OF THE AMAZON REGION**.

The map uses four colors to illustrate soil suitability in the Amazon Region. Red indicates soils that are highly unsuitable for agriculture, such as poorly drained soils with a low concentration of organic matter, which cover approximately 43.2% of the Amazon territory. Soils of moderate suitability (yellow) cover 51.0%. A small portion, 3.19% (green) has good soil suitability. Some of the territory is categorized as unsuitable (gray), corresponding to snow-covered zones, bodies of water, urban areas, and unstudied areas (2.61%).

2.1.3. Climate

The Amazon Region has climatic zones that range from tropical, which covers the vast expanse of the lowlands, to Andean at altitudes above 1,000 masl in the mountainous zone in the western part of the region. It should be mentioned that the ecosystems of the high and low altitude areas of the region are interrelated.

The climate of the Amazon Region is determined by its location in the equatorial zone, east of the Andes, and by the influence of two regional atmospheric circulation systems: The Intertropical Convergence Zone (ITCZ) and the South Atlantic Convergence Zone (SACZ), which modulate or condition precipitation in the region in terms of spatial distribution, annual cycle, and intensity.

2.1.3.1. Air Temperature

Average monthly and annual temperature in the Amazon Region depends mainly on orography and latitude. **MAP 7** shows average annual temperature in the Amazon Region. It can be observed that the highest average temperatures (26 and 28 °C)are recorded from the central area to the mouth of the Amazon River. The lowest temperatures are observed to the west, in the foothills of the Andes, and go as low as 2 °C at the higher altitudes on the eastern flank. There are pockets with average annual temperatures higher than 28 °C (very hot) in the Amazon region of northern Bolivia (Beni), in the central region of the Peruvian Amazon (Ucayali and Loreto), and along the border with Brazil.

During the year there is little variation (amplitude) in the average air temperature (the variation is around 2 °C) in the northern areas of the region, in the equatorial strip. In the southern areas of the region, in the Amazon part of Bolivia and Brazil, the average air temperature fluctuates more over the course of the year, and the variation can exceed 6 °C due to the influence of the seasons in the southern hemisphere. **MAP 7** also contains a mosaic of 12 maps, one for each month of the year.

2.1.3.2. Precipitation

Mean annual rainfall in the Amazon Region is highly variable by region, as may be seen in **MAP 8. ANNUAL PRECIPITATION IN THE AMAZON REGION**. Rainfall greater than 3,000 mm/year (more than 5,000 mm at some locations) is seen in a vast area to the northwest, to the east in an area covering the delta at the river's mouth on the Atlantic Ocean, and in pockets along the eastern foothills of the Andes in the Colombian, Ecuadorian, Peruvian, and Bolivian Amazon. Considerable rainfall is also seen in the Venezuelan Amazon. Lower volumes are observed in the southern part of the region and the highest reaches of the Andes.

In terms of the annual precipitation cycle, the central-south part of the region sees its precipitation maximums (approximately 300 mm/month) between November and March, and minimums between June and August. In the northern part of the region, high precipitation takes place in the middle of the year (between May and July) and low precipitation is seen between October and February. The north-western region (the Colombian and Ecuadorian Amazon) sees high precipitation throughout the year but records its maximum between March and June. The eastern part of the Peruvian Amazon sees its maximum rainfall between January and March, and the season with the least rainfall is from May to November. More details per month may be seen in the internal mosaic of **MAP 8**.

2.1.3.3. Evapotranspiration

Evapotranspiration is the combined process of evaporation (loss of water from the land's surface) and transpiration by plants, as per Turc (real evapotranspiration). In the Amazon Region, the highest evapotranspiration rates are seen in the northwest and at the mouth of the Amazon River on the Atlantic Ocean, due to high precipitation in this area, in addition to the presence of rainforest (tropical forest), as may be seen in **MAP 9. REAL EVAPOTRANSPIRATION IN THE AMAZON REGION**.

Low annual evapotranspiration is seen in a strip that borders the Amazon to the west, on the upper-middle and upper part of the eastern side of the Andes, to the south, and in parts of the Colombian and Venezuelan Amazon, as shown in **MAP 9**.

2.1.3.4. Climatic Water Balance

The zones with greater humidity, and therefore with more water availability, are located in the region's northwest, along a strip in the Peruvian Amazon and on the delta of the Amazon River.

Water deficits are observed in the southern and eastern parts of the region, and in the west on the eastern side of the Andes, as may be seen in **MAP 10. WATER BALANCE OF THE AMAZON REGION**.

2.1.3.5. Climate Zones

Several authors have developed climate classifications according to the area's characteristics (vegetation, topography, temperature, and precipitation, among other factors). In 1900, German meteorologist Köppen created a classification of the Earth's natural climate, based on seasonal precipitation and temperature patterns. The Köppen climate classification system is the most commonly used.

2.1.3.6. Köppen's Climate Classification

According to Köppen (1884) (Kottek et al., 2006), the climate of the Amazon Region is mainly tropical which, in turn, may be classified as tropical equatorial, tropical monsoon, and tropical savanna. Some small areas within the Amazon have other types of climate, notably a thin strip to the west, on the eastern slope of the Andes.

The Amazon's tropical equatorial climate is found in the western, central, and northern areas of the region. This climate is seen in the Amazon territories of Colombia, Ecuador, Guyana, Suriname, and southern Venezuela. In Brazil, it is located towards the northwest, at an altitude of 50 to 1,200 masl. Small pockets of this type of climate are also seen at the mouth of the Tocantins River, in the mesoregions of Marajó, Paraense northeast, the metropolitan area of Belem, and Marajó Island.

The tropical monsoon climate is found from 250 masl, at the headwaters of the Orthon, Madre de Dios, and Beni Rivers in Bolivia's floodplain ecoregion. This climate extends from the middle of the Ucayali River in Peru and the Tapajós and Xingú Rivers on the south side of the Amazon River, continuing towards the northeast, including the Jari, Parú, and Trombetas Rivers in Brazil, all of which are tributaries of the Amazon, to the river's mouth at 0 masl.

The tropical savanna climate is seen on the southern side of the Amazon Region, in the middle area, starting at 150 masl. This climate is seen in much of the Bolivian and Brazilian plains, which are floodable, located at approximately 200 masl. It extends to a maximum altitude of 2,000 masl along the Eastern range of the Andes.

Fourteen climates may be seen in **MAP 11. KÖPPEN'S CLIMATE CLASSIFICATION FOR THE AMAZON REGION**.

2.1.3.7. Climate Variability in the Amazon Region

Climate patterns in the Amazon Region recur at different frequencies, from intra-seasonal (or inter-monthly) to inter-annual, and inter-decadal (Liebman and Marengo, 2001; Labat et al., 2004; Espinoza et al., 2009; Marengo, 2004, 2009). The different phases of these cycles cause variations (increases/decreases) in the predominance of the different hydrometeorological and hydroclimatic events seen in the region.

In the region, intra-seasonal variability in cycles of 30 to 60 days, activates/deactivates convection, which is the transfer of heat between areas of different temperature, associated with the effects of Madden-Julian waves (Souza and Ambrizzi, 2006). During the extreme phases of this cycle, the frequency of extreme weather events associated with convective processes (intense rain, storms) increases/decreases.

The inter-annual climate variability of the Amazon Region has been widely studied (see the synthesis and analysis of Marengo et al., 2001). Precipitation and flow rates for the rivers of the Amazon follow cycles of 2-3 and 4-7 years (Labat et al., 2004). The first cycle, 2-3 years, is associated with a quasi-biennial oscillation in the hydroclimatic variables of the Amazon Region that is recurrent but not very big. The second cycle, 4-7 years, is mainly associated with the El Niño Southern Oscillation (ENSO), as the processes in the central and central-eastern Pacific Ocean (El Niño sectors 3 and 3.4) have been shown to be closely connected to inter-annual climate variability in the Amazon Region. The Amazon's hydroclimatology is also influenced by inter-annual variability in the Atlantic Ocean (Marengo et al., 2011a).

Droughts occurred during the 20th century and at the beginning of the 21st century. The most recent El Niño and La Niña periods occurred in the second half of the 20th century. It is possible to state that the droughts of 2005 and 2010 were not related to El Niño, but to positive anomalies in the sea surface temperature (SST) of the north Atlantic (Valverde and Marengo, 2011).

An analysis of extreme hydroclimatic events (droughts and abnormally rainy periods that led to long-term flooding) has corroborated that SST variability in the central Pacific and Atlantic Oceans influences precipitation and river levels in the Amazon.

It is also necessary to take into account the temperature gradient or rate of change between the subtropical and tropical regions of the south Atlantic Ocean, which causes extreme phases of climate variability in part of the Amazon Region. This was the reason for the 2014 floods in Pando and Beni, Bolivia and Peru's southern Amazon (Espinoza et al., 2014).

Likewise, inter-decadal climate variability cycles have been identified. In the Amazon Region, these are created by oscillatory processes in the Pacific Ocean (Pacific Decadal Oscillation-PDO cycle), the meridional atmospheric pressure gradient between the tropics and the subtropics of South America, and the meridional east-west SST gradient of the tropical Atlantic Ocean. (Marengo J. A., 2009).

2.1.3.8. Climate Change in the Amazon Region

Through paleoclimatology (the study of the Earth's climates throughout history) it may be seen that the Amazon Region has experienced different climatic conditions in the distant past (thousands of years). In general terms, it has been possible to establish that during the pleniglacial (age in the geological timescale), the average annual temperature in the region may have been 4.5 °C below current annual averages and there was less precipitation. The opposite may have occurred in interglacial or warming periods (such as the current period), during which temperature and precipitation have increased noticeably.

During the Last Glacial Maximum, approximately 20,000-21,000 years ago, precipitation was below the current volume. This allowed savanna and *cerrado* (tropical savanna ecoregion in Brazil), vegetation to replace forest, while dry terrain and semi-desert dunes replaced the savannas (Van der Hammen and Hooghiemstra, 2000).

Nonetheless, Colinvaux et al. (2000) argue that the cycles of climate change have not drastically modified conditions in the Amazon Region and that arid conditions have not arisen, maintaining rather that climate changes have resulted in increases or decreases in the size of the biomes in the region.

In contrast with the above, there is clear evidence of past climate change and its influence on the long-term dynamics of the Amazon's biome. Several authors have analyzed the long-term trends in air temperature and precipitation that have taken place in the recent past (20th century).

Marengo (2009) analyzed precipitation and water level data for rivers in the Amazon Region, using a data set that covers much of the 20th century. The analysis did not detect unidirectional long-term trends, but rather multi-decadal cycles (over several decades). Valverde and Marengo (2011) analyzed the number of consecutive dry days and identified a trend towards fewer dry days per year recorded at the weather stations in the western part of the region, whereas in the southwest this trend was on the rise, that is, there were more dry days per year. They attributed this to the effects of the 2005 and 2010 droughts in this region. They also analyzed the number of very rainy days (days on which precipitation exceeded the 95th percentile) and found a decrease in the southeast region.

Using data sets on daily air temperature and precipitation in the Amazon Region from 1950 to 2010, Skansi et al. (2013), identified signs of an increase in both the daily high and low temperature, and also found that the number of days with temperatures above 25 °C has been increasing at a rate of up to six days/decade; likewise, they found a decrease in the number of cold nights.

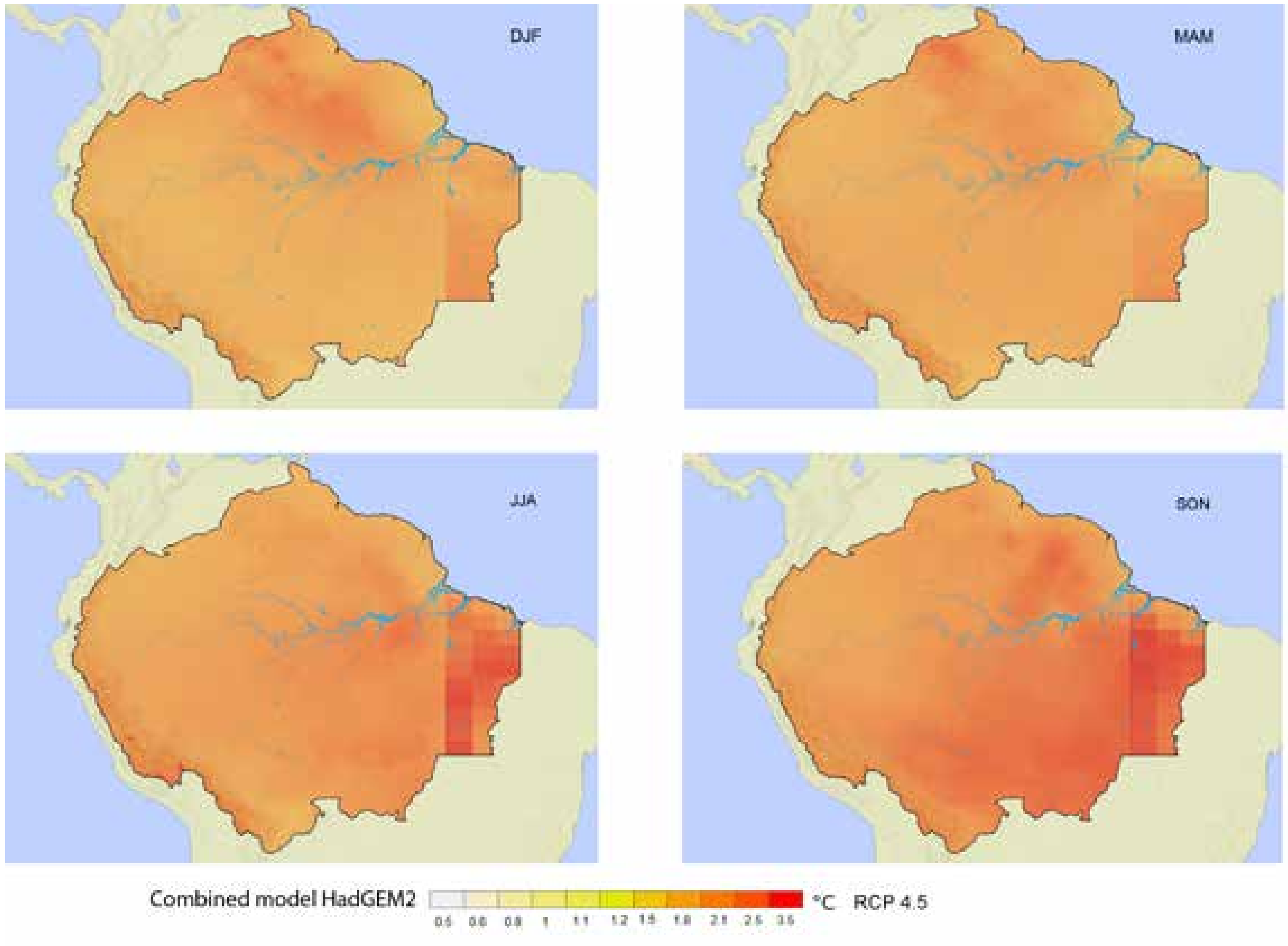
Regarding annual precipitation, Skansi et al. (2013) identified a general trend of an increase of about 50-75 millimeters per decade in the Amazon Region. In summary, according to the analyses of various studies, the climate in the Amazon Region is becoming warmer and, in general, somewhat more humid, with the exception of some locations, in which a slight trend towards less precipitation is occurring.

Various authors have developed projections of possible climate scenarios in the Amazon Region for the 21st century. Nobre et al. (2009) used three regional models in 50x50 km spatial resolution and applied two scenarios: A2 scenario (high emissions) and B2 (low emissions). Nobre's results and the results of Ambrizzi (2007), estimated that towards the end of the 21st century, the climate of the Amazon Region would be warmer (by up to 4-6 °C in scenario A2) and drier than that observed in the 1961-1990 period (Ambrizzi, 2007).

In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014), IPCC presented more recent scenarios, based on 42 models produced by the CMIP5 program (Fifth Phase of the Comparative Modeling Project) and the Representative Concentration Pathway (RCP). According to IPCC's Atlas of Global and Regional Climate Projections (2013), with RCP 2.6 (low emissions), by 2100 the temperature will have increased by 1.5-2.0 °C, compared with the averages observed in the period 1986-2005. Meanwhile, the change in annual precipitation would be between -10% (decrease) and 10% (increase), compared with the volumes observed in the same reference period. In a scenario of RCP 8.5 (high emissions), by 2081-2100 the temperature will have gradually increased until reaching 4-6 °C above what was observed in 1986-2005, and precipitation, as in the previous scenario, would exhibit a range of change between -10% and 10%.

CIIFEN has produced climate change scenarios for the Amazon Region, based on the combination of four CMIP5 models: BCC-CSM1, GFDL, HadGEM2 and ECHAM6-LR (combined CMIP5 climate models applicable to the Amazon Region) published by IPCC (2013). It used an intermediate scenario of RCP 4.5 (moderate emissions). The results of this scenario are shown in **FIGURES 17** and **18**.

FIGURE 17.
Changes in the mean seasonal air temperature in the Amazon Region towards the end of the 21st century, using a scenario of RCP 4.5, according to the combined BCC-CM1, GFDL, HadGEM2 and ECHAM6-LR models (only the HadGEM2 model was applied in the eastern region, which appears pixelated on the map)

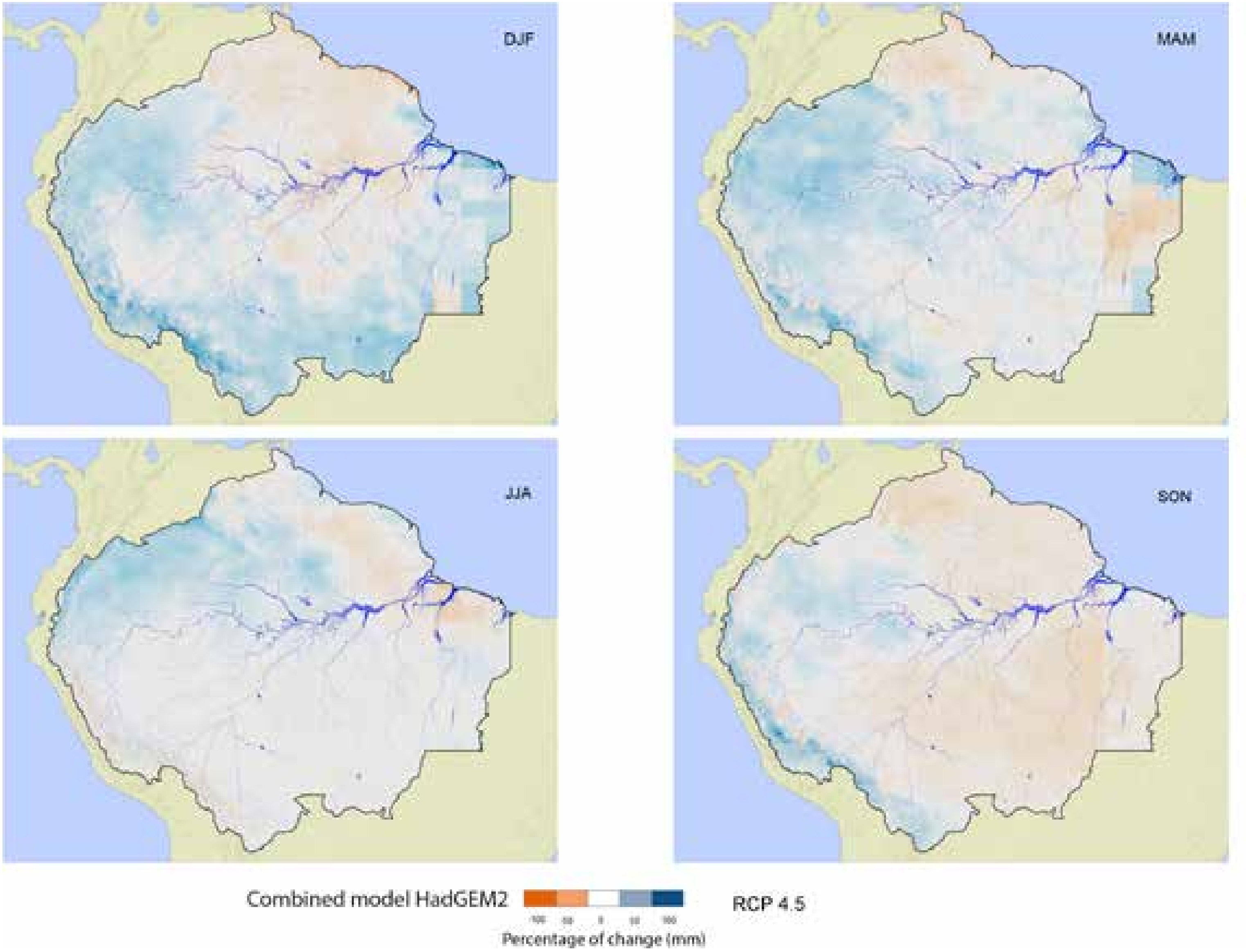


PRODUCED BY: Climate Services-CIIFEN. Note: DJF (December, January, February), MAM (March, April, May), JJA (June, July, August), SON (September, October, November).
SOURCE: Cabos (2014).

FIGURE 17 shows the changes in the mean seasonal temperature towards the end of the 21st century, compared with what was observed in the period 1976-2005. The greatest warming, between 3-4 °C, will occur in September, October, and November (SON) and would be more apparent in the southern and eastern part of the region. During December, January, and February (DJF) and March, April, and May (MAM), the greatest warming would take place in the northern part of the region.

FIGURE 18.

Changes in seasonal precipitation in the Amazon Region towards the end of the 21st century, using a scenario of RCP 4.5, according to the combined BCC-CSM1, GFDL, HadGEM2 and ECHAM6-LR models



PRODUCED BY: Climate Services-CIIFEN. **SOURCE:** Cabos (2014).

According to the models created with the scenario RCP 4.5 (moderate emissions), changes in seasonal precipitation would range from a slight change (increase or decrease) to increases of just over 25% with respect to the volumes during the reference period (1976-2005).

During DJF and MAM, an increase in precipitation would be widespread practically throughout the region, and would be greater in the western part, especially on the slopes of the Andes in Bolivia and Peru. The June, July and August season (JJA) would be wetter than nowadays, with the greatest increases in the Ecuadorian, Colombian, and Venezuelan Amazon. In SON, precipitation would remain very close to what it is today, with only a few areas evidencing marked increases along the slope of the Andes **(SEE FIGURE 18)**.

The magnitude of climate change in the Amazon Region, as predicted by different scenarios for the 21st century, would not significantly affect the spatial-seasonal distribution of extreme hydrometeorological and hydroclimatic events. In the case of the former, the number of storms and associated extreme events could increase slightly in the Andes. In the case of the latter, droughts may be less frequent and there may be a slight increase in flooding. Further studies are needed in order to reduce uncertainty in this regard.

2.1.4. Vegetation, Ecosystems, and Biomes of the Amazon Region

The Amazon rainforest is a reserve that plays a role in the entire planet's ecological functions, thanks to its size and biological diversity. Its importance lies in its ability to absorb large amounts of carbon dioxide (CO_2) from the atmosphere and convert it into oxygen (O_2) (WWF, 2014).

The tropical forest is made up of different categories of rainforest, classified according to their physiognomy, biogeographic vegetation factors (climatic and biotic factors), and type of vegetation (topography/vegetation cover) (Sierra, 1999). Tropical forest covers approximately 67.4% of the Amazon Region, while the tropical savannas constitute about 13.3%. To a lesser degree (less than 4%), there are shrublands, floodable forests, grasslands, plantation crops, and the piedmont forests, among others. This area includes land that is used for raising livestock **(TABLE 19)**.

TABLE 19 and **MAP 12. TYPE OF VEGETATION OF THE AMAZON REGION**, show that the Amazon Region is mainly covered by tropical forest vegetation, which extends from the foothills of the eastern Andes mountain range in the intertropical zone or subtropical thermal floor in Ecuador and Peru, at about 1,800 masl; continues through the northern and central Brazilian Amazon, through the plains and tropical plains; covers wide areas in the Amazon regions of Bolivia, Colombia, Ecuador, and constitutes the most common type of vegetation in Peru. Finally, it reaches the northeast of the Cerrado ecoregion in Brazil, all the way to the mouth of the Amazon River on the Atlantic Ocean.

The tropical forest biome contains 50% of the planet's biodiversity (Orians, 1993). The Amazon Region contains 80.25% of the ecoregions associated with humid tropical forests, which cover approximately 6.3 million km^2 of the region, known as the Amazon Biome. The tropical forest biome covers more than 95% of the Amazon Region in the ACTO member countries, with the exception of Brazil where humid tropical forests cover 80 to 85% and prairies and savannas cover nearly 13.3%.

The main ecoregions of the Amazon Region are tropical rainforests and tropical and subtropical savannas. The greatest diversity of ecosystems and species is found in the ecoregions of the western part of the Amazon Region (Olson and Dinerstein, 2002), areas of mainly tropical forests.

Grassland, savanna, tropical, and subtropical scrub biomes cover about 13.3% of the Amazon Region and are found in the Guiana shield to the northeast and the Brazilian shield to the south. These biomes have an area of about 1.128 million km^2 and are also found in the Gran Chaco region of Bolivia and in the area east of the Guiana shield. These biomes cover most of the southwest in the state of Mato Grosso, south of Maranhão, and about 75% of the state of Tocantins in Brazil, as shown in **MAP 13. ECOREGIONS OF THE AMAZON REGION**.

The biodiversity of the Amazon Region is apparent in the large number of ecosystems, communities, and species that it hosts, which makes it the world's foremost region in terms of biodiversity.

TABLE 19.
Classification of the vegetation of the Amazon Region

Vegetation by class	Percentage
Evergreen lowland forest	40.55
Humid evergreen lowland forest (tropical rainforest)	26.82
Savanna	12.83
Evergreen lowland floodplain forest	3.90
Humid montane scrub	3.18
Agricultural	2.37
Herbaceous lacustrine lowland	2.12
Evergreen low mountain forest	1.98
Vegetation in transition	1.61
Semi-deciduous montane forest	0.80
Deciduous lowland forest	0.97
Evergreen high mountain forest	0.47
Evergreen foothill forest	0.34
Bodies of water	0.19
Humid lowland scrub	0.18
Dry montane scrub	0.09
No vegetation	0.02
Snowy-capped mountains and clouds	0.02
Urban areas	0.01

PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: Compiled from geospatial information provided by ACTO's contract groups and the CIIFEN database.[15]

It is estimated that Brazil's Amazon alone, which accounts for almost 70% of the Amazon Region, contains more than 2,000 species of fish (there are more than 3,000 fish species in the entire region), 550 species of reptiles (of which 62% are endemic), more than 950 species of birds, and 350 species of mammals (including 57 primates) (Goulding, 1980).

2.1.5. Hydrographic Network

The source of the Amazon River is the Apacheta stream, in Arequipa, Peru, at an altitude of about 5,597 masl, on the slopes of the Quehuisha volcano. This is a primary tributary according to the scientific report by the 1996 Amazon Source expedition (Novoa, 1997; Jansky et al., 2008).

15. Compiled from ACTO's contact groups in Brazil, Ecuador, Guyana, Peru, and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Venezuela: Simon Bolivar Geographic Institute. (http://www.igvsb.gob.ve).

Along its path, the network becomes increasingly complex thanks to input from a significant number of tributary rivers that eventually form the Apurímac River, which then becomes the Ucayali River at approximately 210 masl; which then joins the Marañón and Napo Rivers in Peru, at which point it becomes known as the Amazon River. It receives significant water from the Putumayo, Japurá, and Negro Rivers that flow from the northern side of the region, and the Juruá, Purús Madeira, Tapajós, and Xingú Rivers from the south side. It empties into the Atlantic Ocean with a flow of approximately 220,000 m^3/s to 300,000 m^3/s in the rainy season. It is the largest and longest river in the world, as may be seen in **MAP 14. MAIN HYDROGRAPHIC NETWORK OF THE AMAZON REGION**.

According to Pfafstetter's definition of hydrographic units, the Amazon Region has a total of 637 level 4 hydrographic units, the largest being the region of the Solimões River, which has a surface area of 527,750.07 km^2. Its source is in the Andes and it drains into the Jatunyacu and Aguarico Rivers in the Ecuadorian Amazon, between the protected areas of Yasuní and Cuyabeno. **SEE MAP 15. LEVEL 4 HYDROGRAPHIC UNITS OF THE AMAZON REGION**.

The largest tributaries of the Amazon River come from the Andes, while other smaller ones originate in the plateaus of the Guiana and Brazilian Shields. This is the case of the Negro River, one of the largest contributors to the Amazon, which flows between Colombia (Andes) and Venezuela (Guiana shield). Another equally important river, not only because it flows into the Amazon, but also because it has the largest number of human settlements or population centers on its banks, is the Juruá River, which begins at 400 masl in Peru, between the provinces of Atalaya and Esperanza in the department of Ucayali. The course of the Juruá River flows through the states of Acre and Amazonas in Brazil **(SEE MAP 15)**.

The main city located on its banks is Cruzeiro do Sul, with 78,507 inhabitants, according to Brazil's 2010 population census.

2.2. Socioeconomic Aspects

The Amazon Region is home to human populations that have adapted their way of life to the conditions of the surrounding natural area, with a vast diversity of cultures, languages, dialects, and ancestral customs. Among the indigenous populations of the Amazon, there are some whose cultures allow direct contact with urban and rural communities, but there are also cultures that remain in a state of voluntary isolation.

2.2.1. Population

The first inhabitants appeared in the Amazon Region when humans from Asia arrived in the Americas and settled in the southern parts of the region, which then led to important processes of territorial occupation. The last such process, Portuguese and Spanish colonization, took place between the years 1500 and 1840.

Between 1840 and 1945, there were two periods of expansion related to the extraction and exploitation of minerals and forest resources with the rubber boom (IDB et al., 1992).

In 2012, it was estimated that the population of the Amazon Region (considering the entire territory of the Amazon biome) was more than 48.5 million inhabitants, a number that is an estimate due to the lack of homogeneity in the census data of the Amazonian countries.

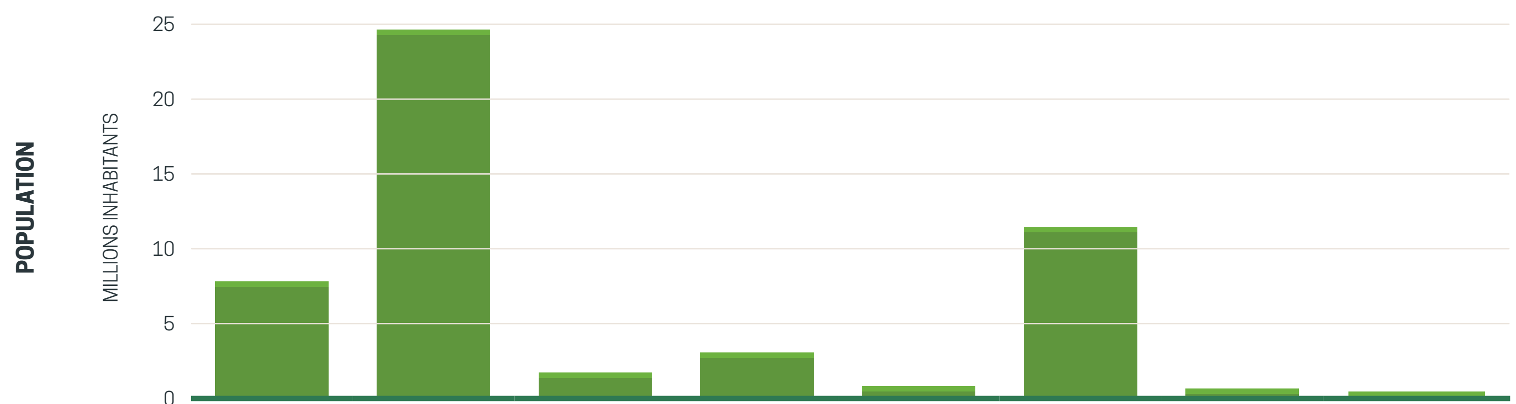
FIGURE 19 shows the distribution of the Amazon's population according to censuses from each country.

Demographic distribution is not homogeneous, with a greater concentration in the Atlantic plains and the Andean part of the Amazon Region, as shown in **MAP 16. POPULATION DENSITY IN THE AMAZON REGION**.

The population of the Amazon Basin (referring only to the river basin) has diverse sociocultural characteristics. It was estimated at 33,485,900 inhabitants in 2007, which represents 11% of the total population of ACTO's member countries (UNDP, 2008).

FIGURE 19.

Amazonian population in ACTO member countries



	BOLIVIA	BRAZIL	COLOMBIA	ECUADOR	GUYANA	PERU	SURINAME	VENEZUELA
Census year	2012	2010	2005	2010	2012	2007	2012	2011
Total population	7,892,850	24,445,337	2,031,011	3,071,469	747,884	9,803,930	534,180	2,300

PRODUCED BY: Geospatial Services-CIIFEN. **SOURCE:** Statistical and census institutes in each country.

16. Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil: Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

In the case of the Bolivarian Republic of Venezuela, data referring to tributaries of the Casiquiare and Negro Rivers, corresponding to the Venezuela's Amazon Region, were taken into consideration.

Brazil accounts more than 50% of the total Amazon population, followed by Peru with 20%. The Amazon population grew at an average annual rate of 1.6% in the period 1990-2012; with Ecuador reporting 3.6% growth, the highest average annual rate.

The geographic distribution of the population is quite diverse. There are urban centers with more than 1.8 million inhabitants, municipalities with up to 500,000 inhabitants, disperse rural towns, communities, indigenous settlements, and nomadic peoples.

As of 2011, the Amazon's cultural diversity was represented by 400 indigenous peoples who speak more than 300 languages (plus innumerable dialects), as well as isolated villages and recently contacted populations. These peoples have their own demographic dynamics, fertility and mortality profiles and rates, and diverse settlement patterns. They move across borders based on social, rather than geographic, boundaries (SITEAL, 2011). The socioeconomic and environmental changes that have occurred have severely affected the Amazon's indigenous population, forcing them to change their way of life and reducing their numbers (SAP, 2018). **MAP 17. INDIGENOUS TERRITORIES OF THE AMAZON REGION**.

The main urban centers in the Amazon Region are: Manaus (1,802,014 inhabitants [Brazil: IBGE, 2010]) and Belem (1,393,399 inhabitants [Brazil: IBGE 2010]) in Brazil; Murillo (1,669,807 inhabitants [INE, 2012]) and Andres Ibañez (1,654,311 inhabitants [INE, 2012]) in Bolivia; and Maynas-Iquitos in Peru (492,992 inhabitants [Peru: INEI, 2014]).

2.2.1.1. Population Change

Population change reflects migratory movement in the region. The greatest growth is taking place in urban areas, while rural areas are decreasing in relation to total population. The exceptions are Ecuador and Guyana, where agriculture is a main economic activity.

MAP 18 shows this process of change in the Amazon's population. **MAP 18. POPULATION GROWTH IN THE AMAZON REGION**.

The cities with the greatest population growth include Araguana, Pedra Branca do Amapari, and São Félix do Xingu in Brazil; Barranco Minas in Colombia; and Federico Román in Bolivia, as the rural population increasingly migrates to villages.

2.2.1.2. Age Dependency Ratio

The age dependency ratio (as a percentage) represents the economically dependent population (children and young people aged 0-14, and adults over 65) in relation to the population aged 15-64, which is considered non-dependent (Saad et al., 2008). The distribution may be seen in **MAP 19. AGE DEPENDENCY RATIO IN THE AMAZON REGION**.

In the Amazon Region, the age dependency ratio ranges from 25% in Puerto Alegria, Colombia, to 104.6% in Sipaliwini, Suriname. Age dependency is concentrated in the southeastern part of Brazil's Amazon, with scattered pockets in southeastern Colombia, and northern and southern Peru where it reaches over 65% **(SEE MAP 19)**.

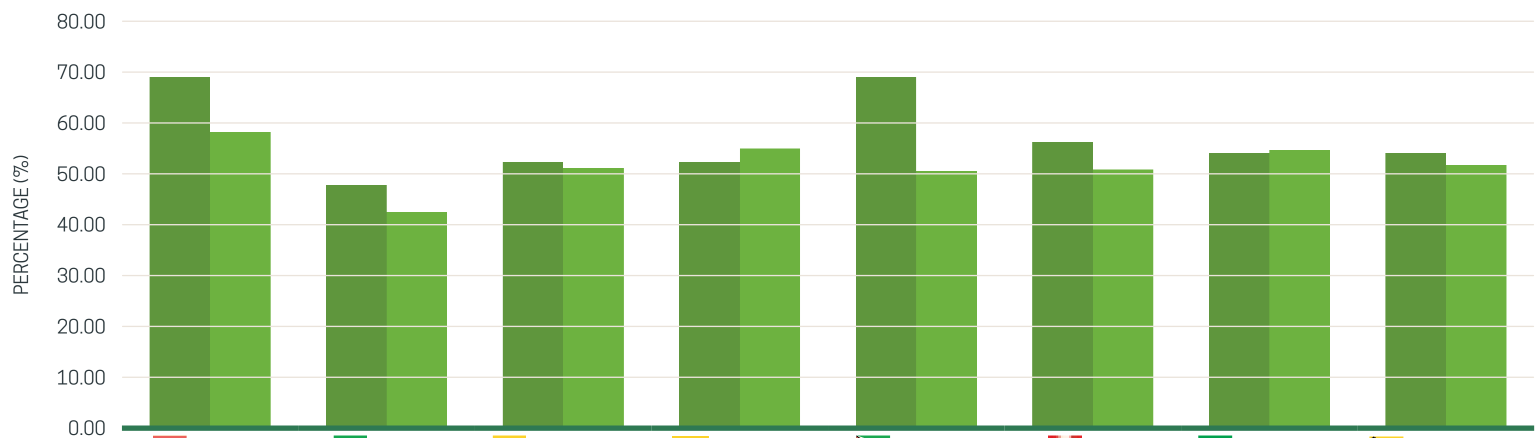
In general, the age dependency ratio is between 37% and 65% in the Amazon Region of Ecuador, Colombia, Peru, and Venezuela, as well as north of Roraima State and in western Brazil. It correlates with the riverbanks and main tributaries of the Amazon River and other waterways, primarily the populated areas along the Morona, Marañón, Ucayali, Javarí, and Tigre Rivers, and in the Amazon River delta.

ECLAC's projections of age dependency in 2020 for the ACTO member countries, show a decrease in the rate of change, mainly in Brazil and Guyana, which show a likely decrease of more than 10% in the dependent population by 2020. Ecuador, in contrast, shows a slight increase of 2.5% in the total dependent population, as shown in **FIGURE 20** (ECLAC, 2013b).

In general, these ratios indicate that the countries of the region have a large young population, or persons between 0 and 14 years of age. Guyana and Suriname are the countries with the highest percentage of dependents in the population.

FIGURE 20.
Dependent population in 2010 and projection for 2020

PERCENTAGE OF DEPENDENT POPULATION IN 2010 AND PROJECTION FOR 2020



	BOLIVIA	BRAZIL	COLOMBIA	ECUADOR	GUYANA	PERU	SURINAME	VENEZUELA
2010	68.8	47.8	52.4	52.4	68.9	56.2	54	54.1
2020	58.2	42.6	51	54.9	50.5	50.9	54.6	51.7

PRODUCED BY: Geospatial Services-CIIFEN. **SOURCE:** Statistical Yearbook (ECLAC, 2013a).

2.2.1.3. Illiteracy Rate

The illiteracy rate is the percentage of people over 15 who, according to national census information, have declared that they do not know how to read and write in the official language.

For purposes of this study, data are provided for each of the political-administrative divisions in the Amazon Region. The figures show the percentage of the population without formal education in Spanish, Portuguese, English, or Dutch, depending on the country. In the case of indigenous populations, they have their own languages, knowledge, and ancestral cultures, which have allowed them to interact amongst themselves (ECLAC, CELADE, 2014).

In the Amazon Region, in the year 2010, illiteracy rates ranged from 0% in some Brazilian cities with few inhabitants, to 66.6% in parts of the Peruvian Amazon and northwestern Brazil, as shown in **MAP 20. ILLITERACY RATES IN THE AMAZON REGION**.

Illiteracy rates per country are approximately as follows: Bolivia from 4% to 22%; Brazil from 0% to 49.5%; Colombia from 8% to 35%; Ecuador from 4% to 23%; Peru from 4% to 67% and Venezuela from 17% to 22%.

Education for indigenous people is a factor in social development that allows them to be included and integrated into society, since it guarantees the enjoyment of human and collective rights (United Nations, 2005; ECLAC, CELADE, 2014).

2.2.1.4. Poverty in the Amazon Region

Poverty due to unsatisfied basic needs (UBN) is a multidimensional poverty measure developed in the 1980s by the Economic Commission for Latin America and the Caribbean (ECLAC). The measurement considers five aspects and uses indicators to measure unmet needs for each aspect.

For purposes of empirical estimates, a person with at least two unsatisfied indicators from the list of unsatisfied basic needs (UBN)[17] is considered poor (ECLAC, 2013b), (SAP, 2018).

17. UBN: It is a method to assess critical deficiencies and identify poverty in a population. It looks at indicators of basic needs (housing, healthcare, basic education and minimum income), using population and housing census information. https://www.cepal.org/en/work-areas/statistics.

Illiteracy, chronic malnutrition, and limited access to food in the Amazon Region are factors that weigh heavily in poverty assessment. However, it is necessary to consider that, although there are countries with a marked deficiency in the availability of access to basic services (as in the case of indigenous populations), these peoples may have high levels of literacy and access to livelihoods in keeping with their cultural development (IDB, UNDP, TCA, 1992), while others who may have greater access to basic services, exhibit serious problems of illiteracy and malnutrition (ECLAC, 2010).

MAP 21. POVERTY DUE TO UNSATISFIED BASIC NEEDS (UBN) in the Amazon Region, shows the spatial distribution of poverty according to UBN, expressed as a percentage. The map shows information from Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, and Venezuela, updated based on information from each country's latest census.

In some parts of the Colombian Amazon, the rate of unsatisfied basic needs is 100%, as follows: Solano, Caquetá Department; Piamonte, Cauca Department; El Retorno, Guaviare Department; La Macarena, Mesetas, Puerto Concordia, and Puerto Rico, Meta Department; Puerto Guzmán, Putumayo Department; and Carurú, Vaupés Department.

The Amazon regions of Bolivia, Ecuador, and Guyana have high percentages of unsatisfied basic needs, ranging from 68.21% to 100%. In Brazil and Peru, this distribution is associated with the populations living on the banks of the main rivers or tributaries of the Amazon, mainly the Morona, Marañón, Ucayali, Javarí, Tigre, and Mazaruni Rivers.

2.2.2. Economic Activity

Economic activity in the Amazon Region is focused on natural resource extraction (raw materials), be these minerals or timber, as well as trade, farming in some areas, and tourism to a lesser extent.

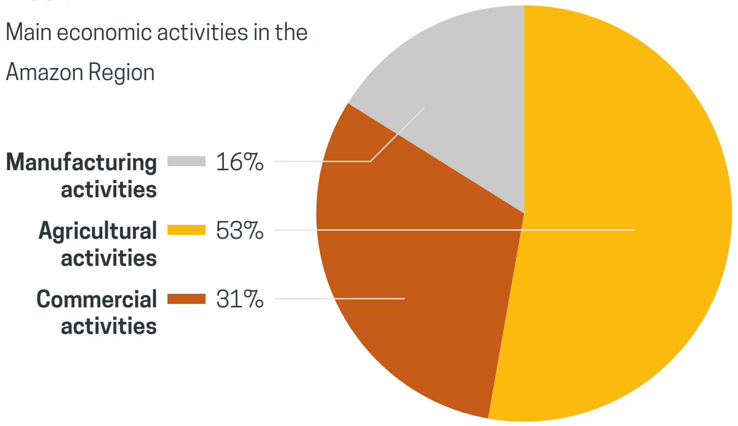
Agriculture is characterized by having low productivity, due to the soil's poor suitability for agriculture (IDB, UNDP, ACT, 1992), with the result that "the more agriculture expands, the less productive it becomes" (ECLAC, 2013), due to changes in land use and climate in the region (J.C. Oliveira, Costa, Soares-Filho, & Coe, 2013).

The exploitation of the region's resources began with the rubber boom that lasted until 1914, after which extractive activities declined considerably (in particular, after the Second World War), which changed land use in the Amazon toward forestry, agriculture, and livestock. During this process, the population increased considerably and it continues to grow, with the construction of infrastructure for electricity (hydroelectric projects) and roads, key resources for the development of communications and the extraction of mineral resources and petroleum (Salati et al., 1990).

FIGURE 21 shows the main economic activities in the Amazon Region. Agricultural and farming activities, which include forestry, fishing, and hunting, employ approximately 6,229,800 people, according to census data between 2005 and 2012. Second are activities related to trade, and third are manufacturing and construction.

FIGURE 21.

Main economic activities in the Amazon Region



PRODUCED BY: Geospatial Services-CIIFEN.

SOURCE: Compiled from geospatial information provided by ACTO's contract groups and the databases of the statistics and census institutes of each country.[18]

2.2.2.1. Agriculture

About 25.58% of the Amazonian surface is used for agriculture, with the highest percentage taking place over the areas of tropical grasslands and savannas in the southern sector of the Brazilian Amazon Region. The other portion is settled in mountain areas of mountains or high areas located in the Bolivian highlands and in the eastern Andes of Ecuador, Colombia, and Peru.

In the case of Colombia, the largest areas of agricultural production are found in the departments of Caquetá, Meta, Putumayo, and Guaviare, while in Peru, the largest area is found in the province of Maynas-Iquitos, as shown in **MAP 22. AGRICULTURAL AREAS IN THE AMAZON REGION**.

Crops in the region, produced on single-species plantations or monoculture, are one of the main causes of deforestation, or change of land use, resulting in the loss of significant forested areas in the Amazon Region. The construction of highways and the development of waterways also foster the expansion of agriculture (Houghton, 2005; SAP, 2018).

In Brazil, agricultural establishments occupy 23% of that country's Amazon area (115.5 million hectares). According to Brazilian law, 80% of the Amazon land that is being used for agriculture is supposed to be legally protected reserve land (Legal Amazon Reserve, IBGE Agricultural Census, 2006; Castrillón Fernández A. J., 2006; SAP, 2018).

The main agricultural product is biofuel. Peru and Brazil are the countries with largest percentages of their Amazon regions devoted to farming, including livestock ranching, with 31.2% and 31%, respectively.

In the case of Peru, 70% of the country's territory is in the Amazon and agricultural activities are carried out there mainly because of easy access to water. Agricultural activity is, therefore, part of economic growth and food production for the country in general, with large extensions of maize, rice, cassava, and banana crops (CIAT, 1993).

Indigenous peoples also grow crops. They have identified more than 2,000 species of plants used as medicines, food and oils, fats, waxes, varnishes, scents, saponins, latex, gums, condiments, poisons, etc., and about 4,000 timber species (Rutter, 1990).

Peru has the greatest diversity of plant species. Peru's Amazon population consumes more than 200 species of fruit and uses 2,786 timber species (Vásquez and Gentry, 1989). In Brazil, there are approximately 260 species of high economic value (Sternadt et al., 1988). About 90% of the economic value of the forest comes from a variety of products other than timber (Peters et al., 1989; IDB, UNDP, ACT, 1992; SAP, 2018).

18. ACTO contact groups in Brazil, Ecuador, Guyana, Peru and Suriname; web portal of Bolivia, GeoBolivia (http://geo.gob.bo/), web portal Venezuela - Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve); databases of the statistics and census institutes of each country: Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics - Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

2.2.2.1.1. Economically Active Population (EAP) Involved in Agriculture

Many people in the Amazon Region pursue agricultural activities as part of their economic sustenance. The population engaged in agriculture lives in the riverside areas of the main tributaries of the Amazon River and in the Andean region, as illustrated in**MAP 23**. Economically active population involved in agriculture in the Amazon Region.

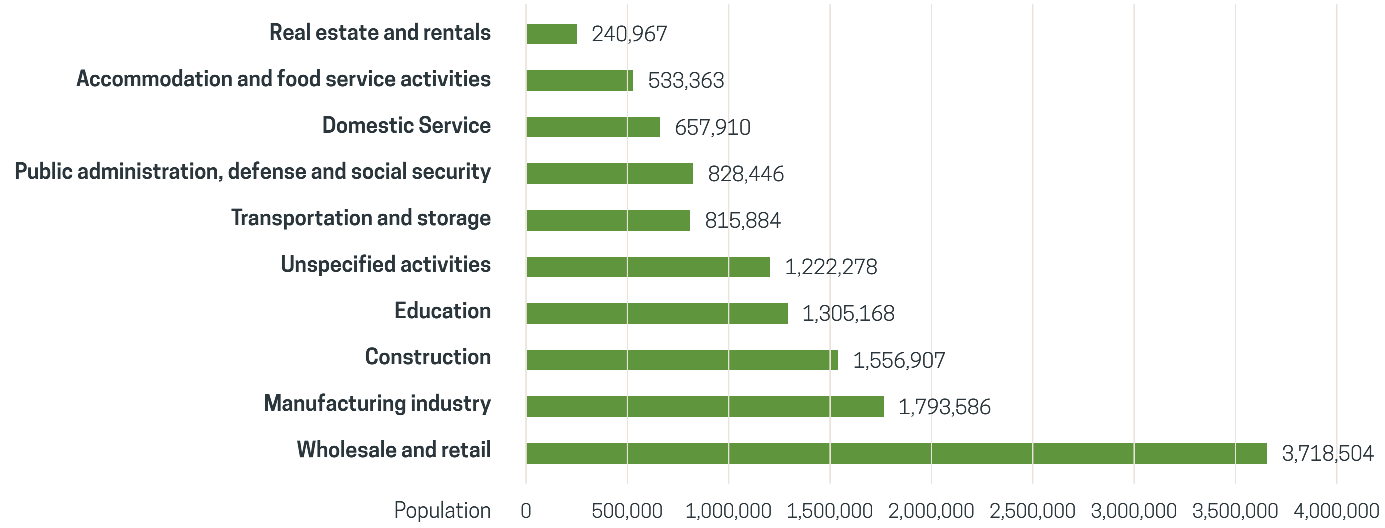
Most of the population engaged in agricultural activities is in the western part of the region, from Peru's Amazon and south of that area. In Bolivia's southern Amazon, up to 85.76% of the economically active population works in agricultural activities. Agriculture is also practiced in the municipality of San Sebastián in Colombia's Amazon.

2.2.2.1.2. Economically Active Population (EAP) Involved in Alternative Activities

This is the population whose economic activities do not depend directly or indirectly on agriculture and livestock, that is, the population whose livelihoods are linked to trade, fishing, mining, masonry, administrative and educational activities, etc.

FIGURE 22.

Economic alternatives to agriculture in the Amazon Region



PRODUCED BY: Geospatial Services-CIIFEN.

SOURCE: Compiled from statistical information provided by ACTO's contact groups[19].

MAP 24. ECONOMICALLY ACTIVE POPULATION WITH ALTERNATIVES TO AGRICULTURE IN THE AMAZON REGION, shows the distribution (in number of inhabitants) of the EAP working in areas other than agriculture or livestock.

The most common alternative economic activities in the Amazon Region include trade and activities associated with manufacturing and construction. **FIGURE 22** shows the ten alternative economic activities that employ the most people, based on census data between 2005 and 2012.

19. Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics - Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), Population and Housing Census 2007.

2.3. Infrastructure

2.3.1. Healthcare Infrastructure

Based on information on the location of healthcare facilities in the Amazon Region, according to the information provided by the ACTO member countries, **MAP 25. DISTRIBUTION OF HEALTHCARE FACILITIES IN THE AMAZON REGION**, was created. The map shows the areas with the greatest number of healthcare centers, including hospitals and small clinics in each of the political-administrative divisions.

2.3.2. Educational Infrastructure

This refers to the infrastructure pertaining to educational establishments in the political-administrative divisions of the Amazon Region. **MAP 26. DISTRIBUTION OF EDUCATIONAL CENTERS IN THE AMAZON REGION**, shows the number of educational establishments of all levels in the region. For each country, the locations of schools, colleges, and universities were identified, based on the latest census information, which ranged from 2008 in Bolivia to 2013 in Brazil. Information from 2012 was available for Ecuador, Guyana, Peru, and Suriname.

MAP 26 shows the total number of educational establishments in each of the political-administrative divisions of the Amazon Region. The information comes from annual updates and surveys in each country, on the services these establishments provide, their shortcomings, number of students, teachers, and type of education, etc.

In the Amazon Region, the locations with the highest concentrations of educational establishments are in the western part of the region (Peru) and pockets of Colombia (Cumaribo, Vichada Department), with moderate numbers in the center of the region to the Amazon delta. The southeastern part of the region has the fewest educational centers.

2.3.3. Transportation Infrastructure

The region's road development is closely related to population growth and the expansion of the agricultural frontier. The construction and maintenance of road networks facilitates access to agricultural territories and the commercialization of products, as a means to improve social and economic development for the people of the Amazon. However, such development has resulted in considerable deforestation in the region.

Some ways that roads contribute to social development in the Amazon Region are: distribution of products or merchandise between the main ports and cities, commercialization, use by extractive industries, and the integration of the Amazon's peoples.

In the region, transport mainly takes place by land or river routes, with ports in urban settlements of regional importance.

Land routes are classified as: **I)** primary or main roads, with a total length of approximately 168,191 km, and **II)** secondary roads, with a length of about 326,850 km, which are shown on **MAP 27. MAIN ROAD NETWORK IN THE AMAZON REGION**, and **MAP 28. SECONDARY ROAD NETWORK IN THE AMAZON REGION**.

Waterways are one of the main means of transport for people and for shipping goods in the Amazon Region. There are approximately 24,000 km of navigable rivers, as may be seen in **MAP 29. HYDROGRAPHIC NETWORK OF THE AMAZON REGION**.

The Initiative for the Integration of Regional Infrastructure in South America (IIRSA), together with the South American Council for Infrastructure and Planning (COSIPLAN) of the Union of South American Nations (UNASUR), have developed an agenda of projects and programs for economic and social development in Latin America. Integrated planning and development in the Amazon is one of the strategic areas.

Among the projects that have been implemented is one of the most important roadways in the region, the Manta-Manaus multimodal corridor. It begins at the port of Manta in Ecuador on the Pacific Ocean, crosses that country's Andean and Amazon regions, goes into Peru, continues east into Brazil, to the port of Manaus, from which it continues to Belem on the Atlantic Ocean.

It serves to connect the main ports of the Pacific with those of the Atlantic, and the towns of the Andean and Brazilian Amazon. Its area of influence is 5,657,679 km² (UNASUR/COSIPLAN, 2011).

This transport route consists of an asphalt concrete road that runs from Manta to Puerto Providencia in the Province of Orellana (Ecuador). From there, the route continues by river, passing through the port of Manaus (Brazil), finally arriving at Belem and the Amazon delta on the Atlantic Ocean, as shown by **MAP 30. MANTA-MANAUS MULTIMODAL TRANSPORT SYSTEM**.

The settlement of the territory is directly linked to deforestation and road construction, which began in the 1960s when Brazilian Government prioritized the road network to encourage agricultural production in the area (de Jong et al., 2010).

2.3.4. Electrical Infrastructure

In the Amazon Region, hydroelectric plants produce 60% of the electricity. Other types of energy include:

- Thermoelectric
- Thermonuclear
- Wind
- Solar

MAP 31. ELECTRICAL INFRASTRUCTURE OF THE AMAZON REGION, shows the distribution and location of the electricity generation facilities.

Hydroelectric plants are mainly located in the Amazon's Andean region and in the foothills of the most significant elevations of the region. Thermoelectric plants, which make up 34% of the infrastructure, are found in low altitude areas.

2.4. Environment

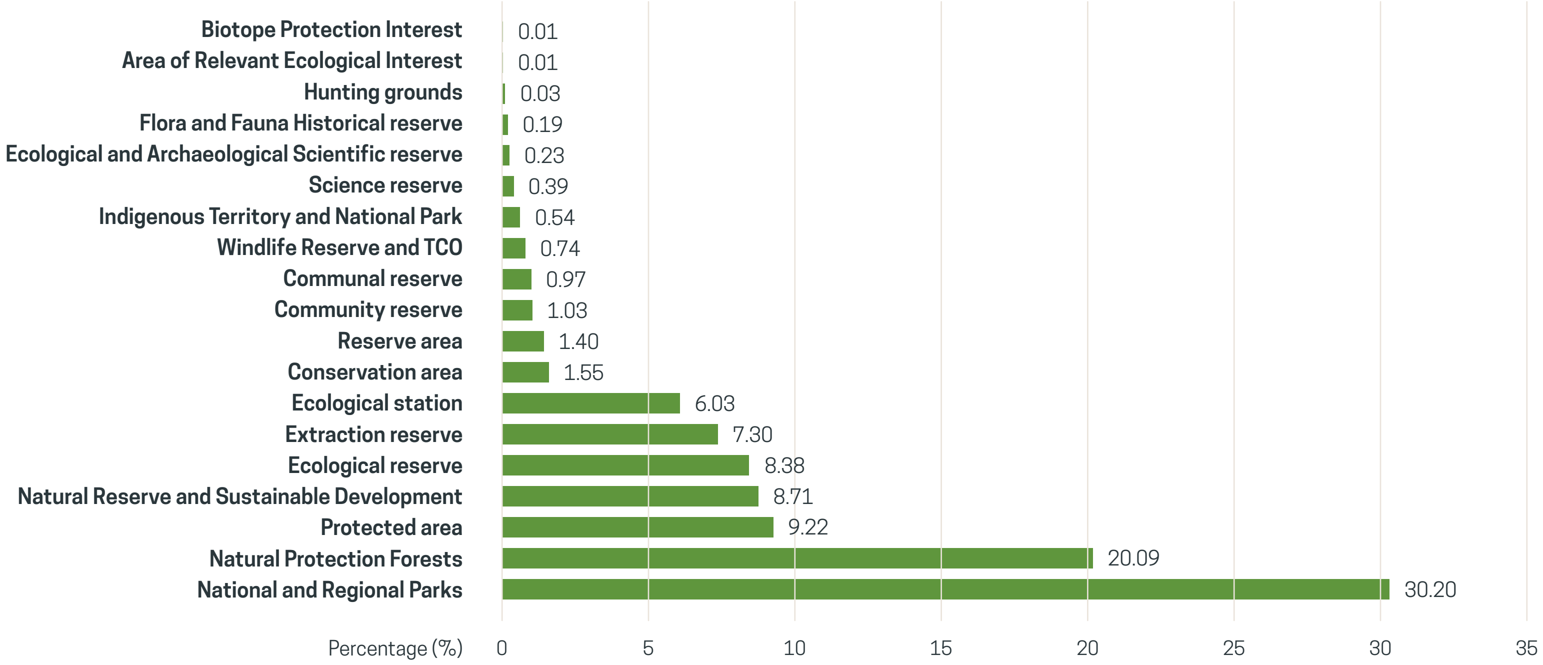
2.4.1. Protected Areas

In the Amazon Region, there are areas defined for conservation and protection, known collectively as "protected areas" (PA), which are designated as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley et al., 2012).

These areas make up approximately 20.3% of the Amazon territory, equivalent to an area of 1,607,896 km², not including the areas specifically designated for indigenous peoples. Of the total territory under protection and conservation, approximately 30% is national and regional parks; 20% is protected natural forests, and less than 10% is classified as reserve areas with different denominations such as: Natural Reserve and Sustainable Development Areas, Scenic Reserve, Extractive Reserve, Ecological Reserve, Wildlife Refuge, Communal Reserve, Ecological and Archaeological Scientific Reserve, and Natural Monuments (compiled from information provided by the ACTO contact groups).

FIGURE 23.

Protected areas in the Amazon Region



PRODUCED BY: Geospatial Services-CIIFEN.

SOURCE: Compilation of information provided by ACTO's contact groups.[20]

Of the protected areas in the Amazon Region, only 22.5% have been designated as conservation and protection areas, of which national parks and natural forests make up a significant portion, as may be seen in **FIGURE 23**.

MAP 32. PROTECTED AREAS IN THE AMAZON REGION, shows that most protected areas are in the northern, central, and eastern parts of the region, from the humid tropical forest to the Amazon delta.

The protected areas indicated have been declared official conservation and protection areas in each of the ACTO member countries, information that is part of the database available for each country.

20. ACTO's contact groups: Brazil, Colombia, Ecuador, Guyana, Peru y Suriname. Web portal of Bolivia: GeoBolivia (http://geo.gob.bo/). Web portal Venezuela-Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve).

3

Hydroclimatic Threats

Within climate variability, occasionally extreme anomalies occur, that is to say, marked deviations from what is considered normal or average. These extreme phases bring with them hydroclimatic events, such as long-term droughts or flooding. Similarly, these phases can also lead to extreme meteorological events (extreme events such as storms, tornadoes, hail, frost, and heatwaves) of greater or lesser frequency, intensity, or duration.

Thus, for example, during an extreme phase with a greater than usual amount of precipitation, storms, floods, flash floods, and landslides become more frequent; whereas a phase with abnormally low precipitation (drought) is conducive to forest fires.

Extreme hydroclimatic events are a threat to ecosystems and human systems. They result in impacts that can cause disasters.

In the conceptual framework of this study, a threat is considered to be a situation in which a system, or element of a system, is exposed to the impact of an extreme hydroclimatic event. Threat is assessed in terms of the probability of loss or damage.

The extreme hydroclimatic events that are the most significant threats, due to their spatial coverage and the magnitude of their impacts, are long-term drought and flooding in flatlands. This conclusion was reached by analyzing disasters (using disaster records from the countries of the region), as described below.

3.1. Analysis of the Most Common Disasters in the Amazon Region

The DesInventar disaster information management system (https://www.desinventar.net/index.html), developed by Corporación OSSO-LA RED-UNDRR (Corporación OSSO, 2013), was used to identify the most common disasters caused by extreme hydroclimatic events in the Amazon Region.

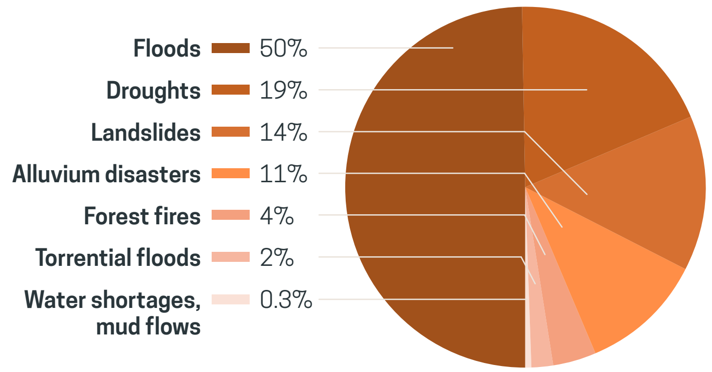
The DesInventar datasets for Bolivia, Colombia, Ecuador, Guyana, and Venezuela were consulted. Information on Suriname came from EM-DAT: the International Disaster Database, by the OFDA (OFDA/CRED, 2009). Information on Brazil came from that country's Integrated Disaster Information System-S2ID (Brazil Civil Defense, 2014).

The DesInventar database records the date of the extreme event and indicates: number of elements affected, including dwellings, crops, livestock, forests (in hectares), roads (in meters), educational centers, and hospitals, as well as the duration of the event, among other factors, all of which is information applicable to this study.

FIGURE 24 shows the incidence of disasters caused by meteorological and hydroclimatic events, showing the frequency of each type of disaster by percentage, based on data from the abovementioned databases, for the period 1970-2015. Floods are the most common type of disaster, accounting for 50% of the total number of disasters reported in the Amazon Region. Droughts and associated events (forest fires), corresponded to 19% and 4%, respectively.

FIGURE 25 shows that floods are the most common type of disaster, accounting for 49% of disasters in the Andean Amazon, followed by landslides (21%), and alluviums (15%). Other disasters associated with hydroclimatic events are less common, such as droughts (7%), forest fires (5%), and torrential floods (3%).

FIGURE 24.
Incidence of disasters associated with extreme hydroclimatic events in the **Amazon Region**, based on historical records (1970-2015)

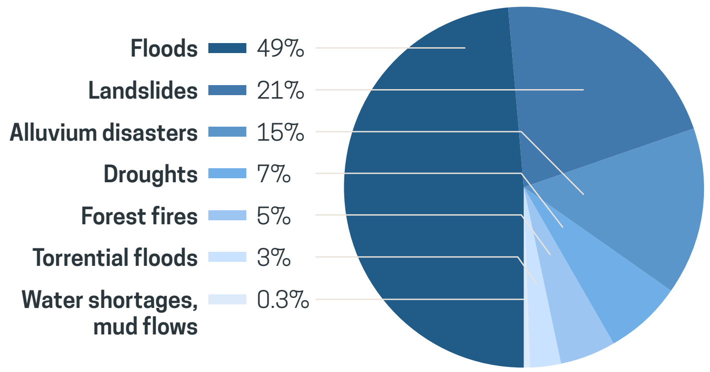


PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: DesInventar Disaster Information Management System-Corporación OSSO; EM-DAT, OFDA; Brazil Civil Defense -S2ID.

Finally, water shortages and mudflows account for 0.3%. This indicates that climate variability associated with above-normal rainfall is what causes most disasters in the Amazon Region.

Analysis of the incidence of extreme meteorological and hydroclimatic events in the Andean part of the Amazon, reveals that most disasters in this sub-region are also related to rainfall and its associated events, accounting for about 88% all disasters reported, while droughts and forest fires combined account for 12%, as may be seen in FIGURE 25.

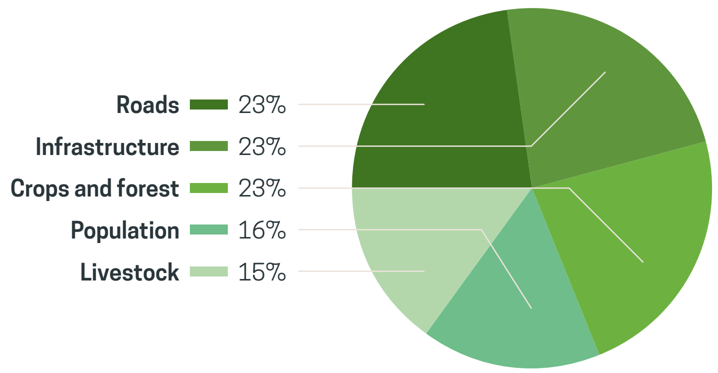
FIGURE 25.
Incidence of disasters associated with extreme hydroclimatic events in the **Andean Amazon**, based on historical records (1970-2015)



PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: DesInventar Disaster Information Management System-Corporación OSSO.

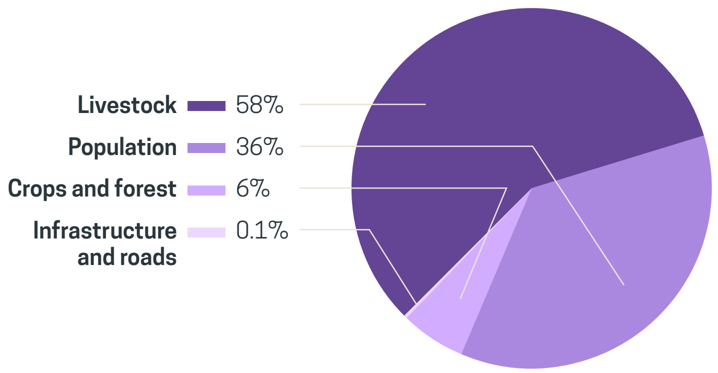
Having identified floods as the most common disasters, their impact on socioeconomic systems was explored, as may be seen in FIGURE 26. In the case of floods, crops and forest areas, along with roads, schools, and healthcare facilities, are the sectors most impacted, with 23% each, while the human population and livestock were impacted less frequently, 16% and 15%, respectively.

FIGURE 26.
Impact of floods on socioeconomic and biophysical systems (1970-2015)



PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: DesInventar Disaster Information Management System-Corporación OSSO; EM-DAT, OFDA; Brazil Civil Defense-S2ID

FIGURE 27.
Impact of droughts on socioeconomic and biophysical systems (1970-2015)



PRODUCED BY: Geospatial Services-CIIFEN.
SOURCE: DesInventar Disaster Information Management System-Corporación OSSO; EM-DAT, OFDA; Brazil Civil Defense-S2ID

In terms of droughts, **FIGURE 27** shows that the greatest impact occurs on livestock with 58%, followed by the human population, with 36%. Drought's impacts on crops and forests were 6% of the total impacts in the Andean part of the Amazon (Corporación OSSO, 2013). However, forest fires also play an important role as a main cause of forest loss in the region.

3.2. Drought and Flood Threats

Threat maps for extreme hydroclimatic events were created using the Standardized Precipitation Index (SPI), described in **SECTION 1.2.4. METHODOLOGY FOR THE ANALYSIS OF HYDROCLIMATIC THREATS** (McKee et al., 1993).

First, extreme events (anomalous droughts or excess of precipitation) were zoned in the region. This entailed spatialization or mapping where these events happened. For each point on the map, we used Standardized Precipitation Index data at an interval of six months (SPI6), and counted the number of times the SPI6 was below the value of -2.0 and above the value of 2.0, to determine the number of instances of extreme drought and long-lasting flood events, respectively, over a 35-year period.

MAP 33. INCIDENCE OF EXTREME DROUGHT EVENTS IN THE AMAZON REGION, presents the spatial distribution of the incidence of events in which the Standardized Precipitation Index (SPI) had a value of -2.0, meaning, the locations where extreme droughts are common in the Amazon Region.

In the period analyzed, droughts were most frequent in the southern part of the region, in the southern part of the Bolivian plains, and at the Bolivia-Brazil border in the basins of the Beni, Mamoré, Guaporé, and Machado Rivers.

Droughts were least frequent in the Andean area, from northern Peru to Ecuador, Colombia, Venezuela, Guyana, and Suriname. This coincides with the results of the analysis of the reports of disasters related to droughts, as mentioned above.

MAP 34. INCIDENCE OF EXTREME RAINFALL EVENTS IN THE AMAZON REGION, shows that extreme events that produce floods have a SPI6 greater than 2.0. The map shows that these are more frequent in the upper basins of the Madre de Dios, Purús, Juruá, and Marañón Rivers (Bolivian and Peruvian Amazon), although the floods themselves occurred in the lower parts of the basin, on the Madeira and Amazon Rivers. See **MAP 35. FLOOD ZONES IN THE AMAZON REGION**.

MAPS 33 and **34** show that SPI6 extremes are most frequent in the southwestern part of the region, and they appear to come in cycles of 2-3 years.

In the northern regions of Peru, Ecuador, Colombia, Venezuela, Guyana, and Suriname, the cycles appear to have a longer period (5-6 years, or possibly decades).

Once these extreme hydroclimatic events were mapped, the biophysical and socioeconomic systems and elements that are exposed and threatened by these events were identified, as detailed in **TABLE 20**.

TABLE 20.
Exposure to hydroclimatic events (droughts and floods) in the Amazon Region

EXPOSED SYSTEM	EXPOSED ELEMENT	EXTREME HYDROCLIMATIC EVENT	
		DROUGHT	FLOOD
SOCIOECONOMIC SYSTEM	Population	*	*
	Livelihood	*	*
	Infrastructure		*
BIOPHYSICAL SYSTEM	Natural environment	*	*

PRODUCED BY: Geospatial Services-CIIFEN. **SOURCE:** Methodology for assessing vulnerability indicators (CIIFEN, 2018).

Drought affects the entire biophysical environment and socioeconomic system of the Amazon Region. Farming is the most seriously exposed socioeconomic element, as illustrated by **MAP. 36. THREAT DUE TO DROUGHT IN FARMING AREAS OF THE AMAZON REGION**.

By comparing **MAPS 33** and **36**, it may be seen that extreme events constitute a serious threat to farming in the southwestern part of the region. The threat of drought is lower in pockets of the Andes and on the eastern edge of the Amazon Region.

MAP 36 Threat to farming due to droughts in the Amazon Region, shows in detail that farming is most threatened by drought in the southern part of the region and in the high areas along the Andes.

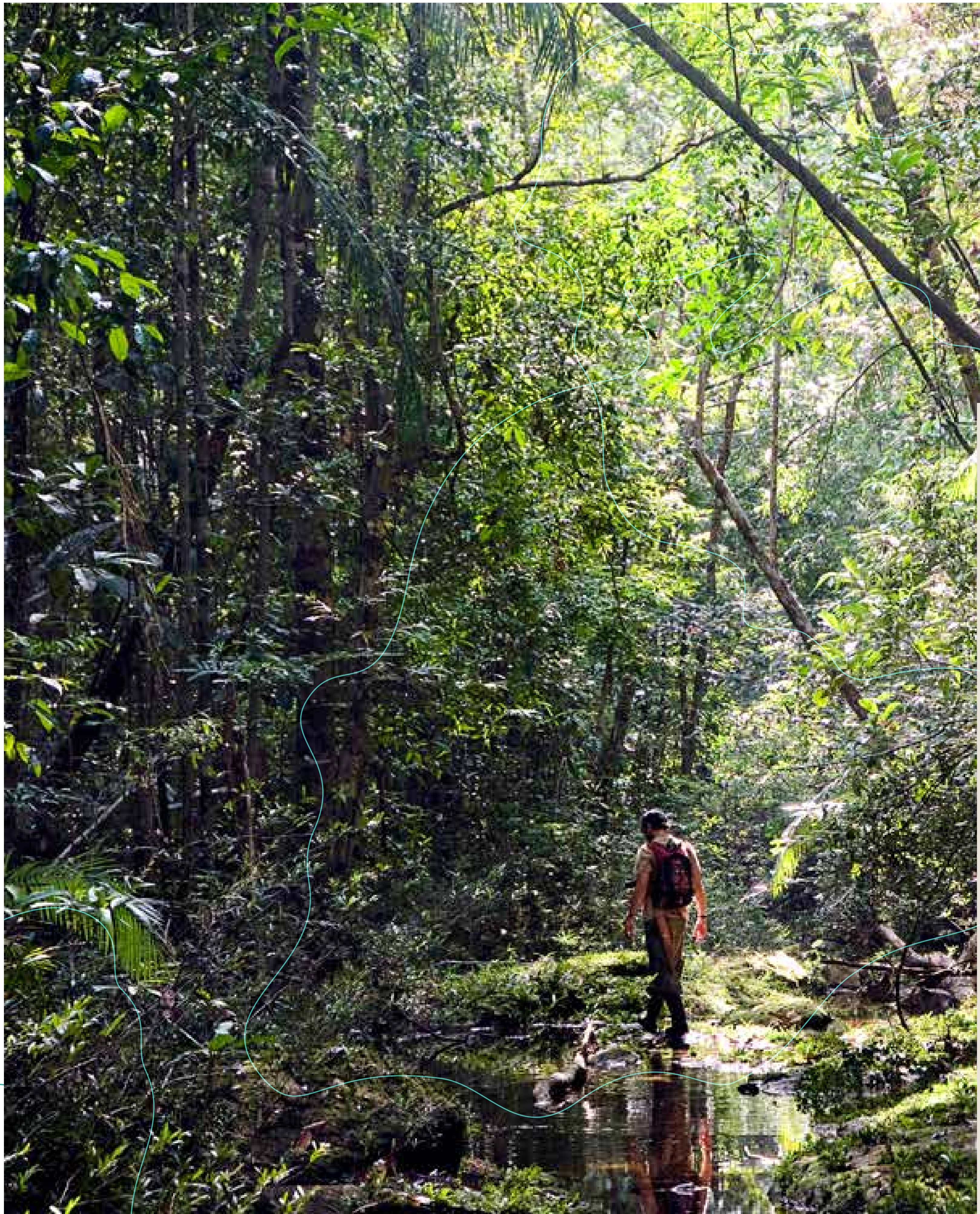
Drought's main problem for the population of the cities and villages in the region, is its impact on drinking water. This is illustrated in **MAP 37. THREAT TO URBAN SETTLEMENTS DUE TO DROUGHTS IN THE AMAZON REGION**. This threat is significant in high altitude areas, whereas in most of the Amazon Region, the threat is moderate.

Threat due to floods is shown in **MAP 38. THREAT TO FARMING DUE TO FLOODS IN THE AMAZON REGION**; and in **MAP 39. THREAT TO URBAN SETTLEMENTS DUE TO FLOODS IN THE AMAZON REGION**. These maps reveal that the threat of floods affects both farming and the population of the Amazon Region.

As mentioned above, there is flood threat in the region's floodplains **(SEE MAP 35)**, and this threat increases in the areas with the highest incidence of abnormally abundant rain.

MAP 38 shows farm areas and threat levels. This threat is particularly significant for rivers and plains in Bolivia. Although crops and pasture land near rivers always face a latent threat of flooding, it is notable that the threat is considerably higher in parts of the southern Amazon Region. The threat of flooding is generally highest in the most densely populated riverside areas.

In the eastern flatlands of Bolivia, the threat of flooding is high, compared with the rest of the Amazon Region, due to the fact that this area has the highest frequency of extreme precipitation events, as shown on **MAP 39**.



4

Hydroclimatic Vulnerability

Having identified droughts and floods as the main hydroclimatic threats that impact the Amazon Region, indicators were developed to determine the extent to which these events affect the region's socioeconomic and biophysical systems, as well as the characteristics that indicate adaptive capacity to cope with the impacts of extreme hydroclimatic events.

The region's socioeconomic and biophysical vulnerability, as well as its sensitivity and socioeconomic adaptive capacity, are presented in thematic maps that illustrate vulnerability and its factors, rated in five levels that range from very low to very high.

4.1. Socioeconomic Vulnerability

Socioeconomic vulnerability consists of four sensitivity indicators, based on the characteristics of the population of the Amazon Region and their relationship with the land, as follows: age dependency, farming, soil suitability for agriculture, and roads.

Adaptive capacity consists of four indicators: presence of healthcare establishments, educational establishments, economic alternatives to agriculture, and household drinking water supply.

MAP 40. SENSITIVITY TO DROUGHTS AND FLOODS DUE TO SOIL SUITABILITY IN THE AMAZON REGION, shows the spatial distribution of sensitivity due to soil suitability in areas where agriculture is practiced in the Amazon Region.

It may be seen that sensitivity is greater in the eastern and southeastern parts of the region. The soil's poor suitability in these areas, and the fact that large extensions of land are used for agriculture, makes them highly sensitive to extreme hydroclimatic events.

As may be seen in **MAP 41. SENSITIVITY TO DROUGHTS AND FLOODS DUE TO AGE DEPENDENCY IN THE AMAZON REGION**, very high sensitivity is mainly concentrated in Guyana and Suriname, as the areas with the largest percentage of young people (0-14 years) in the region.

MAP 42. SENSITIVITY TO DROUGHTS AND FLOODS DUE TO AGRICULTURAL ACTIVITY IN THE AMAZON REGION, shows that the economically active population's socioeconomic sensitivity to droughts and floods due to agricultural activity is highest in the Andean regions of Bolivia and Peru, as well as around the midsection of the Andean tributary rivers.

MAP 43. SENSITIVITY TO FLOODS DUE TO ROADS IN THE AMAZON REGION, shows the highest sensitivity along a narrow strip that borders the Andes, and also in a wider area along the southern and eastern edge of the region. This particular distribution is explained by the fact that there are more roads in these areas, and they are affected by floods.

The analysis of adaptive capacity to floods and droughts produced very relevant results for ACTO's member countries.

MAP 44. SOCIOECONOMIC ADAPTIVE CAPACITY TO FLOODS AND DROUGHTS due to economic alternatives to agriculture in the Amazon Region, shows how having economic alternatives to agriculture and livestock affects the population's socioeconomic adaptive capacity. Locations with more alternatives to agriculture show greater adaptive capacity. Areas with less adaptive capacity are seen in the Andean region and along the Amazon River.

MAP 45. SOCIOECONOMIC ADAPTIVE CAPACITY TO FLOODS DUE TO EDUCATIONAL INFRASTRUCTURE IN THE AMAZON REGION, shows that large sections of Colombia and the southeast Amazon Region have very low adaptive capacity to floods, due to having little educational infrastructure. More densely populated areas have moderate to high adaptive capacity. In the southern and eastern part of the region, this indicator is low because there are few urban settlements.

MAP 46. SOCIOECONOMIC ADAPTIVE CAPACITY TO DROUGHTS DUE TO DRINKING WATER SUPPLY IN THE AMAZON REGION, shows the impact of having a public water supply network. In general terms, the adaptive capacity for this indicator is very low, as much of the region does not have a drinking water supply. However, there is good water supply coverage in the eastern part of the region and in pockets of Venezuela, Colombia, and Ecuador's Amazon Region. Some parts of the Bolivian plains, the Colombian Amazon, and southern Venezuela have very high adaptive capacity.

4.2. Biophysical Vulnerability

The analysis of biophysical elements included the consideration of soil texture, terrain slope, hydrographic network, and vegetation type, among others, detailed in the different maps described below.

MAP 47. BIOPHYSICAL SENSITIVITY TO DROUGHTS DUE TO TERRAIN SLOPE IN THE AMAZON REGION, shows that the areas with the steepest terrain exhibit the greatest sensitivity to droughts, as may be seen along the Andes.

MAP 48. BIOPHYSICAL SENSITIVITY TO FLOODS DUE TO TERRAIN SLOPE IN THE AMAZON REGION, shows that sensitivity to floods is higher in the flat areas of the region and in some pockets of the Andes.

Vegetation type and terrain slope are important factors in assessing the vegetation's biophysical sensitivity to droughts and floods. **MAP 49. BIOPHYSICAL SENSITIVITY TO DROUGHTS DUE TO VEGETATION TYPE IN THE AMAZON REGION**, shows the highest sensitivity in the agricultural areas at higher altitudes in the foothills of the Andes, and in pockets on both sides of the Amazon River (low-lying areas).

MAP 50. BIOPHYSICAL SENSITIVITY TO FLOODS DUE TO VEGETATION TYPE IN THE AMAZON REGION, shows that sensitivity is high or very high in agricultural and low-lying areas of the region that are regularly flooded.

Biophysical sensitivity to droughts and floods due to soil texture may be seen in **MAP 51. BIOPHYSICAL SENSITIVITY TO DROUGHTS DUE TO SOIL TEXTURE IN THE AMAZON REGION**, and **MAP 52.**

BIOPHYSICAL SENSITIVITY TO FLOODS DUE TO SOIL TEXTURE IN THE AMAZON REGION. MAP 51 shows that the region is not very sensitive to drought due to soil texture. There are only a few areas with high sensitivity, located in the southeastern part of the region. For the same reason, the entire region is very sensitive flooding, as may be seen in **MAP 52**.

The region's biophysical sensitivity to droughts and floods due to the hydrographic network is illustrated in **MAP 53. BIOPHYSICAL SENSITIVITY TO FLOODS DUE TO THE HYDROGRAPHIC NETWORK IN THE AMAZON REGION**, and in **MAP 54. BIOPHYSICAL SENSITIVITY TO DROUGHTS DUE TO THE HYDROGRAPHIC NETWORK IN THE AMAZON REGION**. The highest biophysical sensitivity to floods is in the Andean region, as shown in **MAP 53**, while highest sensitivity to droughts is in the lower, flat part of the Region **(MAP 54)**.

4.3. Integrated Mapping of Hydroclimatic Vulnerability

The socioeconomic and biophysical vulnerabilities of the Amazon Region mean that its socioeconomic and biophysical systems are likely to suffer negative impacts from droughts and floods.

The combination of these two vulnerabilities (total vulnerability), makes it possible to identify the region's biophysical limitations and to relate these to the socioeconomic dynamics of the population. Integrated vulnerability maps, therefore, make it possible to do regional planning, identifying the areas of greatest socioeconomic vulnerability, which are often located in areas with high and very high biophysical vulnerability to droughts and floods.

The Amazon Region's overall vulnerability to drought is presented in the following maps:

MAP 55. SPATIAL DISTRIBUTION OF SOCIOECONOMIC VULNERABILITY TO DROUGHTS IN THE AMAZON REGION; **MAP 56. SPATIAL DISTRIBUTION OF BIOPHYSICAL VULNERABILITY TO DROUGHTS IN THE AMAZON REGION**; and **MAP 57. SPATIAL DISTRIBUTION OF INTEGRATED VULNERABILITY TO DROUGHTS IN THE AMAZON REGION**.

As may be seen in **MAP 57**, the highest integrated vulnerability is found in the upper reaches of the Andes (Bolivian, Peruvian and Ecuadorian Amazon); to the south, around the Juruena River (a tributary of the Tapajós); to the east, in a wide area between the basins of the Xingú and Tocantins Rivers; and to the north, in a small pocket on the upper part of the Branco River.

The reasons for this distribution of vulnerability to drought may be seen by analyzing **MAPS 55** and **56**. Biophysical vulnerability to drought in the Andean part of the region is due to biophysical sensitivity. In the southern part of the region, it is due equally to biophysical and socioeconomic sensitivities. In the east, vulnerability to drought is influenced to a greater extent by socioeconomic sensitivity.

By observing **MAP 58. SPATIAL DISTRIBUTION OF SOCIOECONOMIC VULNERABILITY TO FLOODS IN THE AMAZON REGION**; **MAP 59. SPATIAL DISTRIBUTION OF BIOPHYSICAL VULNERABILITY TO FLOODS IN THE AMAZON REGION**; and **MAP 60. SPATIAL DISTRIBUTION OF INTEGRATED VULNERABILITY TO FLOODS IN THE AMAZON REGION**, it may be deduced that biophysical sensitivity plays the most important role in determining integrated vulnerability in the region.

A similar analysis of floods demonstrates that the highest integrated vulnerability **(MAP 60)** is in a large area in the southeastern part of the Amazon Region, as well as in pockets along the Amazon River, in the Amazon plains, in the foothills of the Andes, and throughout flatland area adjacent to the Amazon River and its tributaries, where vulnerability to floods is known to be high or very high.

5

Conclusions

The first Atlas of Hydroclimatic Vulnerability of the Amazon Region is a collection of maps that serves as a starting point for ACTO's member countries to better understand the magnitude and complexity of the region's biogeophysical characteristics (relief, soils, climate, vegetation, biomes, hydrographic network) and its socioeconomic characteristics (including the healthcare and educational infrastructure, and the transport network), from the Andes to the Atlantic.

This unprecedented and innovative tool provides technical and scientific information about climate, climate variability, and climate change in the Amazon Region. It explains the methodology used to create the climatological maps. Six climatological maps show annual precipitation, mean annual temperature, real evapotranspiration, water balance, and the Standardized Precipitation Index, which were used to define threats.

The Atlas offers much more. It presents and explains a methodology to determine socioeconomic and biophysical vulnerability, sensitivity, and adaptive capacity to extreme events.

This was used to determine the location and frequency of hydroclimatic threats due to droughts and floods, and produce maps of integrated hydroclimatic vulnerability.

In conclusion, a variety of extreme hydrometeorological and hydroclimatic events take place in the Amazon Region. The droughts and floods that periodically affect the region are the most significant events, due to the extent of the areas they affect and the magnitude of their impacts on the population, because they result in significant socioeconomic losses and changes to the ecosystems.

One of the Atlas's greatest benefits is its contribution to greater understanding and knowledge about climate change, hydroclimatic threats, and vulnerability to floods and droughts in the Amazon Region. It demonstrates that both floods and droughts are part of the extreme phases of the interdecadal and interannual climate variability. Some of the main findings are as follows:

5.1. Climate Change in the Amazon Region

- Projections of changes in average air temperature suggest that the Amazon Region will be 3 to 4 °C warmer by the end of the 21st century (2080-2100), compared with the period 1976-2005. This would have strong impacts on how the ecosystem of the Amazon interacts with global and local climate.
- Projections of changes in seasonal precipitation in the region suggest an increase in extreme rainfall events, in terms of their number and intensity.
- It is estimated that during the months December-February and March-May, there will be an increase of 0% - 50% in the headwaters of the Amazon River in the Colombian, Ecuadorian, Peruvian, and Bolivian Amazon, and the southern part of the region.
- It is expected that during the months of June-August and September-November, precipitation will be 0% - 50% lesser than what was observed in the period 1976-2005; this will be much more evident in the northern, central, and southeastern part of the region.

5.2. Climate Variability in the Amazon Region: Types of Hydroclimatic Threats and Incidence

Climate variability refers to phases of extreme weather events that vary in frequency, intensity, or duration. During an extreme phase with an anomalous excess of precipitation, storms, flash floods, and landslides often happen, whereas a phase of abnormally low rainfall (drought) is conducive to forest fires.

Threat Due to Droughts

- Some droughts, particularly the more intense ones, have been associated with climatic anomalies caused by El Niño, while others have been associated with abnormal conditions in the tropical Atlantic.
- Drought accounts for 19% of the disasters in the region.
- In Brazil's Amazon, drought accounts for 46% of disasters.
- Forest fires, which result partly from increased drought in the Amazon Region, have considerable impact over vast areas of rainforest ecosystems and agricultural areas.
- The impacts of drought are mainly felt in the livestock and agricultural sectors, people's access to drinking water, and forest fires.

- The areas under greatest threat of droughts are the large tracts of agricultural land in Brazil and high altitude areas in the Bolivian Andes. The most serious impacts of drought are felt by the population located at the border between Bolivia and Brazil, and in the Andean region between Bolivia and Peru.

Threat Due to Floods

- Some high impact floods have occurred because of La Niña, whereas others have been due to particular conditions such as a temperature difference between the tropical and subtropical sectors in the southern Atlantic Ocean.
- Floods are the most common disasters, accounting for 50% of disaster reports.
- In the Brazil's Amazon, flood-related events account for 51% of disasters.
- In addition to impacting farming, floods also cause massive destruction to the infrastructure in the region. Floods are a significant threat along rivers where crops, infrastructure, and human settlements are located, such as the flatland areas of the Bolivian Amazon, the southern part of the Brazilian Amazon, and the banks of the Amazon River and its main tributaries.

5.3. Hydroclimatic Vulnerability

The methodology to determine hydroclimatic vulnerability in the Amazon Region was based on IPCC criteria, published in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014). A set of indicators of sensitivity and adaptive capacity to droughts and floods was developed based on knowledge of the socioeconomic and biophysical characteristics of the region.

5.3.1. Integrated Vulnerability to Droughts

- Biophysical characteristics are mainly responsible for the very high level of integrated vulnerability to droughts in the Andes. Biophysical vulnerability comes from steep slopes, savanna vegetation, farmland, and low water levels in the rivers, which mean that droughts arise when there is less rainfall than normal. This results in low access to water for the population, and losses in livestock and agricultural production. Furthermore, the likely increase in temperature in this part of the region, combined with conditions of drought, could lead to forest fires.
- Socioeconomic characteristics are mainly responsible for the high level of integrated vulnerability to droughts in the eastern part of the region. Socioeconomic vulnerability comes from age dependency, involvement in farming, and the soil's poor suitability for agriculture, which mean that droughts can have considerable impact on the economy.
- The Amazon regions most vulnerable to droughts are: the high altitude Andean part of the Amazon (Bolivia, Peru and Ecuador); the Juruena River basin (a tributary of the Tapajós); a large area between the Xingú and Tocantins Rivers, and a small area on the upper part of the Branco River.

5.3.2. Integrated Vulnerability to Floods

- Biophysical characteristics are mainly responsible for the very high level of integrated vulnerability to floods in the southeastern part of the Amazon Region, along the Amazon River, in the Amazon plains, and in the foothills of the Andes. Biophysical vulnerability comes from flat terrain, soil texture (mainly clayey), and considerable water supply, which mean that an increase in precipitation can cause floods that lead to potential losses in infrastructure and people's livelihoods.
- High levels of socioeconomic vulnerability exist in pockets of the region. Flooding has considerable impact on the population that is engaged in farming for a living, and it also affects roads.

Using the information that the ACTO member countries have provided, it is possible to make plans to deal with flood and drought cycles. The areas with high and very high vulnerability have been identified, making it possible to develop targeted policies to reduce vulnerability.

The Atlas will make things easier for those who are involved in regional planning, integrated water resource management, disaster risk management, climate change risk management, and sustainable human development in our region.

Geographic Information Systems (GIS) software was used to create each of the maps in the Atlas. This is a valuable tool for analyzing the region's socioeconomic and biogeophysical characteristics, including the spatialization of hydroclimatic threats and vulnerability, thus facilitating the process of making decisions and prioritizing areas for intervention.

PART II

The Atlas

PRODUCED BY:
Geospatial Services-CIIFEN.

MAP 1.

Limits of the Amazon Region.

SOURCE: ANA-Brazil, RAISG 2012, CIIFEN.

MAP 2.
Limits of the study area.

SOURCE: ANA-Brazil, RAISG 2012, CIIFEN.

MAP 3.
Relief of the Amazon Region.

SOURCE: NASA (2013), Digital Elevation Model-MDT, resolution 250 m.

MAP 4.

Taxonomic classification of the soil of the Amazon Region.

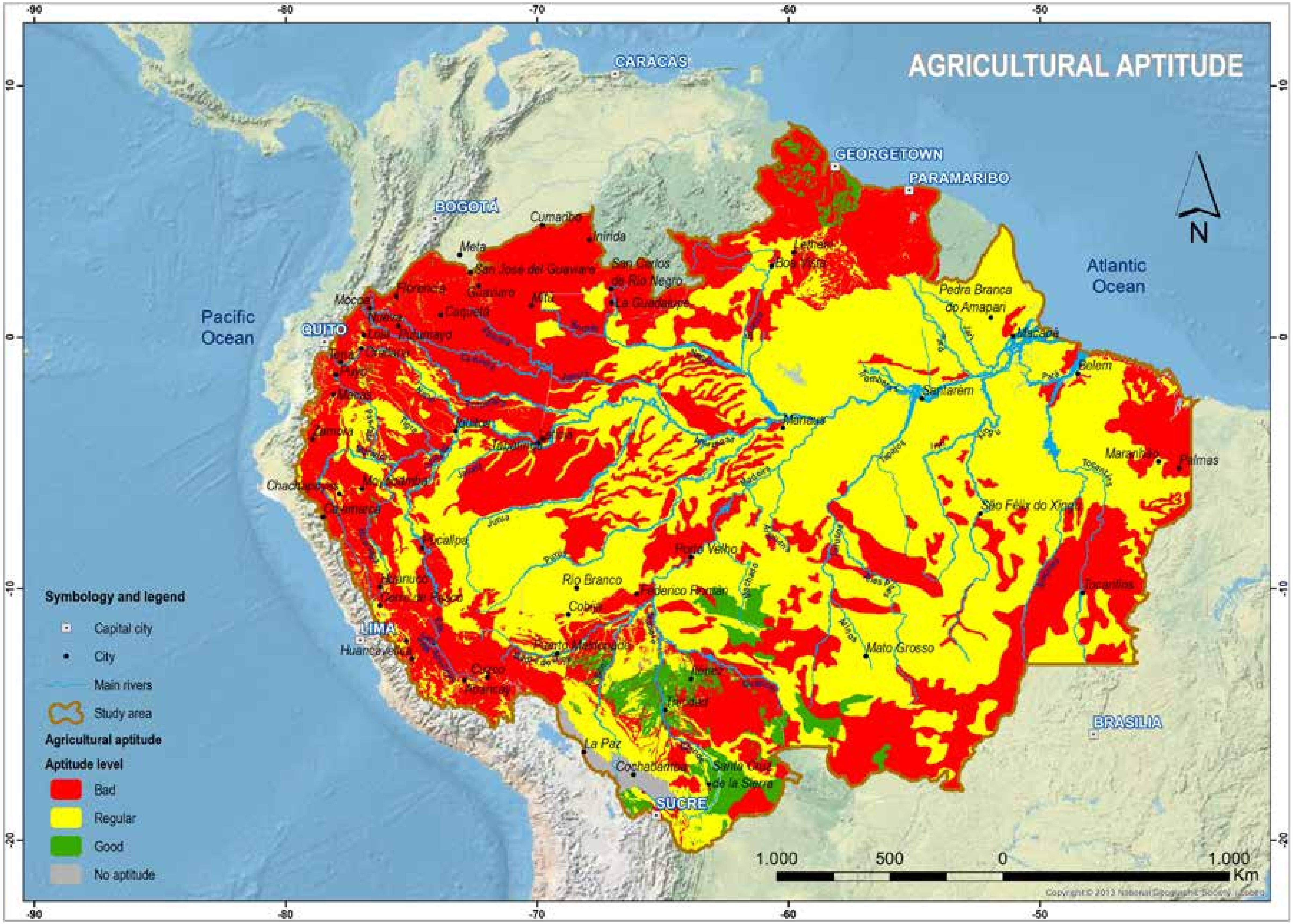
SOURCE: International Soil Reference and Information Centre, ISRIC (2011). Soil taxonomic classification. (https://www.isric.org/).

MAP 5.

Soil texture of the Amazon Region.

SOURCE: Batjes (2010). Regional classification of the soil texture.

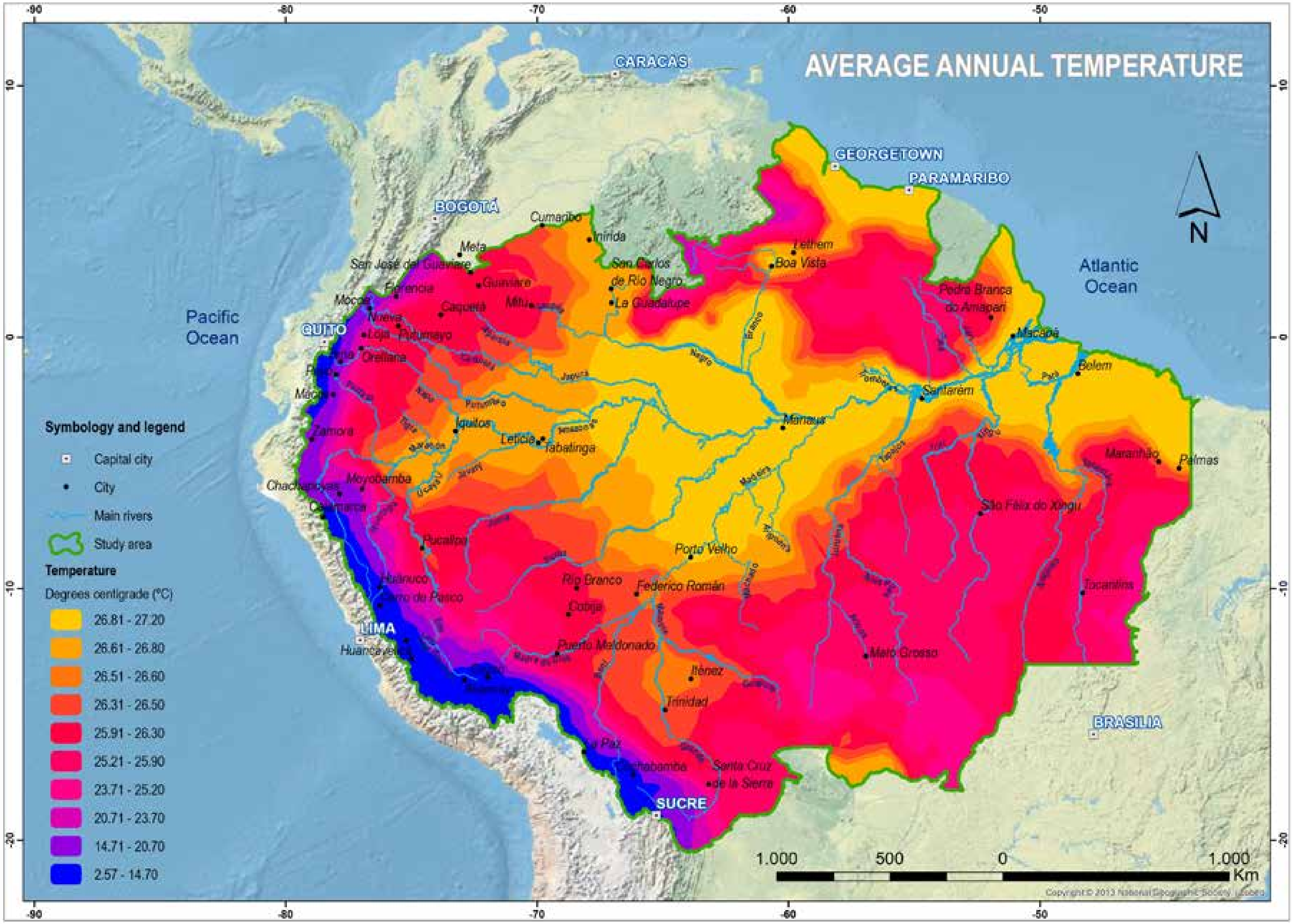
MAP 6.
Agricultural suitability of the soil of the Amazon Region.



SOURCE: Compilation of spatial information through ACTO's Focal Points[1] on the agricultural suitability of soils.

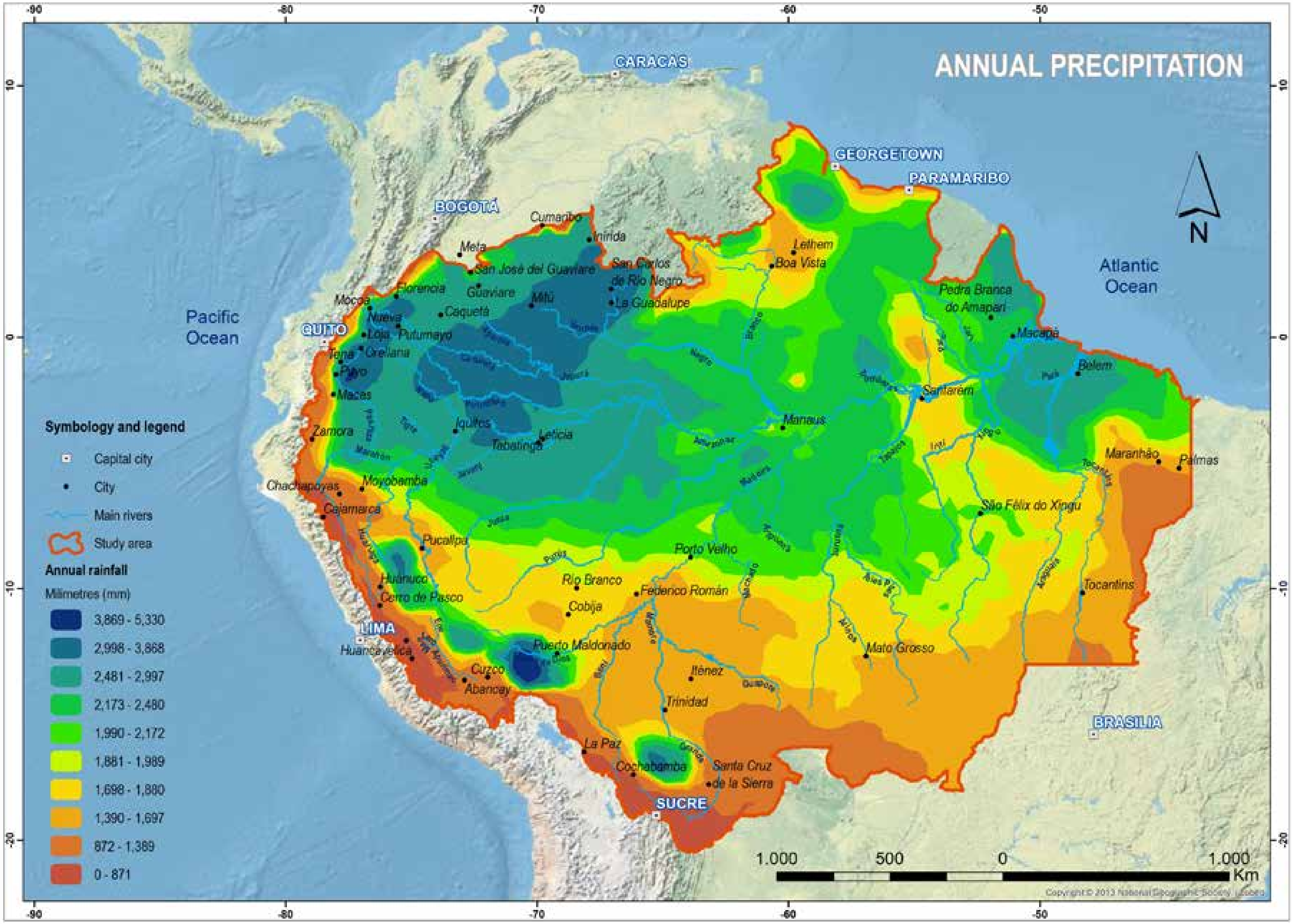
(1) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 7.
Average annual temperature in the Amazon Region.



SOURCE: CIIFEN and NASA climate data files, (2013).

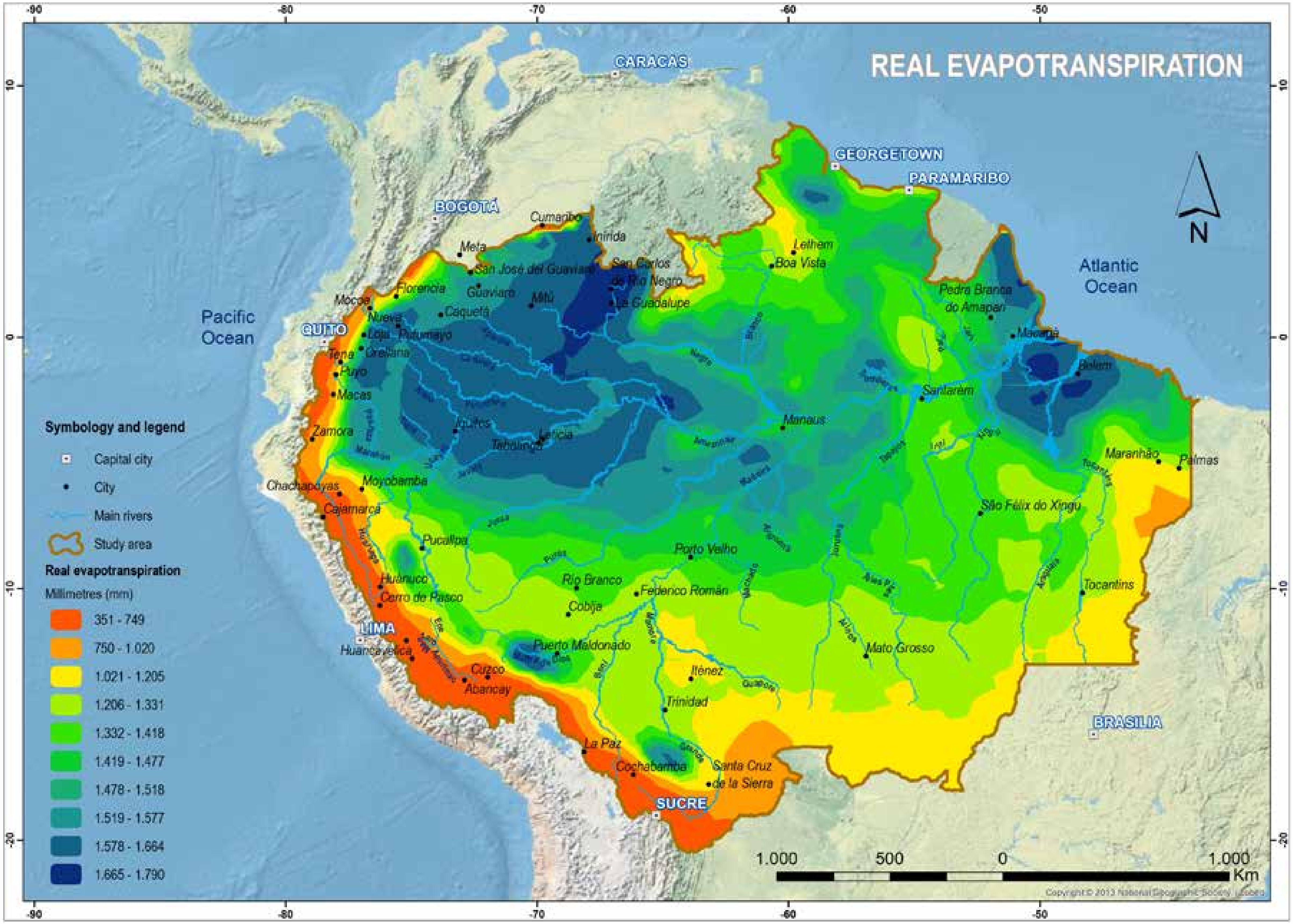
MAP 8.
Annual precipitation in the Amazon Region.



SOURCE: CIIFEN and TRMM-NASA climate data files.

MAP 9.

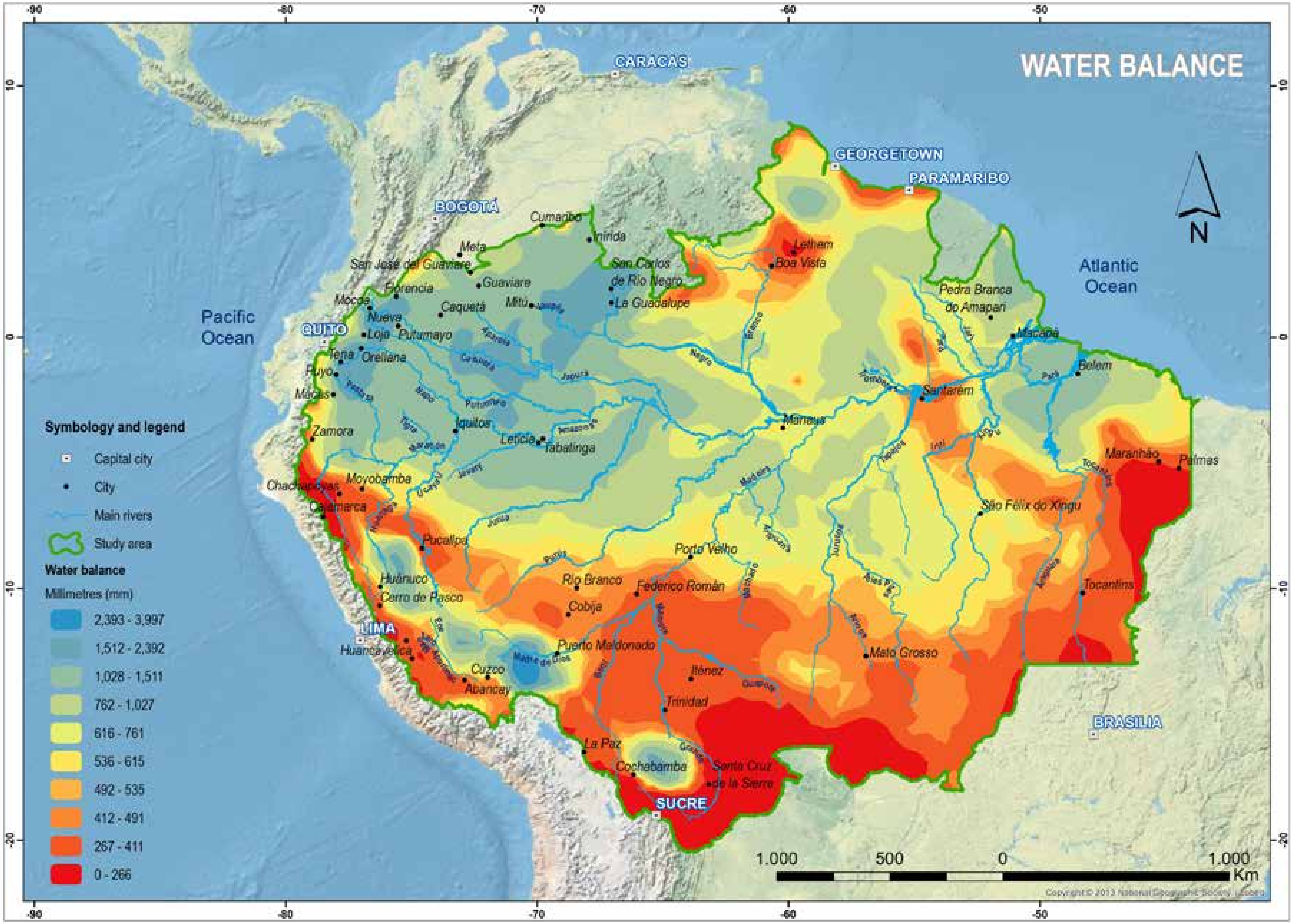
Real evapotranspiration of the Amazon Region.



SOURCE: According to the equation of the Actual Evapotranspiration of Turc, climate data files of CIIFEN and NASA-TRMM.

MAP 10.

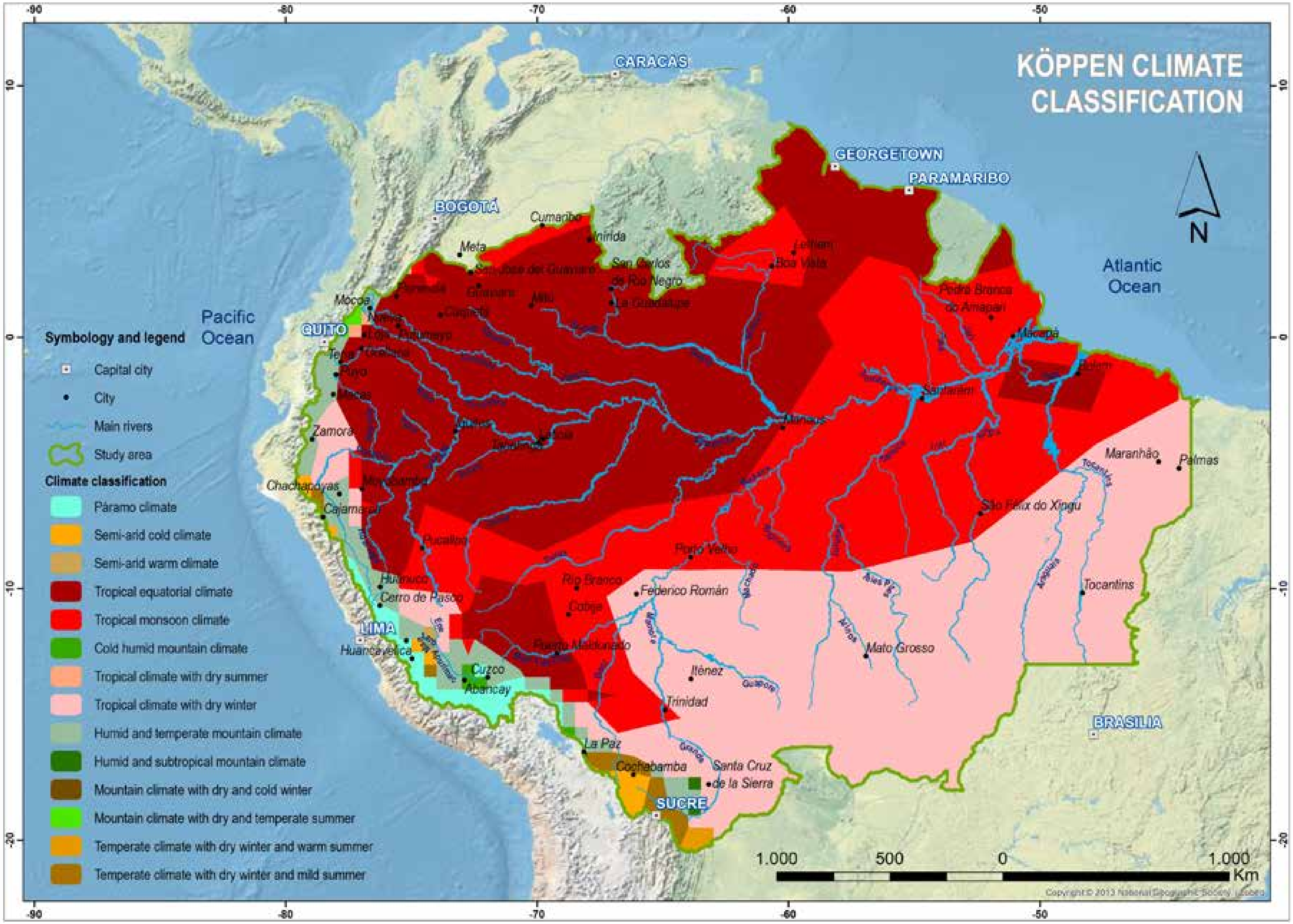
Water balance of the Amazon Region.



SOURCE: According to the general equation of the Elementary Water Balance suggested by UNESCO, 1981 & UNESCO, 2006. CIIFEN climate data files.

MAP 11.

Köppen's climate classification for the Amazon Region.



SOURCE: Kottek et al. (2006).

MAP 12.
Type of vegetation of the Amazon Region.

SOURCE: Compilation of spatial information through ACTO's Focal Points.[2]

(2) (2) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 13.
Ecoregions of the Amazon Region.

SOURCE: UNEP and CATHALAC (2010); Olson et al. (2001).

MAP 14.

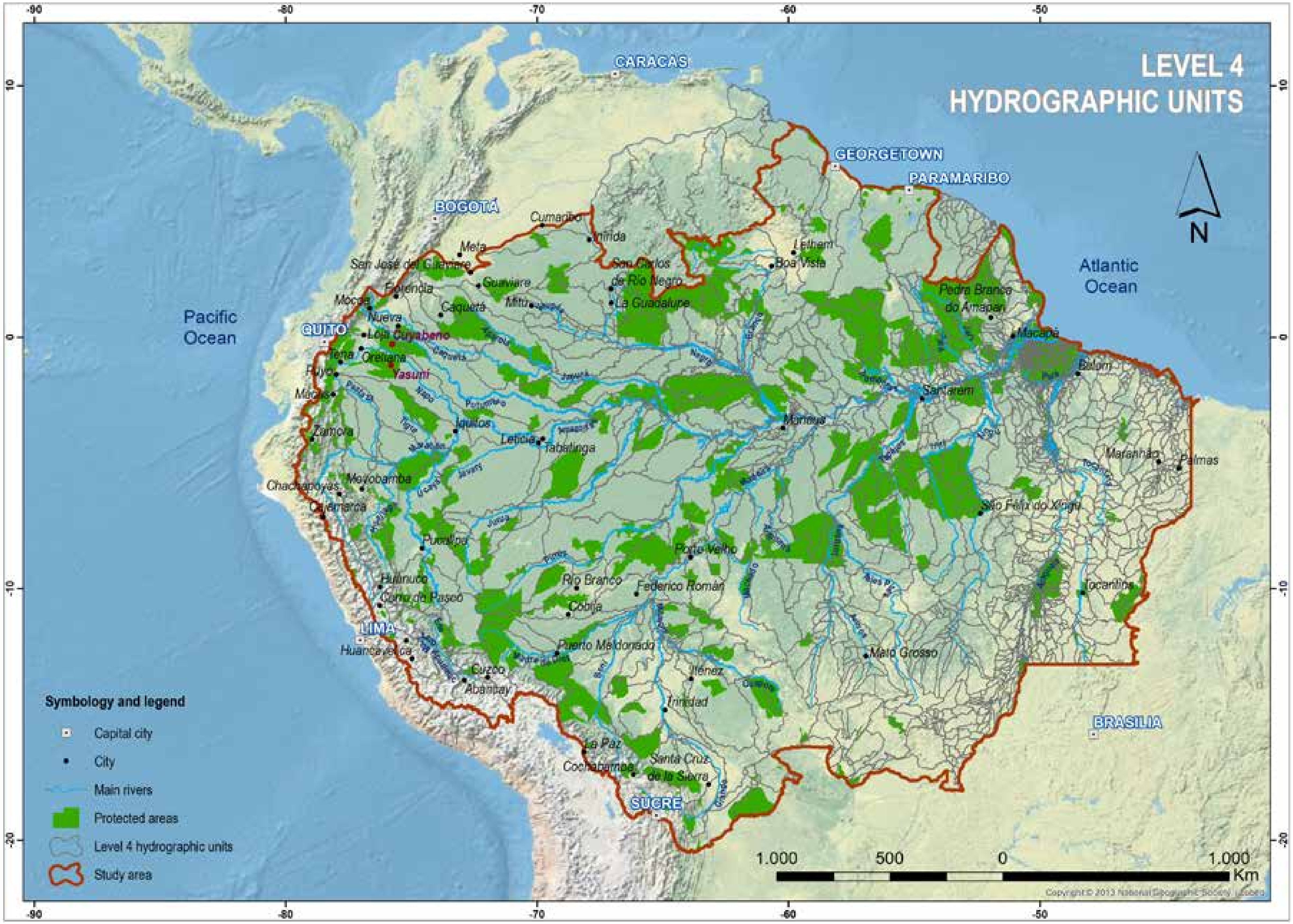
Main hydrographic network of the Amazon Region.

SOURCE: Compilation of spatial information through ACTO's Focal Points.[3]

(3) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 15.

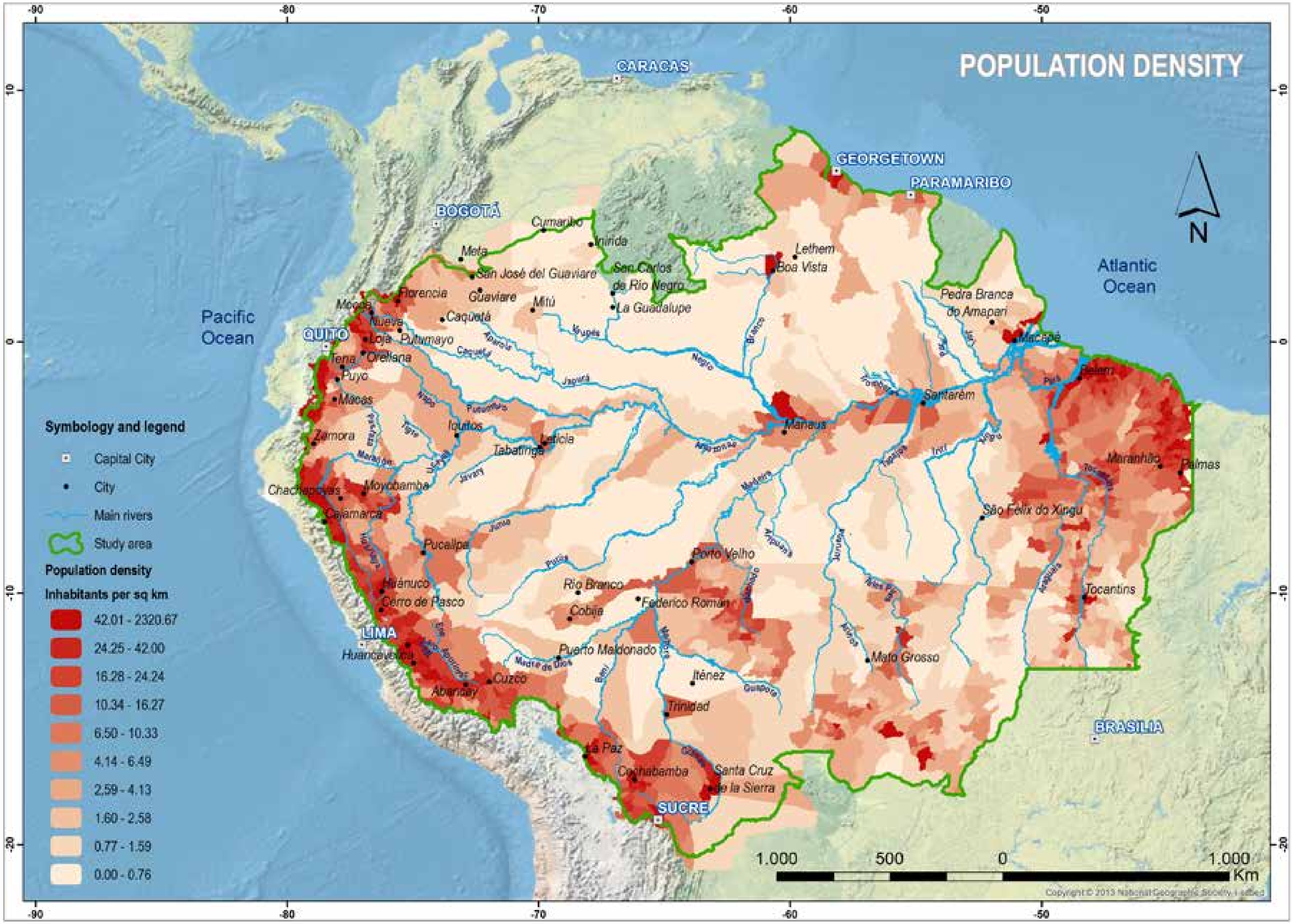
Level 4 Hydrographic Units of the Amazon Region.



SOURCE: Compilation of spatial information through ACTO's Focal Points.[4]

(4) ACTO's Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Water Secretariat (https://aplicaciones.senagua.gob.ec/servicios/descargas/). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 16.
Population density in the Amazon Region.



SOURCE: Information from the Population and Housing Censuses Published by the Statistical Institutes of each ACTO Member Country.[5]

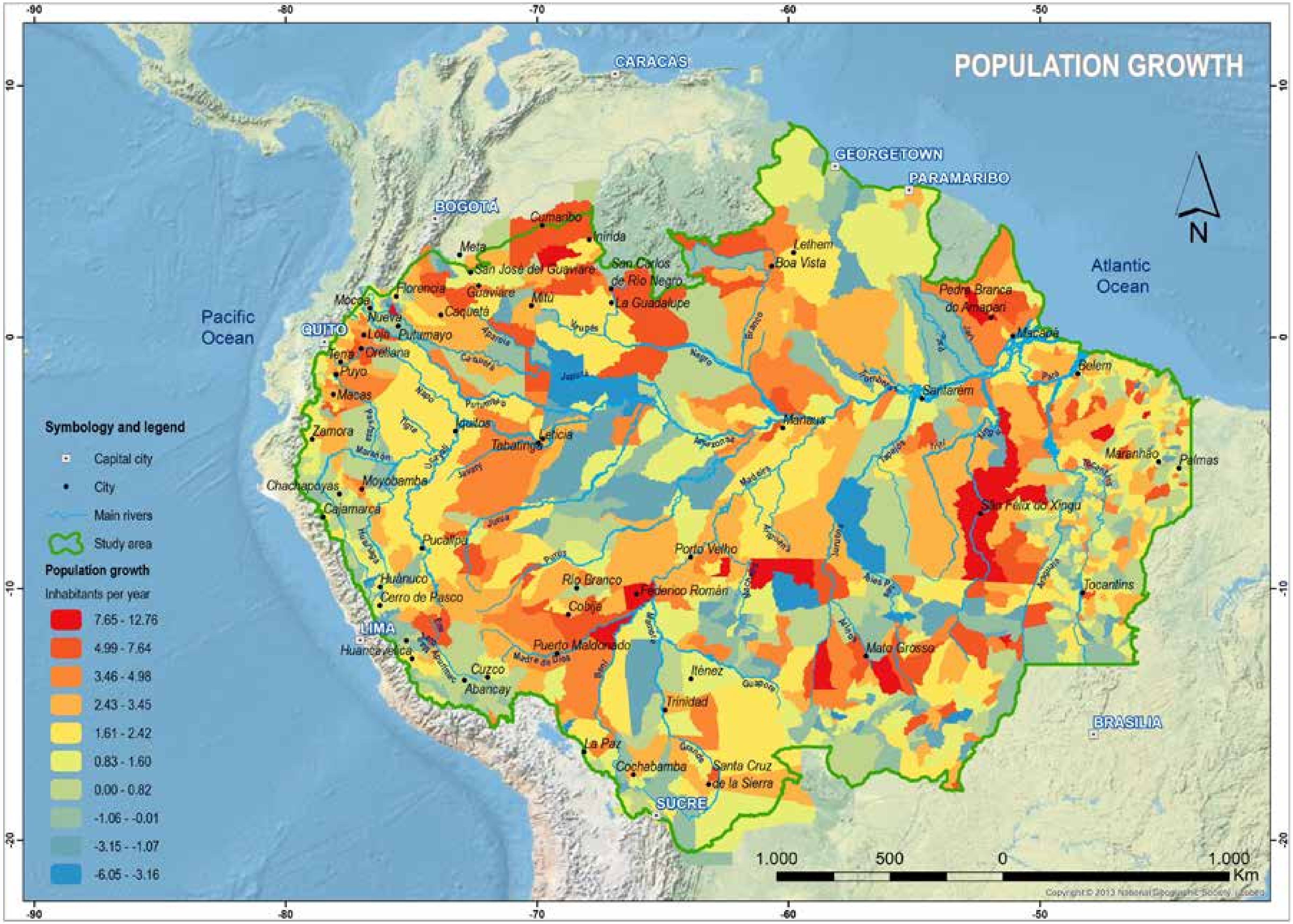
(5) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Census (INEC) Population and Housing Census 2012; Guyana: Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 17.
Indigenous territories of the Amazon Region.

SOURCE: RAISG (2012).

MAP 18.

Population growth in the Amazon Region.



SOURCE: Information from the Population and Housing Censuses Published by the Statistical Institutes of each ACTO Member Country.[6]

(6) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 19.

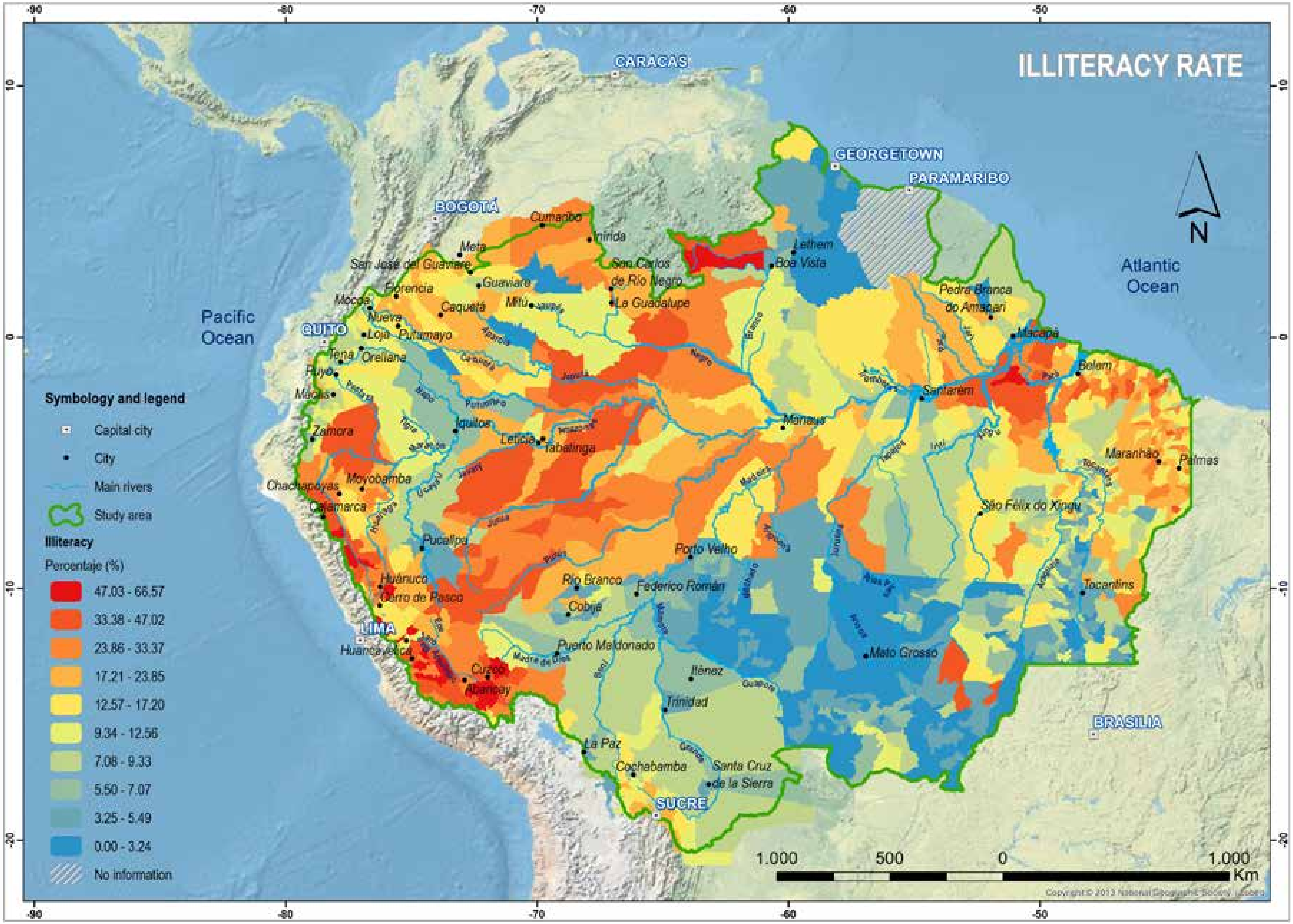
Age dependency ratio in the Amazon Region.

SOURCE: Information from the age groups of the Population and Housing Censuses Published by the Statistical Institutes of each ACTO Member Country.[7]

(7) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 20.

Illiteracy rates in the Amazon Region.

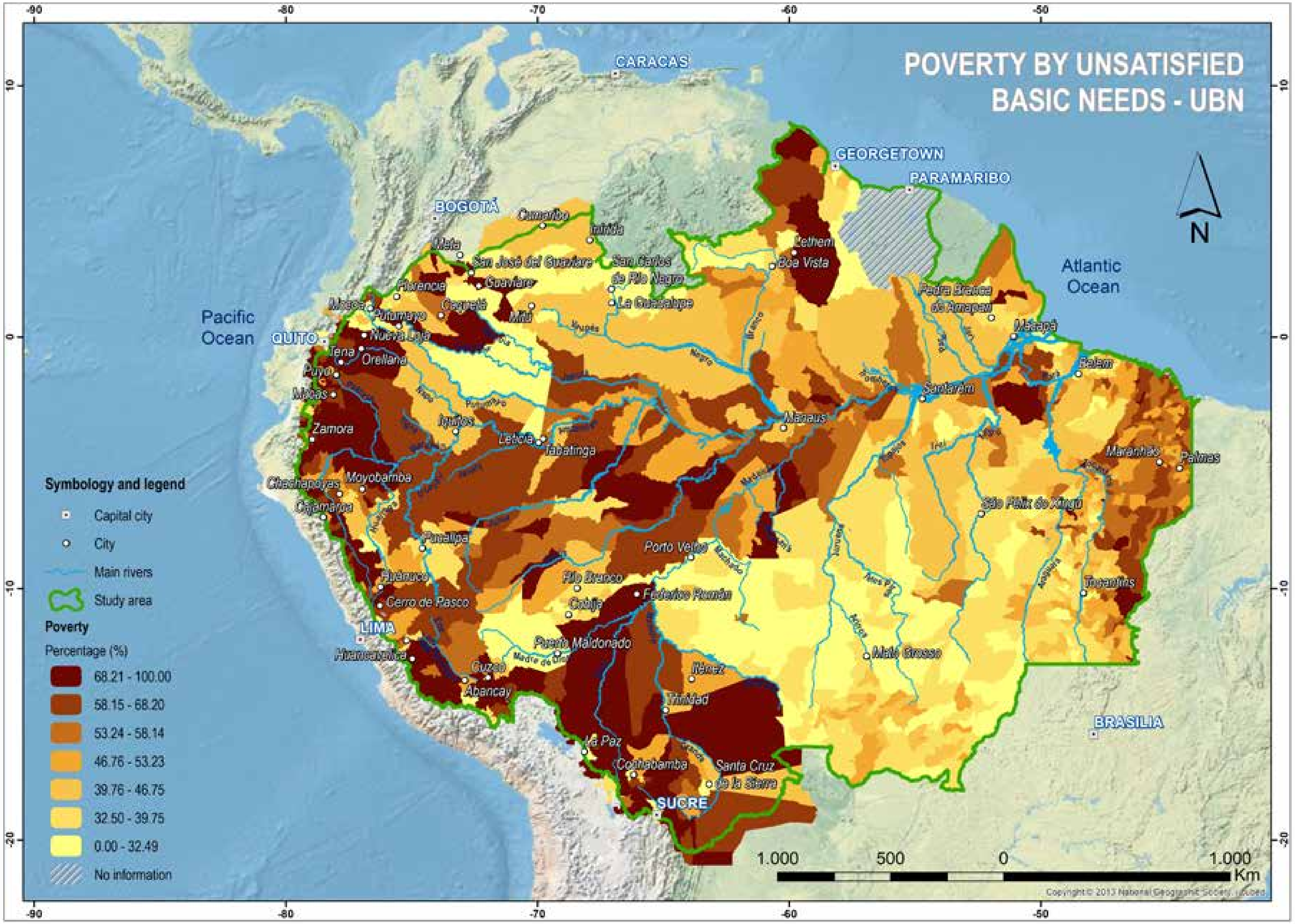


SOURCE: Information on people who cannot read or write in their official language, consulted in the Population and Housing Censuses of each ACTO Member Country.[8]

(8) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 21.

Poverty due to unsatisfied basic needs (UBN) in the Amazon Region.



SOURCE: Information of percentage of people with limitations in the access to goods and services for the satisfaction of the basic needs, consulted in the Censuses of Population and Housing published by the Institutes of statistics of each ACTO Member Country.[9]

(9) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 22.

Agricultural areas in the Amazon Region.

SOURCE: Compilation of spatial information through ACTO's Focal Points.[10]

(10) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

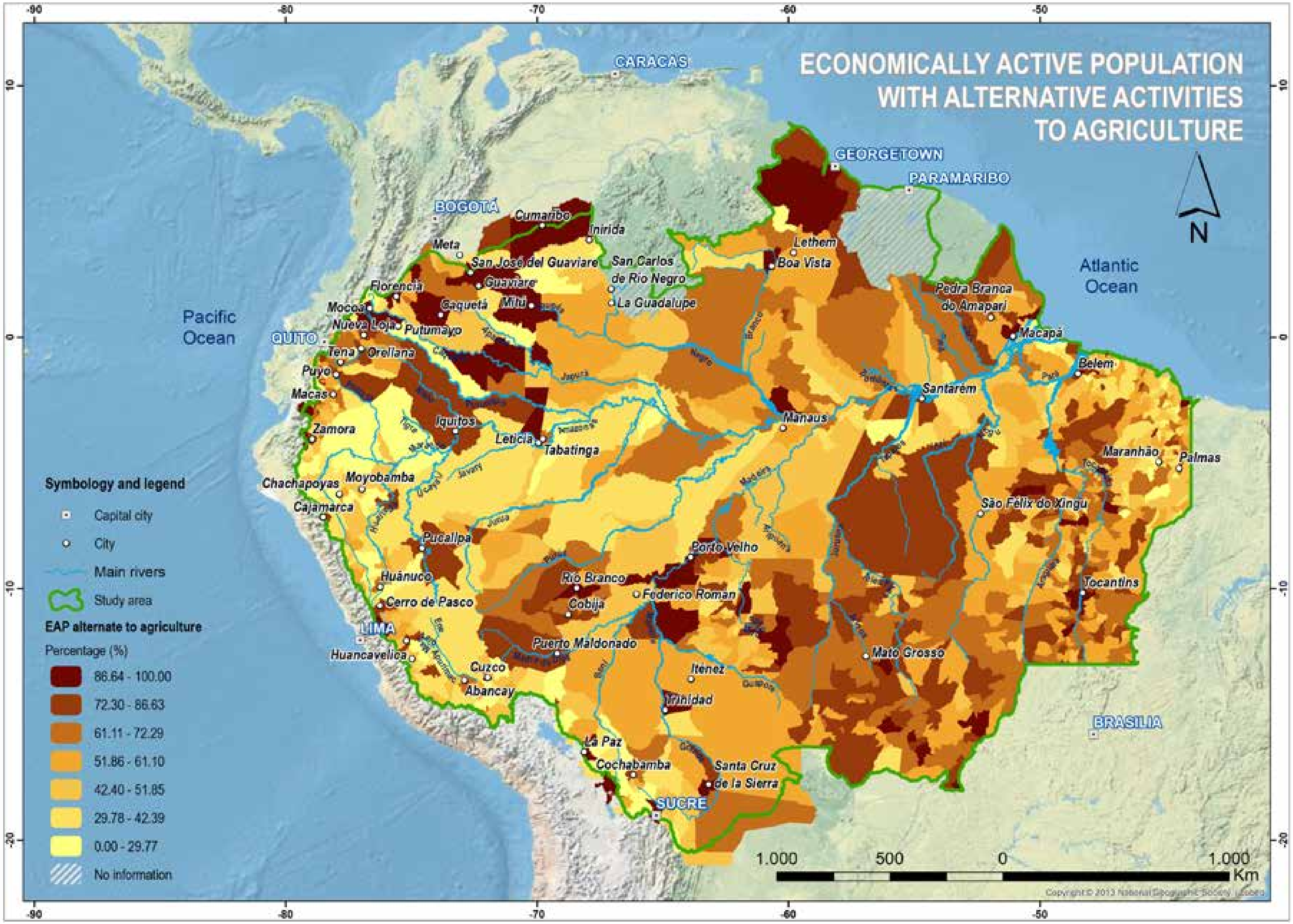
MAP 23.

Economically active population involved in agriculture in the Amazon Region.

SOURCE: Information on the economically active population according to its branch of economic activity, consulted in the Population and Housing Censuses of the Statistical Institutes of each ACTO Member Country.[11]

(11) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 24.
Economically active population with alternatives to agriculture in the Amazon Region.

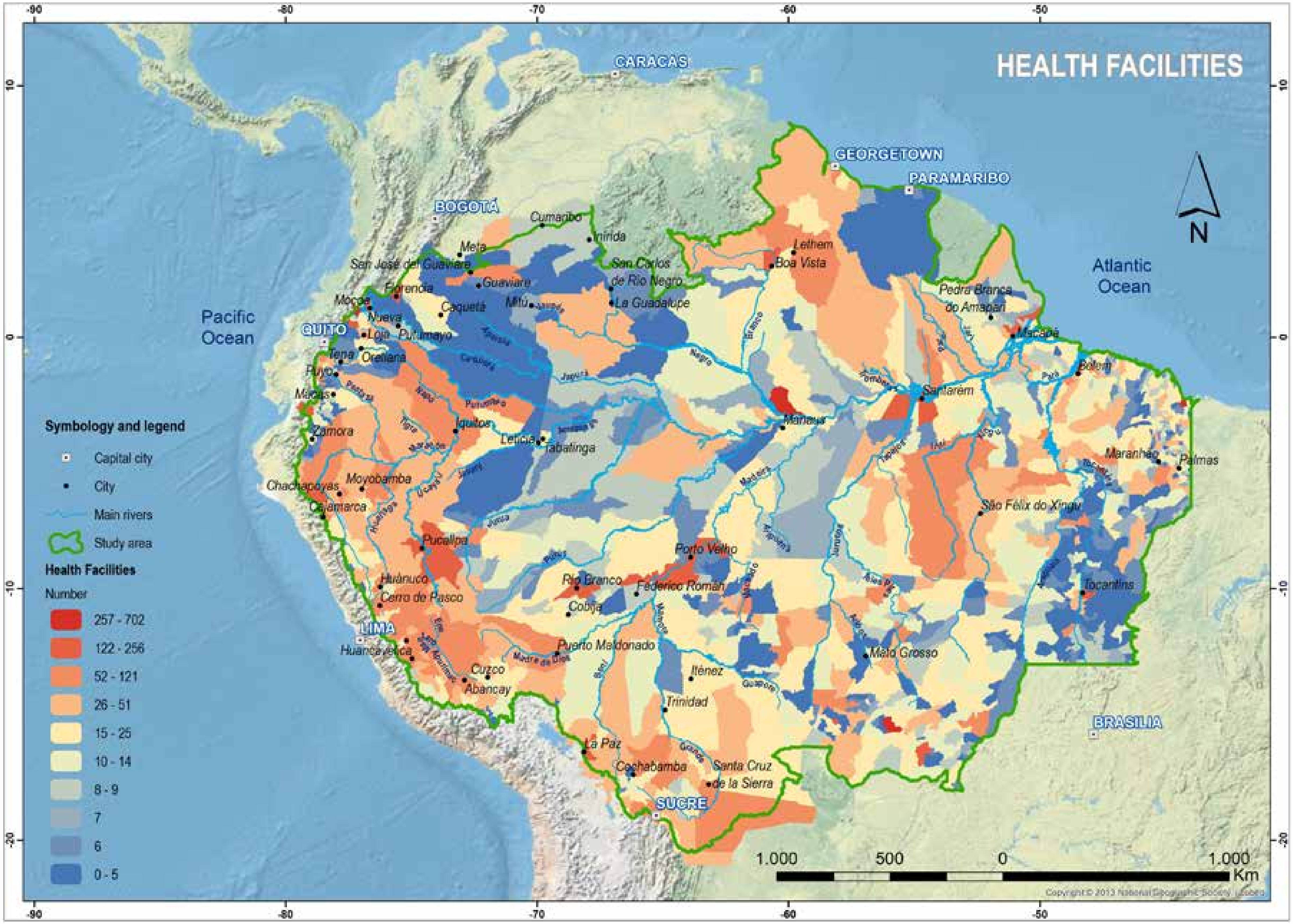


SOURCE: Information on the economically active population according to its branch of economic activity, consulted in the Population and Housing Censuses of the Statistical Institutes of each ACTO Member Country.[12]

(12) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Censuses (INEC), 2012 Population and Housing Census; Guyana Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 25.

Distribution of healthcare facilities in the Amazon Region.

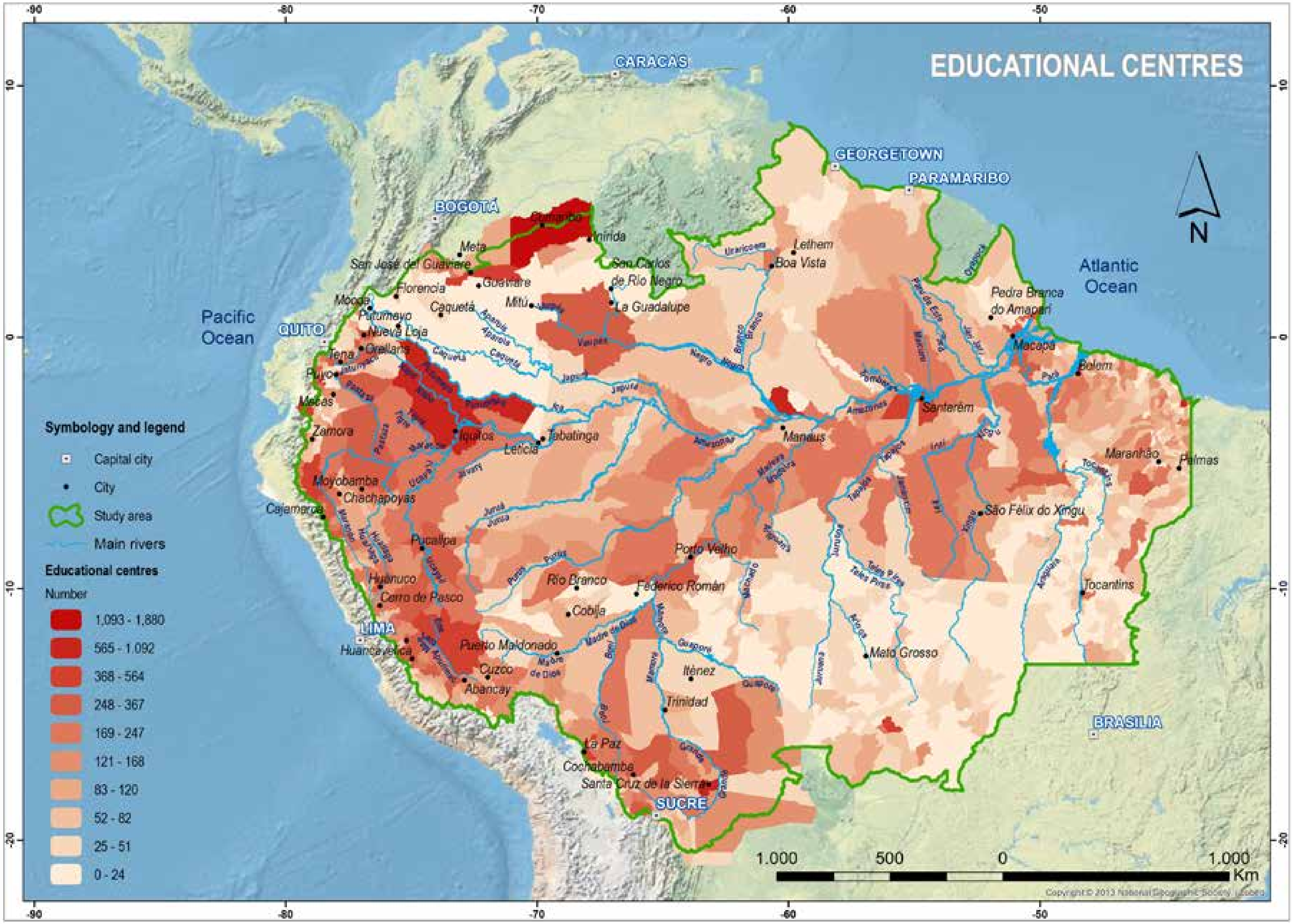


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[13]

(13) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 26.

Distribution of educational centers in the Amazon Region.



SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[14]

(14) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 27.
Main road network in the Amazon Region.

SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[15]

(15) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Simon Bolivar Geographic Institute (http://www.igvsb.gob.ve).

MAP 28.

Secondary road network in the Amazon Region.

SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[16]

(16) ACTO's Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Simon Bolivar Geographic Institute (http://www.igvsb.gob.ve).

MAP 29.
Hydrographic network of the Amazon Region.

SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[17]

(17) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Simón Bolívar Geographic Institute (http://www.igvsb.gob.ve).

MAP 30.

Manta-Manaus multimodal transport system.

SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[18]

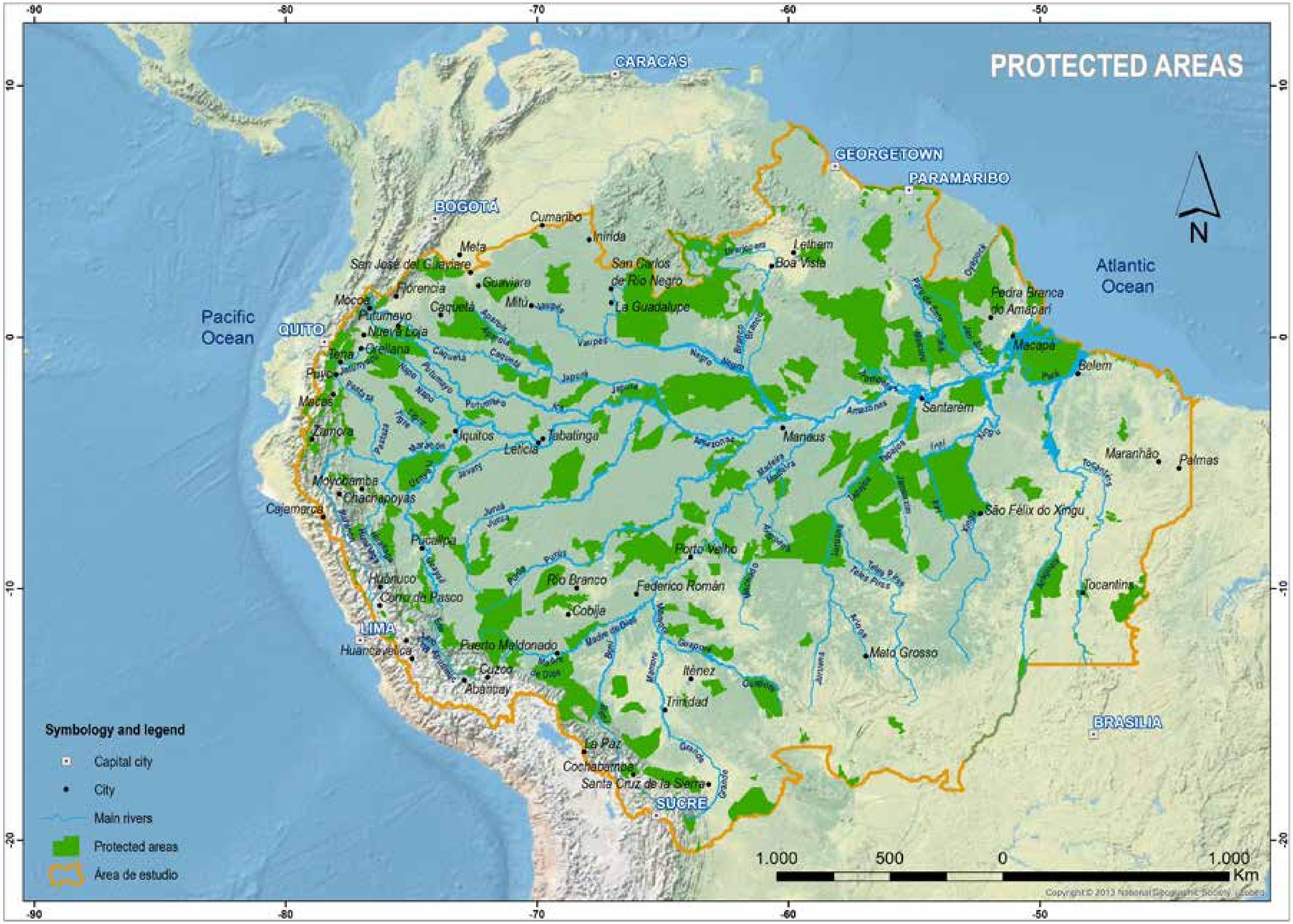
(18) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Ministry of Transport and Public Works of Ecuador; Military Geographic Institute (https://www.obraspublicas.gob.ec/ & http://www.igm.gob.ec). Venezuela: Simón Bolívar Geographic Institute (http://www.igvsb.gob.ve).

MAP 31.
Electrical infrastructure of the Amazon Region.

SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[19]

(19) ACTO Focal Points: Brazil, Colombia, Guyana and Peru. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Simón Bolívar Geographic Institute (http://www.igvsb.gob.ve).

MAP 32.
Protected areas in the Amazon Region.

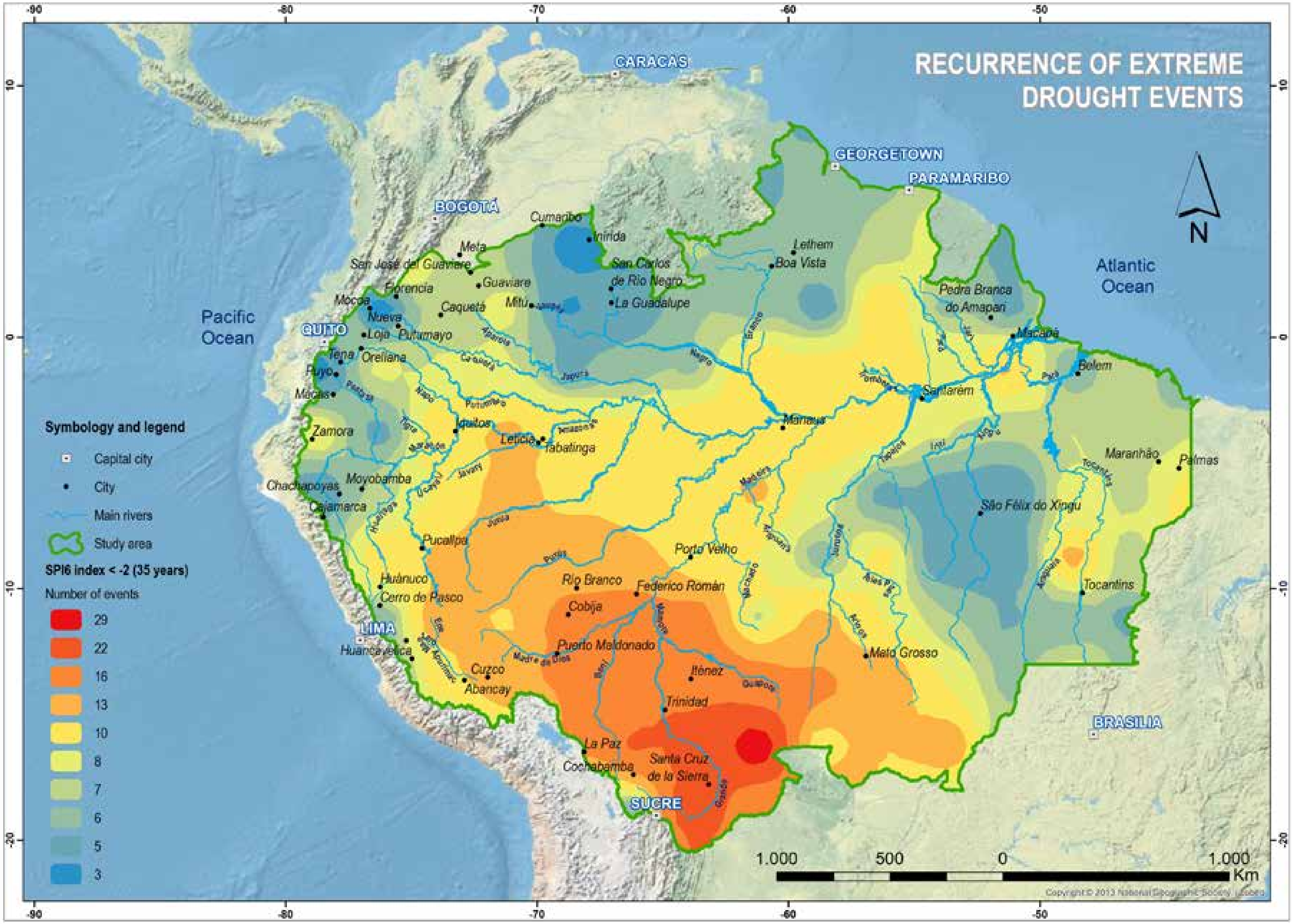


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[20]

(20) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Simón Bolívar Geographic Institute (http://www.igvsb.gob.ve).

MAP 33.

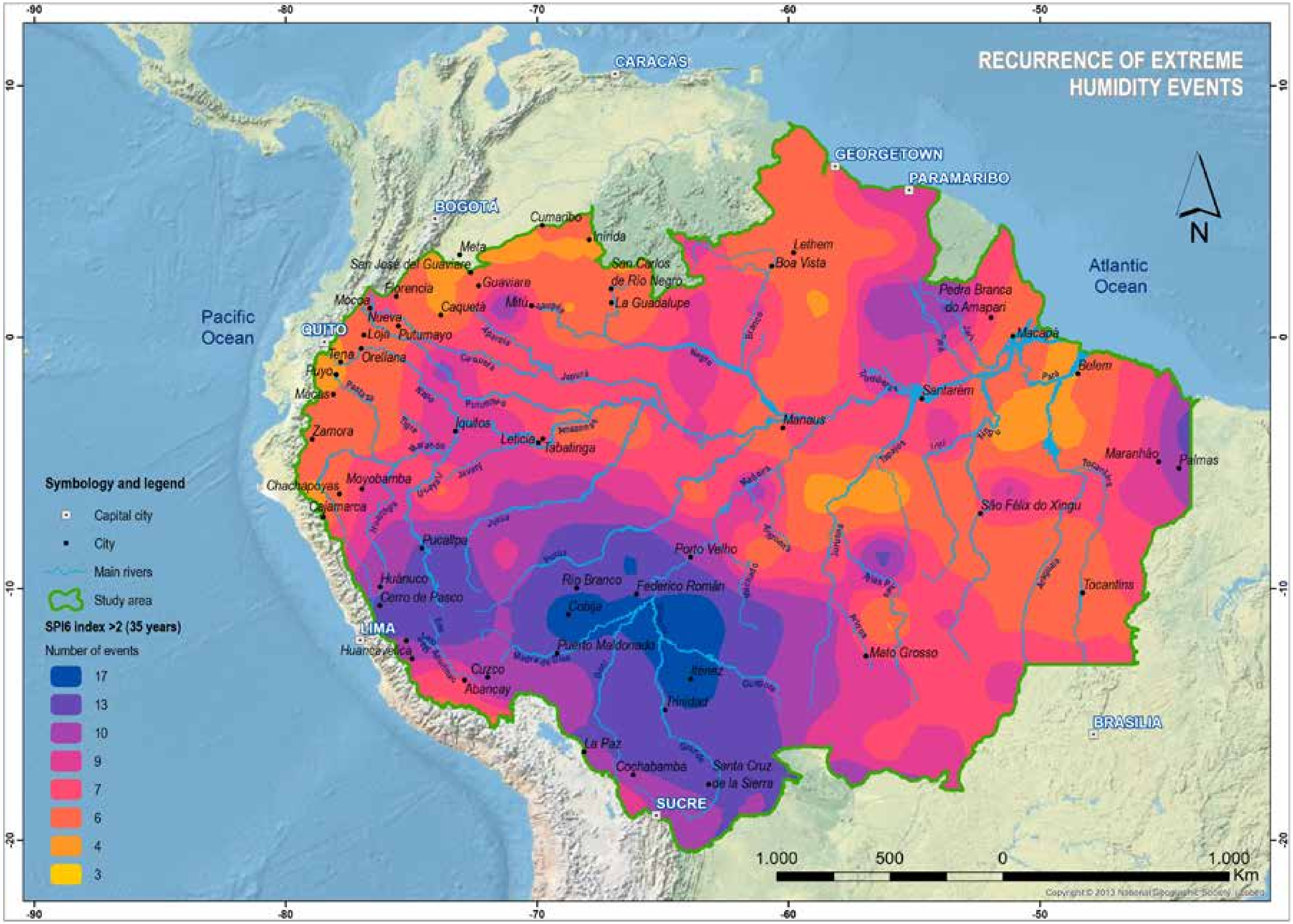
Incidence of extreme drought events in the Amazon Region.



SOURCE: Standardized precipitation index of 6 months. Analysis of the frequency of events with an index lower than -2 (extreme drought) for a period of 35 years. IRI (2014) Climate Anomaly Monitoring System– Outgoing longwave radiation Precipitation Index. Available at: http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CAMS_OPI/.v0208_old/gauge+.count/index.html

MAP 34.

Incidence of extreme rainfall events in the Amazon Region.



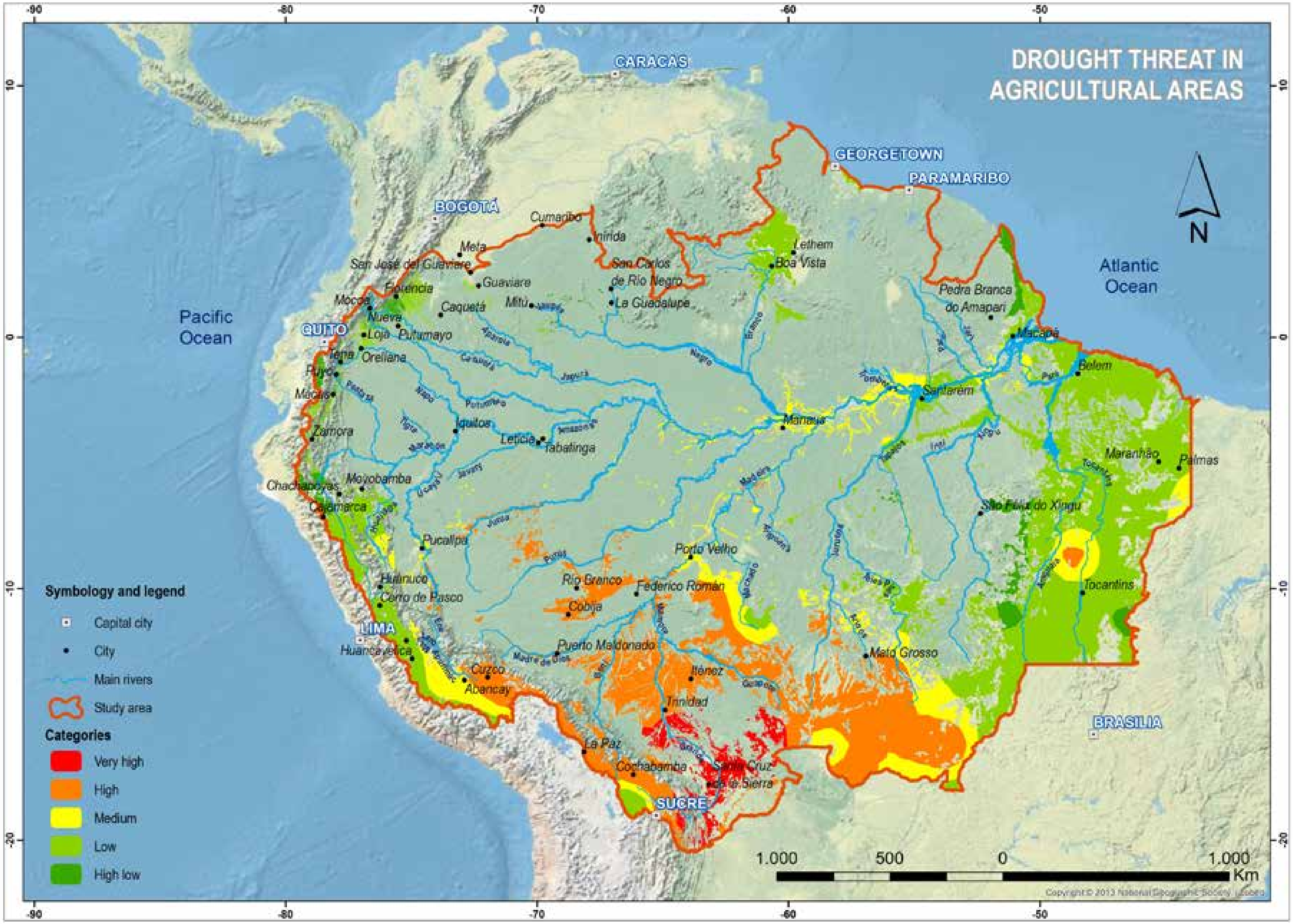
SOURCE: Standardized precipitation index of 6 months. Analysis of the frequency of events with an index higher than 2 (extreme humidity) for a period of 35 years. IRI (2014) Climate Anomaly Monitoring System–Outgoing longwave radiation Precipitation Index. Available at: http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.CAMS_OPI/.v0208_old/gauge+.count/index.html

MAP 35.
Flood zones in the Amazon Region.

SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[21]

(21) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 36.
Threat to farming due to droughts in the Amazon Region.

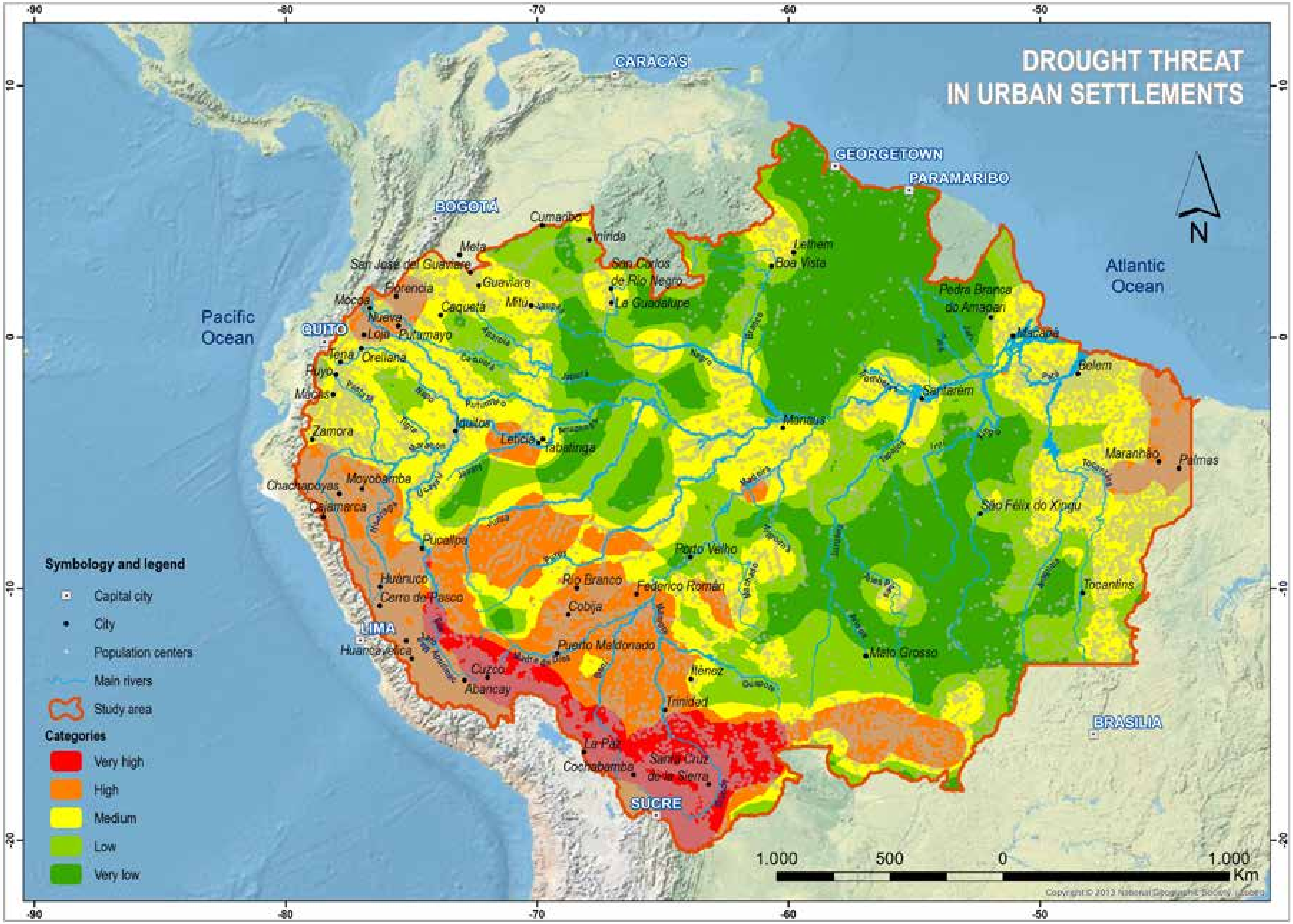


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[22]

(22) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 37.

Threat to urban settlements due to droughts in the Amazon Region.

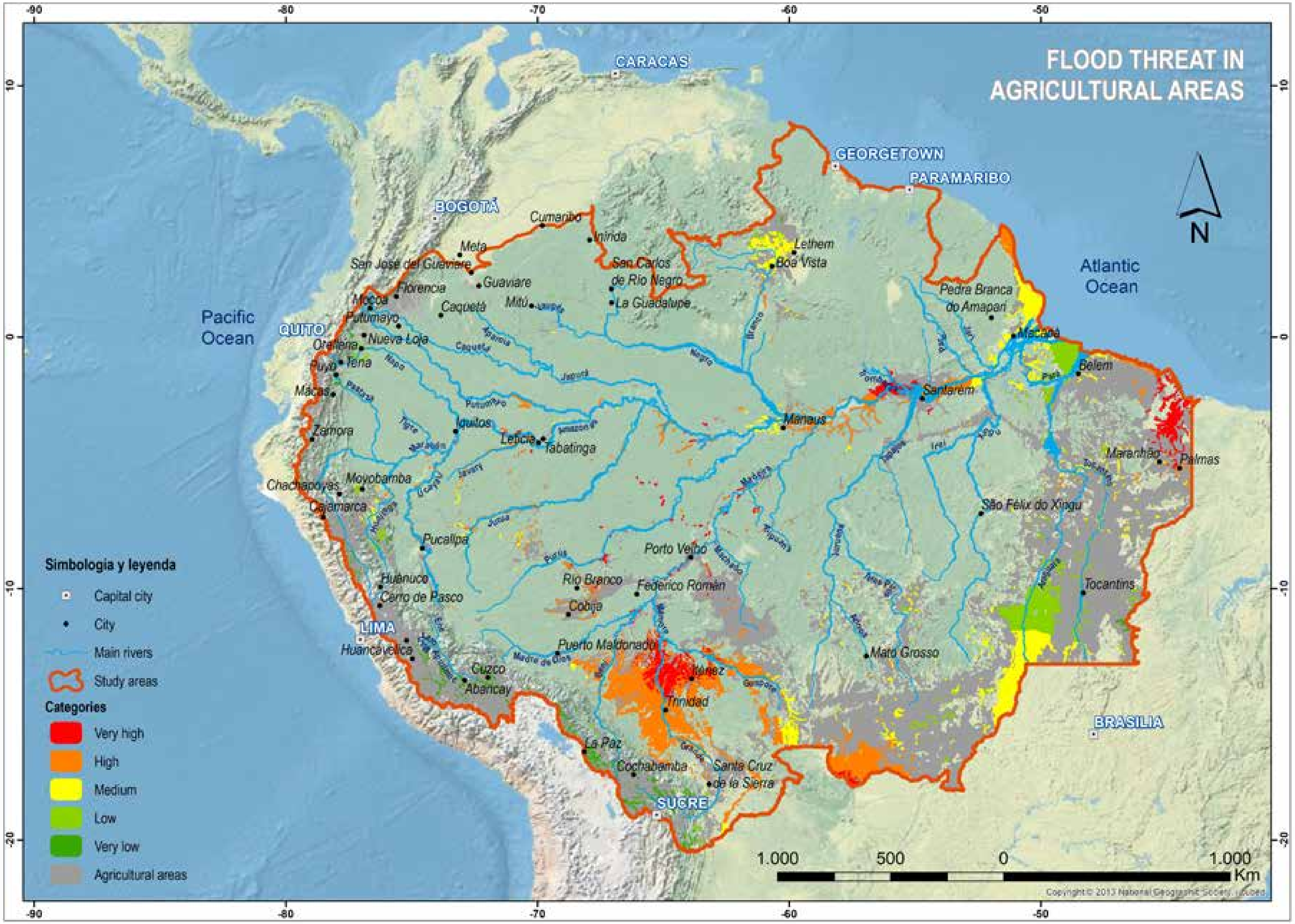


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[23]

(23) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS); Military Geographic Institute (https://sni.gob.ec/inicio & http://www.igm.gob.ec). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 38.

Threat to farming due to floods in the Amazon Region.

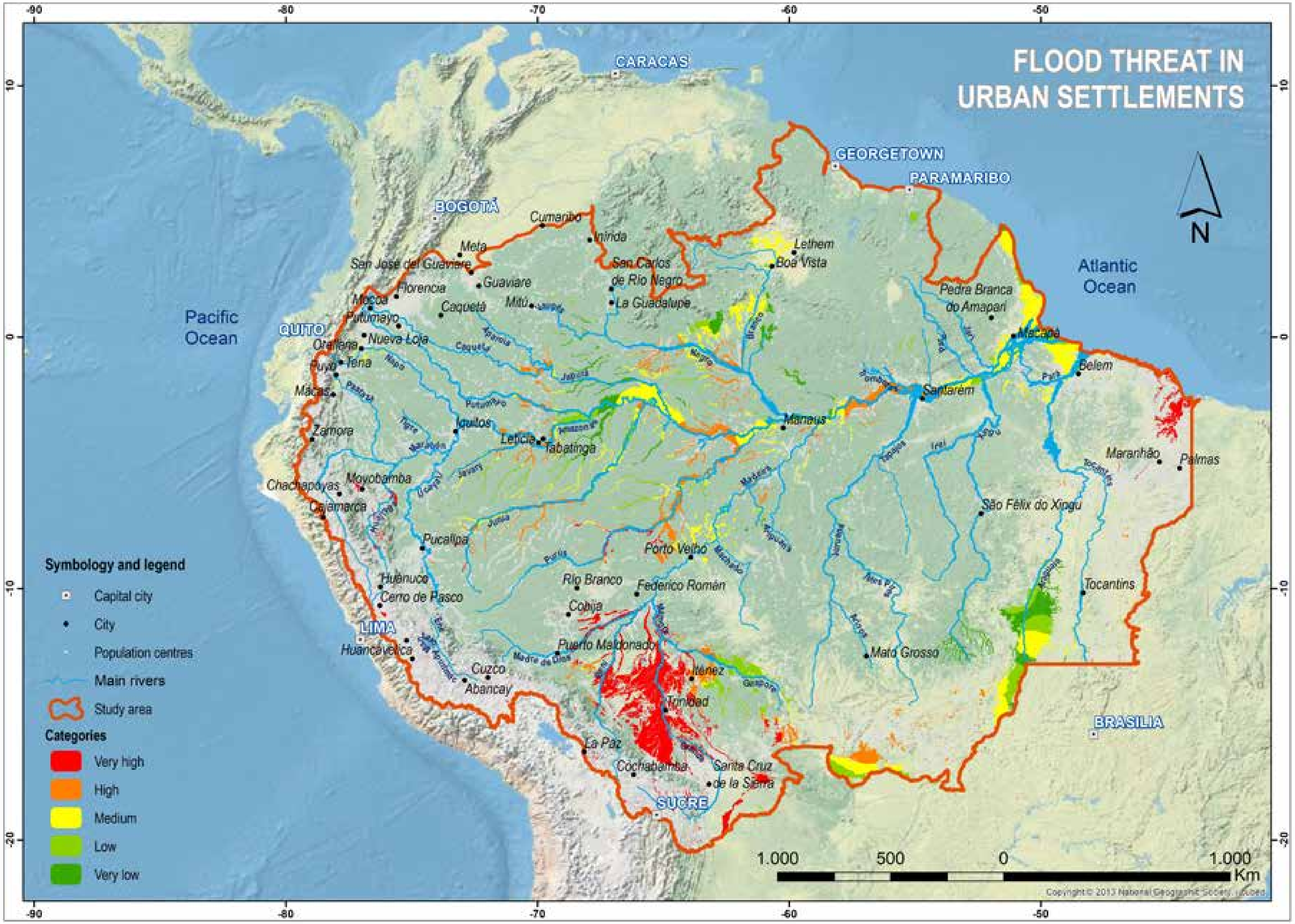


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[24]

(24) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Web portal of Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS); Military Geographic Institute (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 39.

Threat to urban settlements due to floods in the Amazon Region.

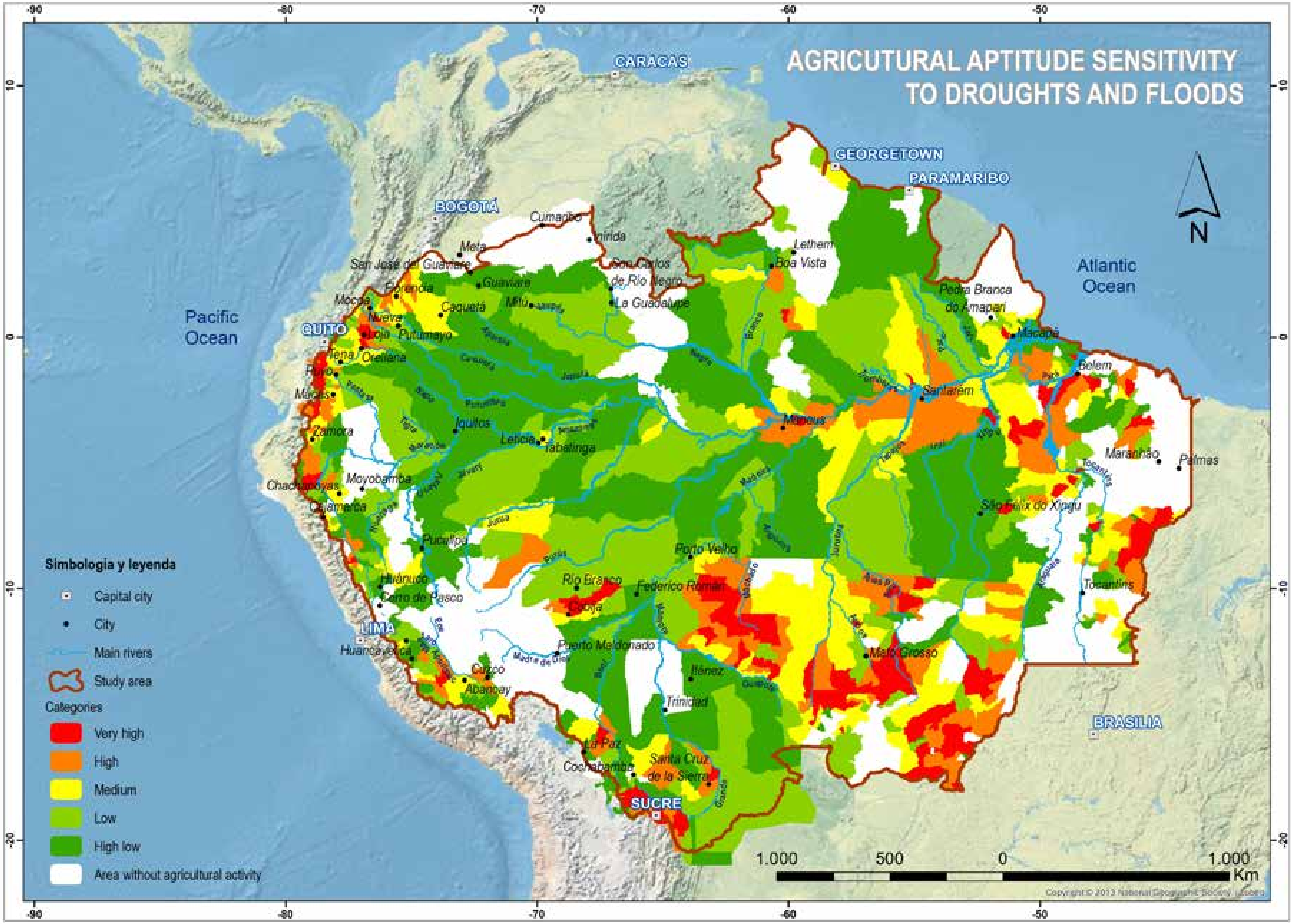


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[25]

(25) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS); Military Geographic Institute (https://sni.gob.ec/inicio & http://www.igm.gob.ec). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 40.

Sensitivity to droughts and floods due to soil suitability in the Amazon Region.

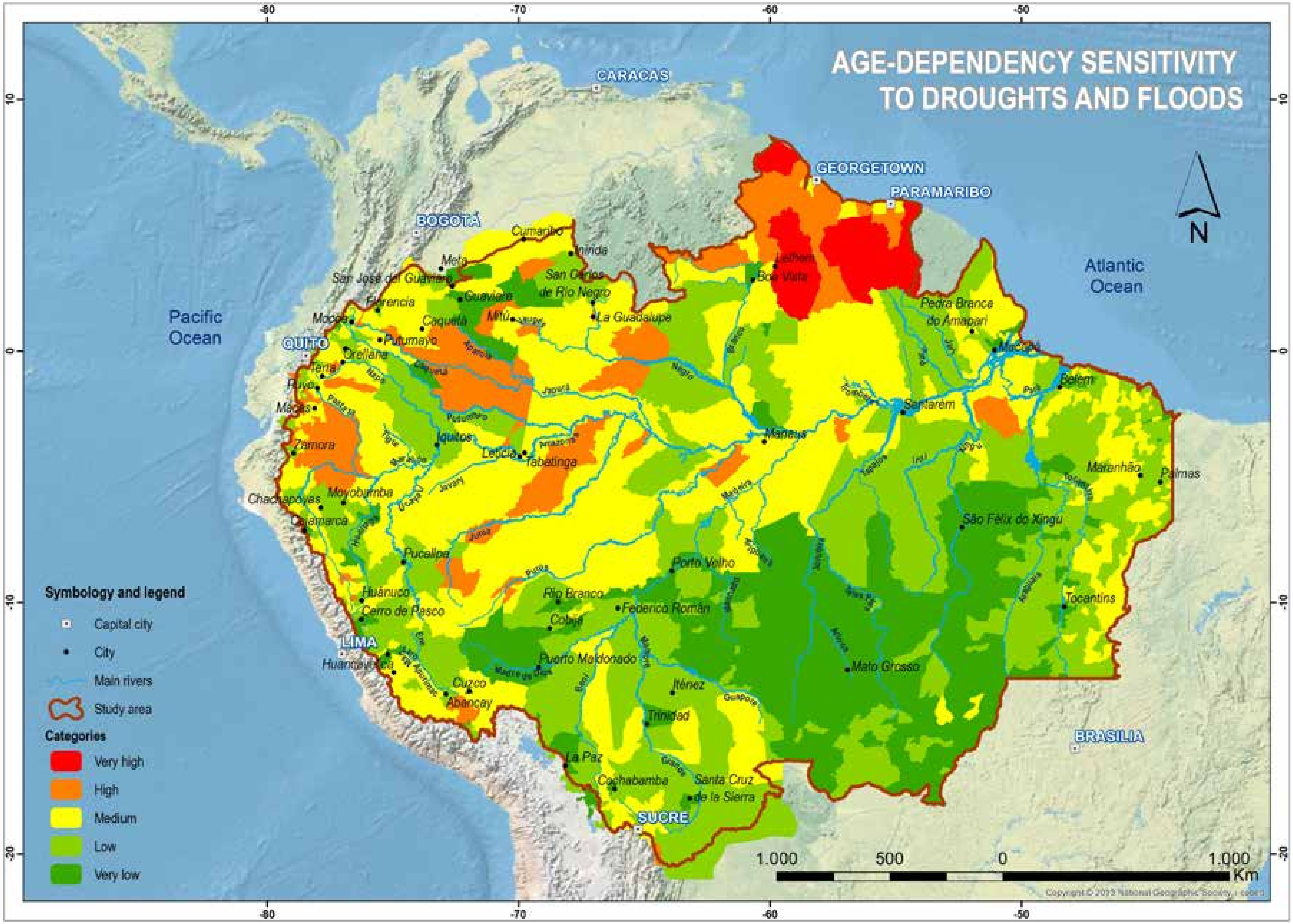


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[26]

(26) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS); Military Geographic Institute (https://sni.gob.ec/inicio); Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 41.

Sensitivity to droughts and floods due to age dependency in the Amazon Region.

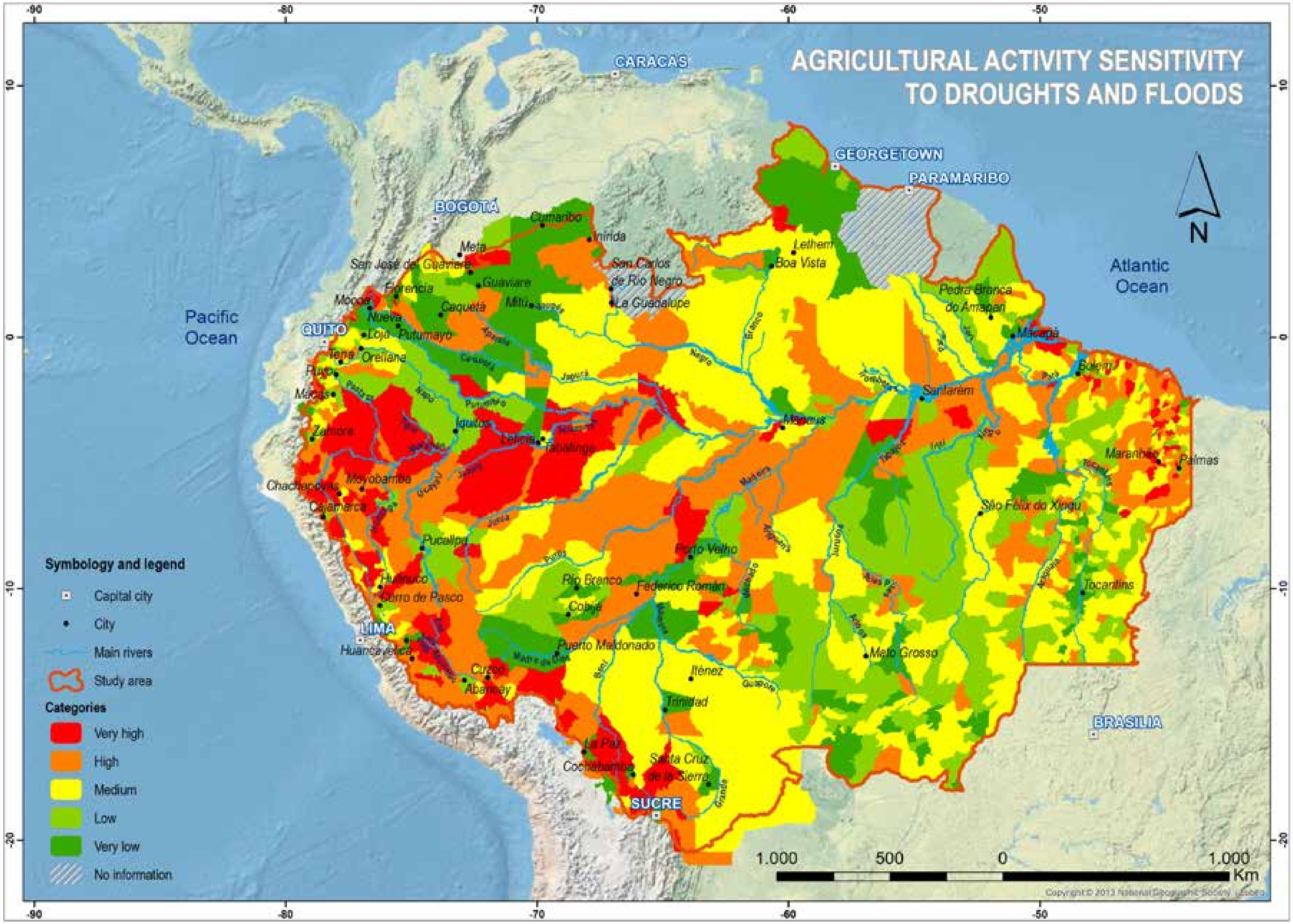


SOURCE: Sensitivity indicator elaborated from information of age groups consulted in the Censuses of Population and Housing of the Institutes of statistics of each ACTO Member Country.[27]

(27) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Census (INEC) Population and Housing Census 2012; Guyana: Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Suriname Algemeen Bureau voor de Statistiek in Suriname, Population and Housing Census 2012; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 42.

Sensitivity to droughts and floods due to agricultural activity in the Amazon Region.

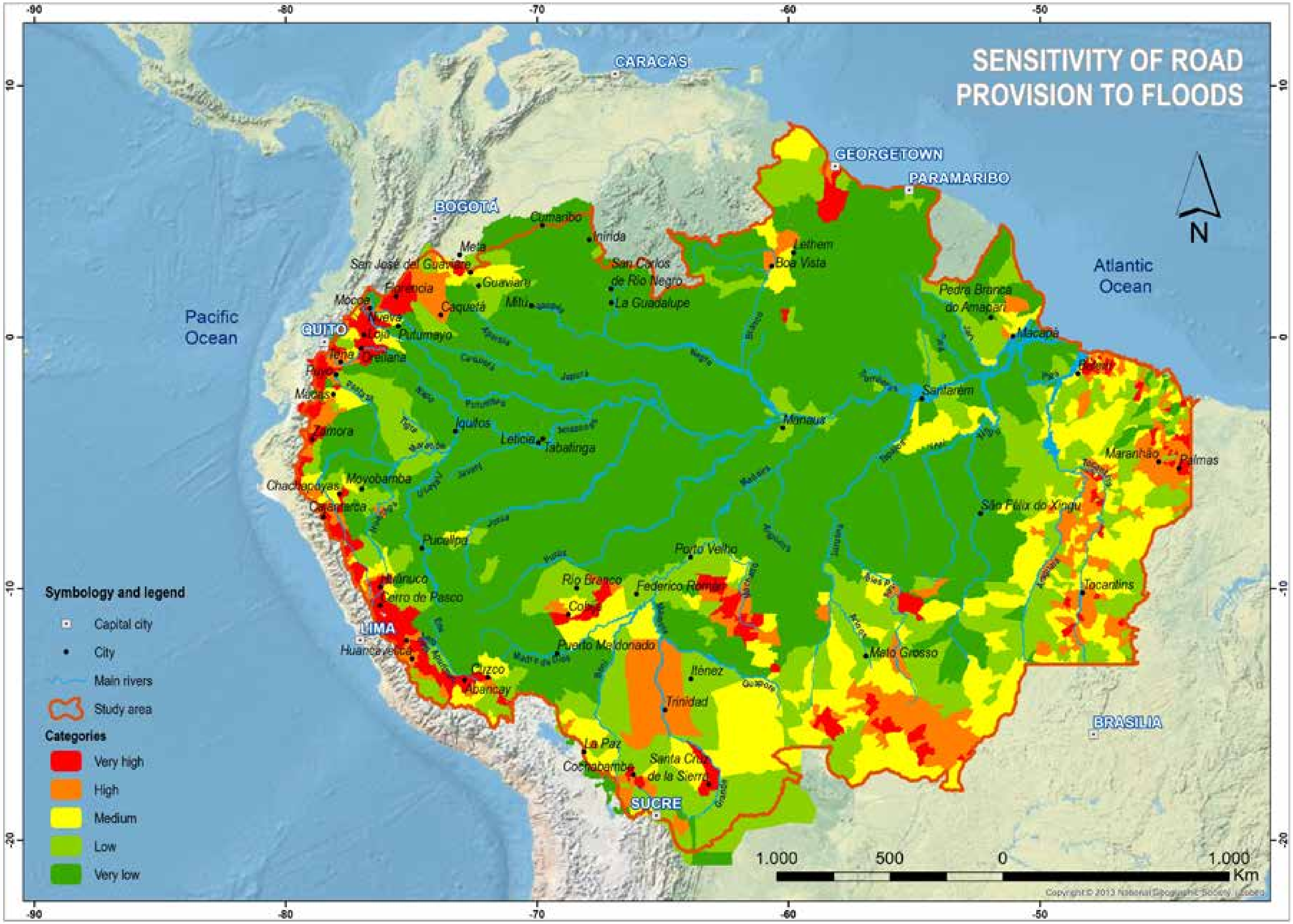


SOURCE: Sensitivity indicator elaborated from information of economically active population according to its branch of economic activity, consulted in the Population and Housing Census of the Institutes of statistics of each ACTO Member Country.[28]

(28) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Census (INEC) Population and Housing Census 2012; Guyana: Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 43.

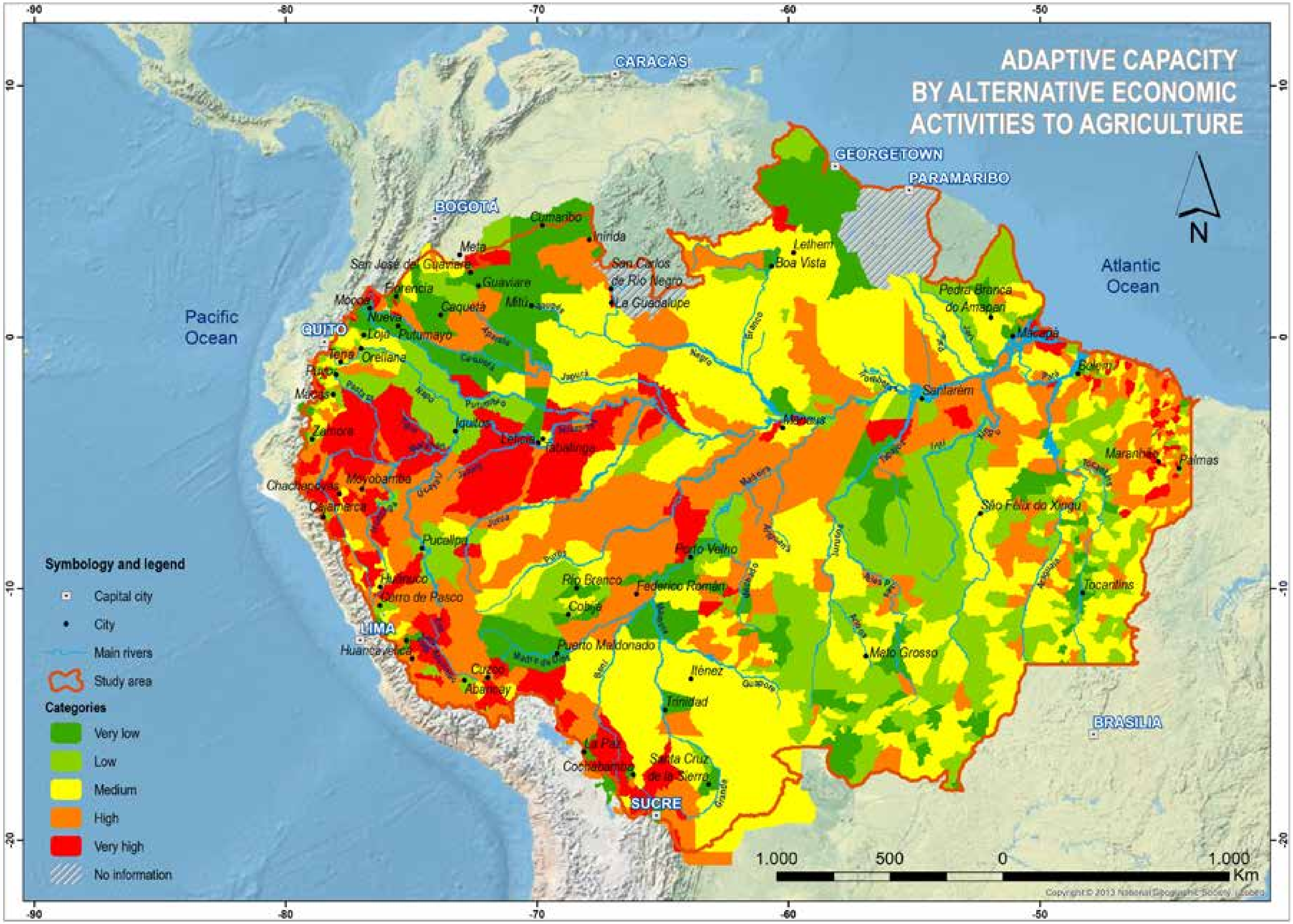
Sensitivity to floods due to roads in the Amazon Region.



SOURCE: Sensitivity indicator elaborated from the main and secondary road system information consulted through official websites and ACTO's Focal Points.[29]

(29) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: Military Geographic Institute (http://www.igm.gob.ec). Venezuela: Simón Bolívar Geographic Institute (http://www.igvsb.gob.ve).

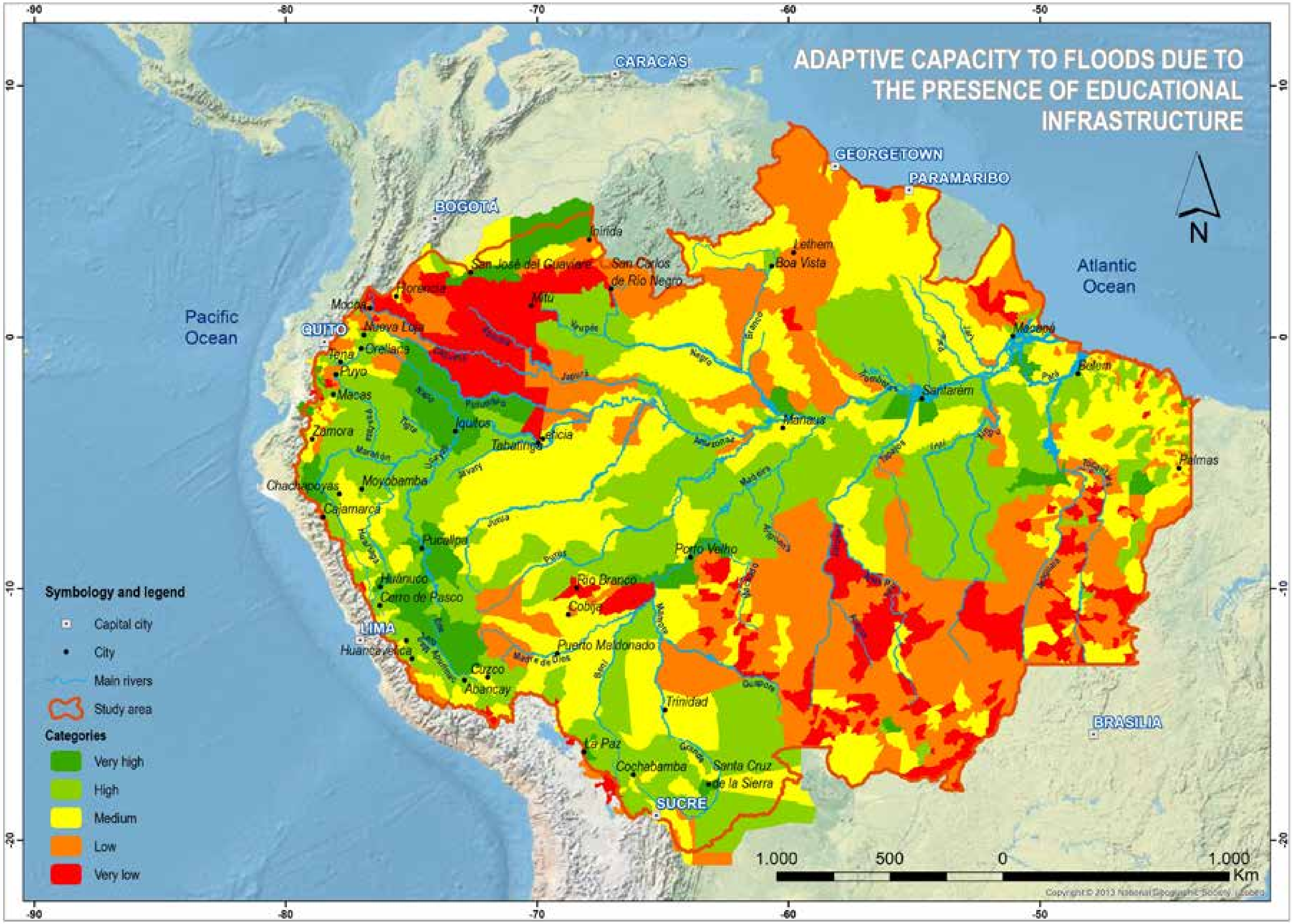
MAP 44.
Socioeconomic adaptive capacity to floods and droughts due to economic alternatives to agriculture in the Amazon Region.



SOURCE: Indicator of adaptation capacity elaborated from information of economically active population according to its branch of economic activity, consulted in the Population and Housing Censuses of the Statistical Institutes of each country.[30]

(30) Bolivia: National Institute of Statistics (INE), Population and Housing Census 2012; Brazil Brazilian Institute of Geography and Statistics (IBGE), 2010 Population and Housing Census; Colombia: National Administrative Department of Statistics (DANE), Population and Housing Census 2005; Ecuador: National Institute of Statistics and Census (INEC) Population and Housing Census 2012; Guyana: Bureau of Statistics-Guyana, Population and Housing Census 2012; Peru: National Institute of Statistics and Informatics (INEI), 2007 Population and Housing Census; Venezuela: National Institute of Statistics (INE), Population and Housing Census 2011.

MAP 45.
Socioeconomic adaptive capacity to floods due to educational infrastructure in the Amazon Region.

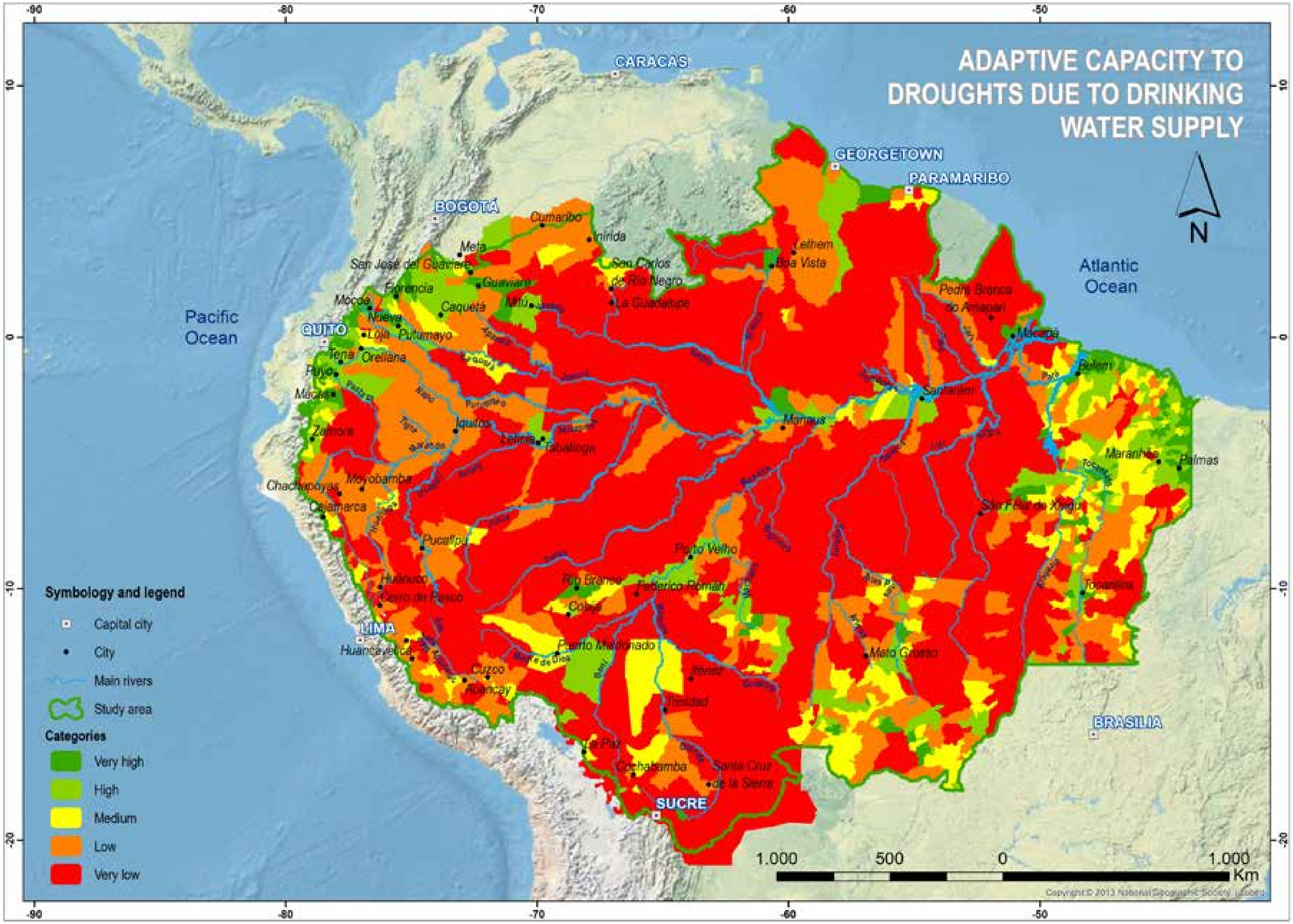


SOURCE: Compilation of spatial information through official websites and ACTO's Focal Points.[31]

(31) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 46.

Socioeconomic adaptive capacity to droughts due to drinking water supply in the Amazon Region.



SOURCE: Indicator elaborated from the information of access to the drinking water network consulted in the Population and Housing Censuses of the Institutes of Statistics of each country.[32]

(32) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

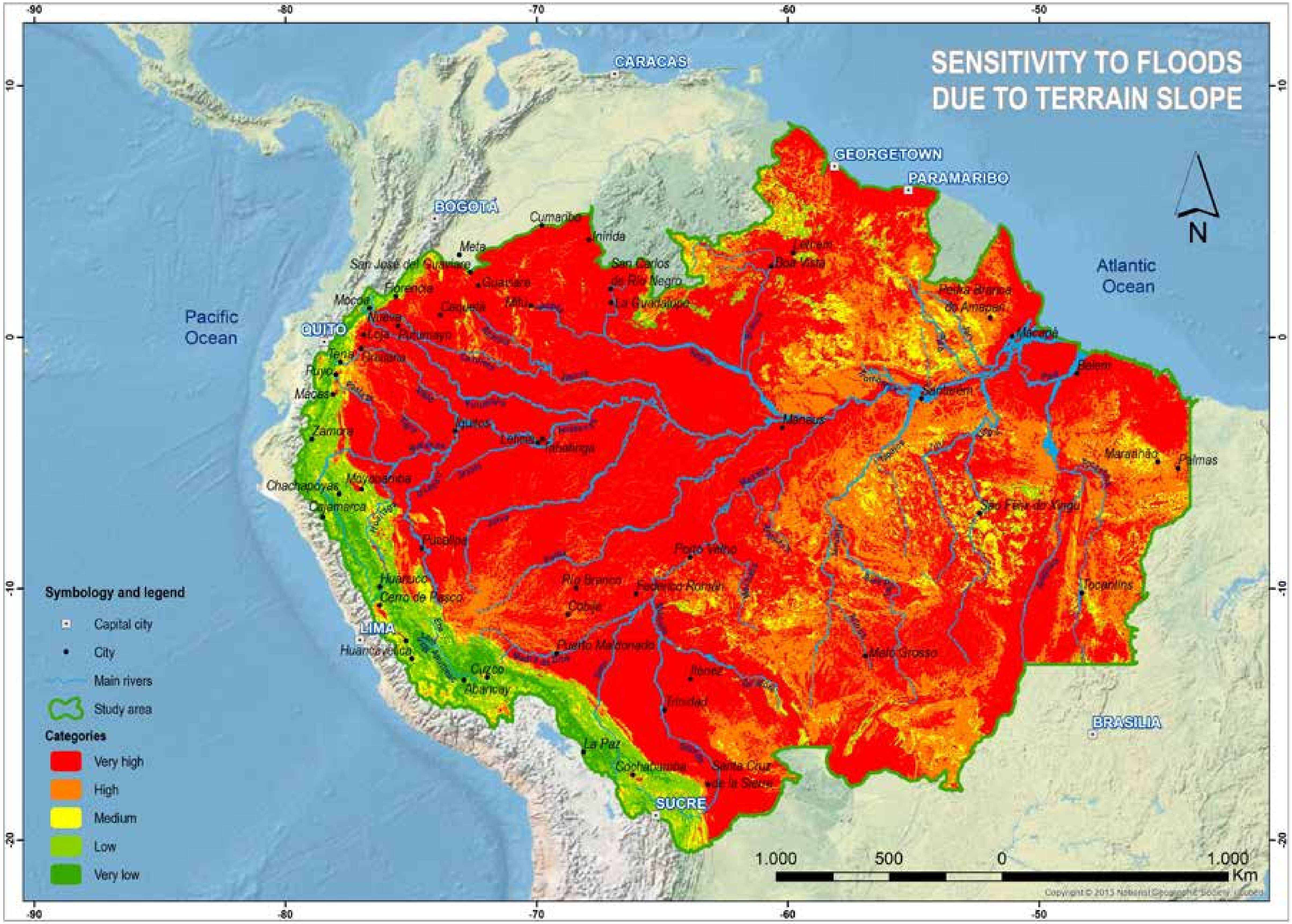
MAP 47.

Biophysical sensitivity to droughts due to terrain slope in the Amazon Region.

SOURCE: Indicator elaborated from the 250 meters resolution Digital Elevation Model of NASA (2013).

MAP 48.

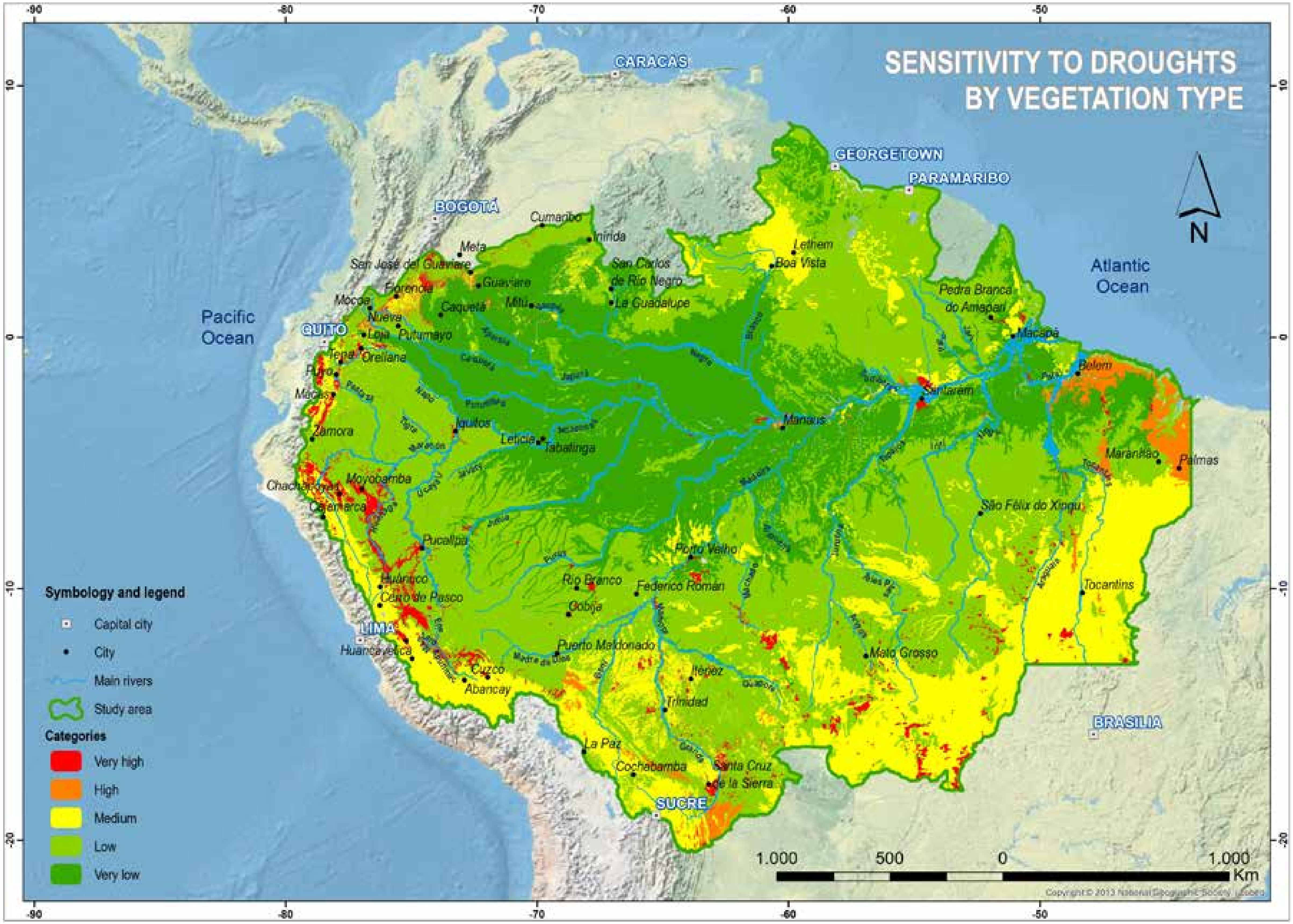
Biophysical sensitivity to floods due to terrain slope in the Amazon Region.



SOURCE: Indicator elaborated from the 250 meters resolution Digital Elevation Model of NASA (2013).

MAP 49.

Biophysical sensitivity to droughts due to vegetation type in the Amazon Region.

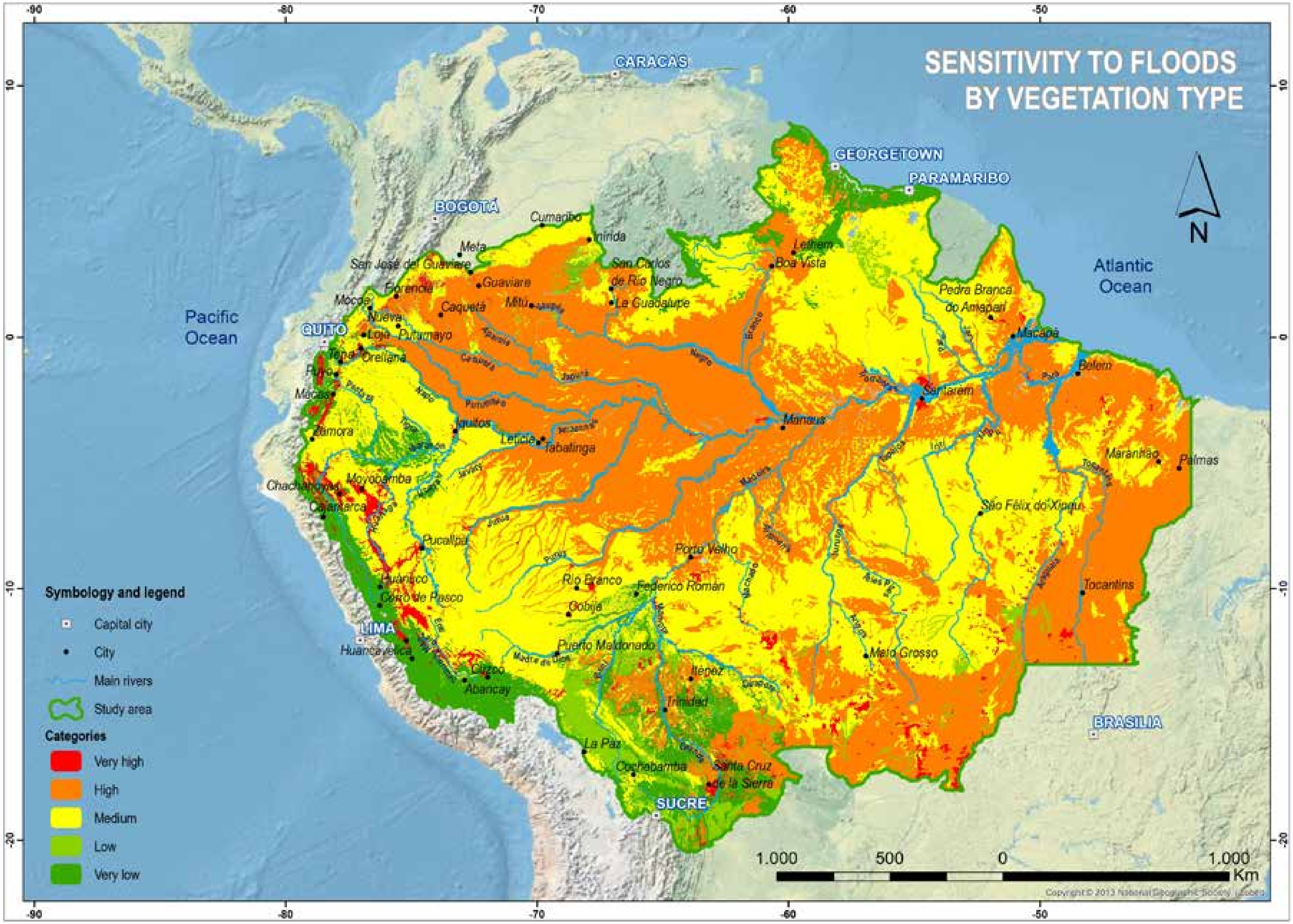


SOURCE: Sensitivity indicator elaborated from the information of type of vegetation consulted through official websites and ACTO's Focal Points.[33]

(33) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 50.

Biophysical sensitivity to floods due to vegetation type in the Amazon Region.

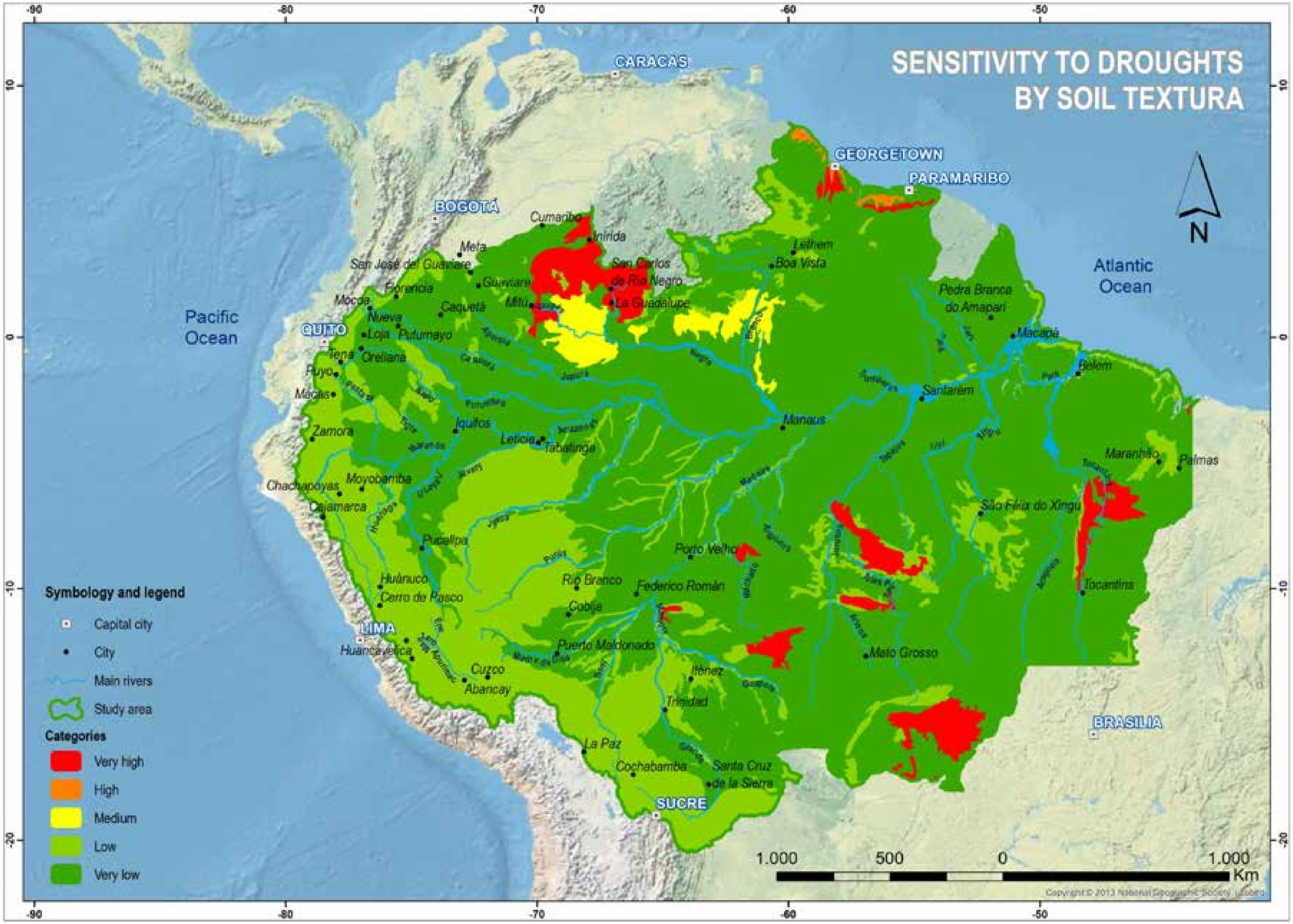


SOURCE: Sensitivity indicator elaborated from the information of type of vegetation consulted through official websites and ACTO's Focal Points.[34]

(34) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS) (https://sni.gob.ec/inicio). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

MAP 51.

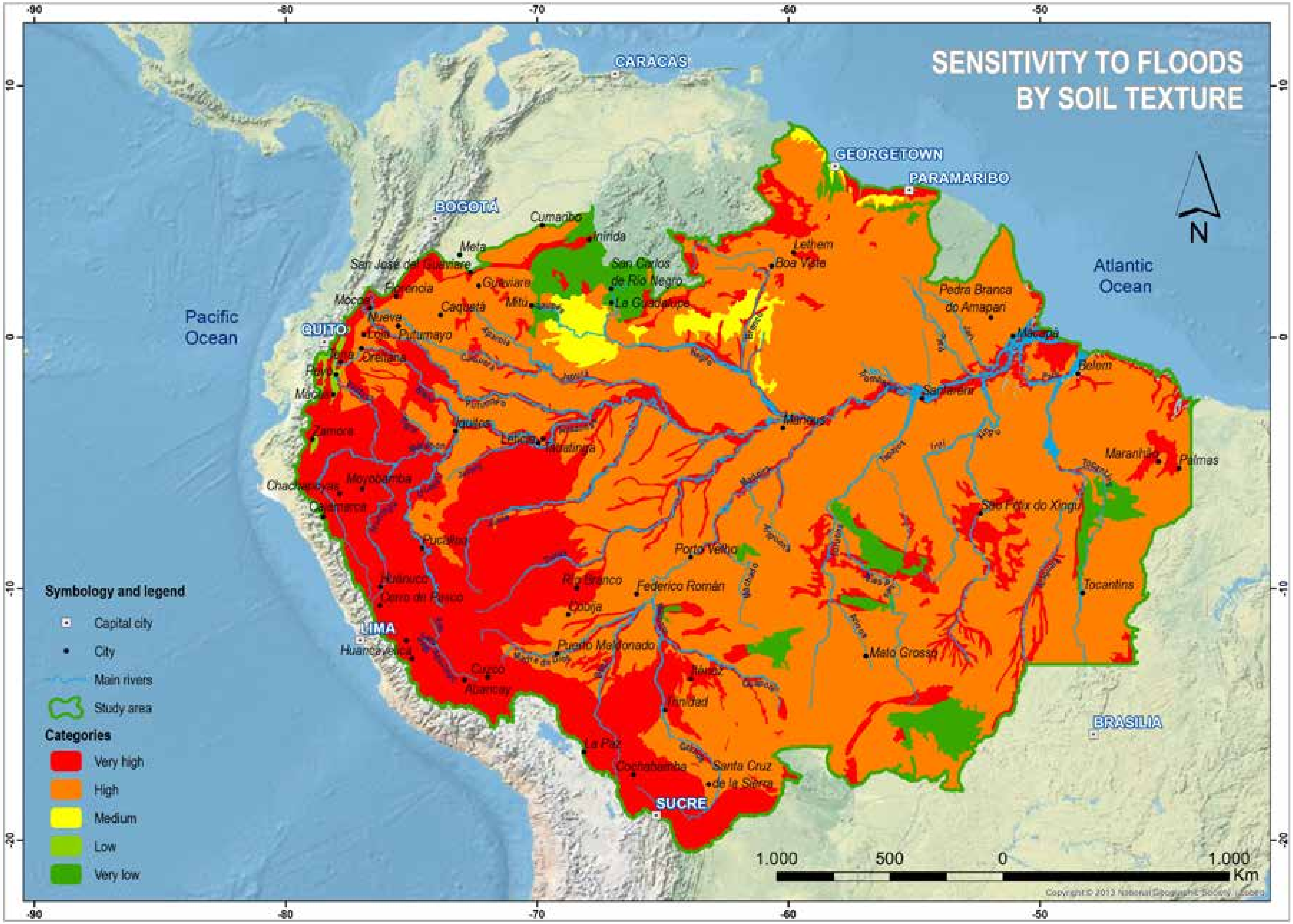
Biophysical sensitivity to droughts due to soil texture in the Amazon Region.



SOURCE: Sensitivity indicator elaborated from the information of the Regional Classification of Soil Texture of Batjes (2010).

MAP 52.

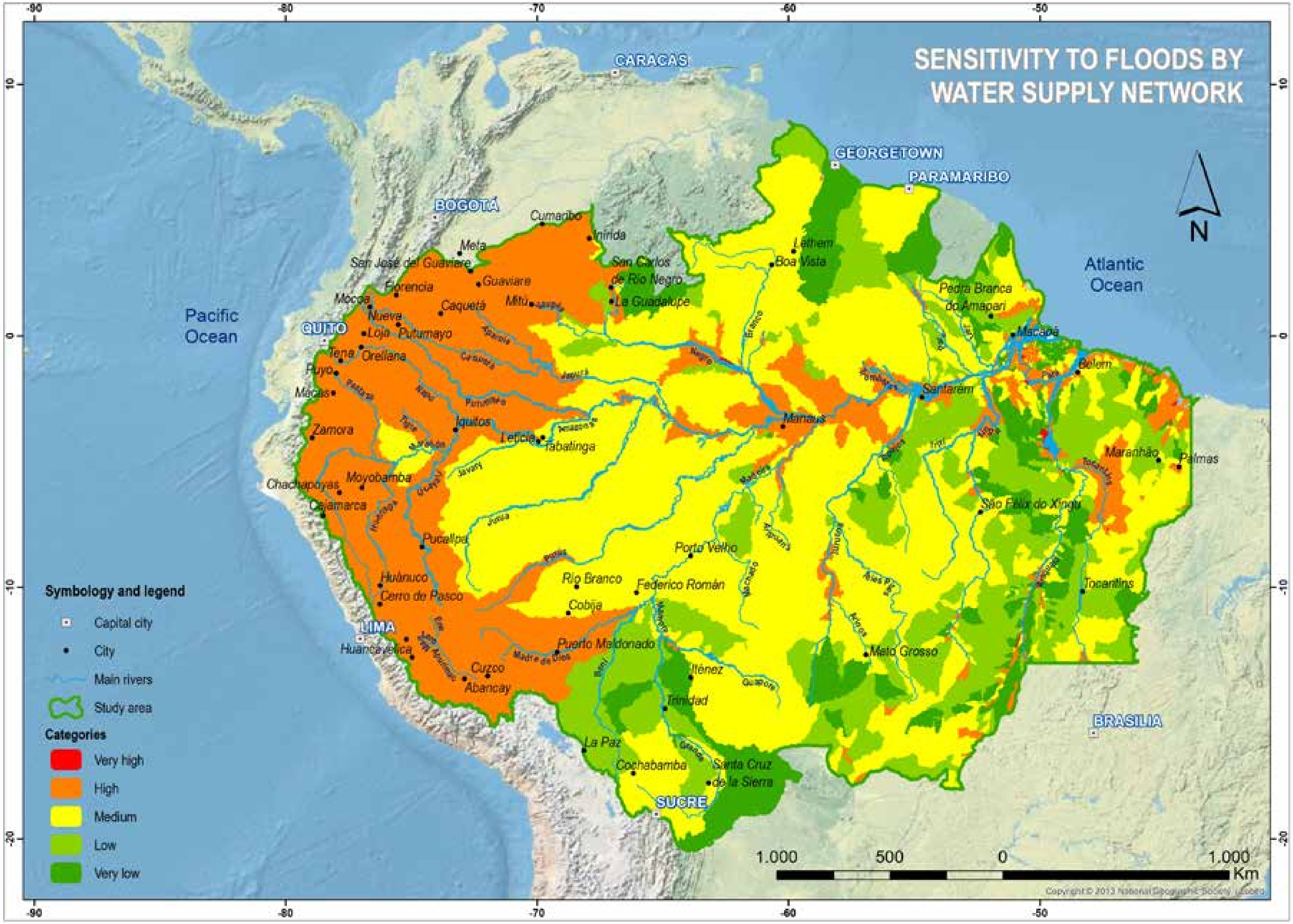
Biophysical sensitivity to floods due to soil texture in the Amazon Region.



SOURCE: Sensitivity indicator elaborated from the information of the Regional Classification of Soil Texture of Batjes (2010).

MAP 53.

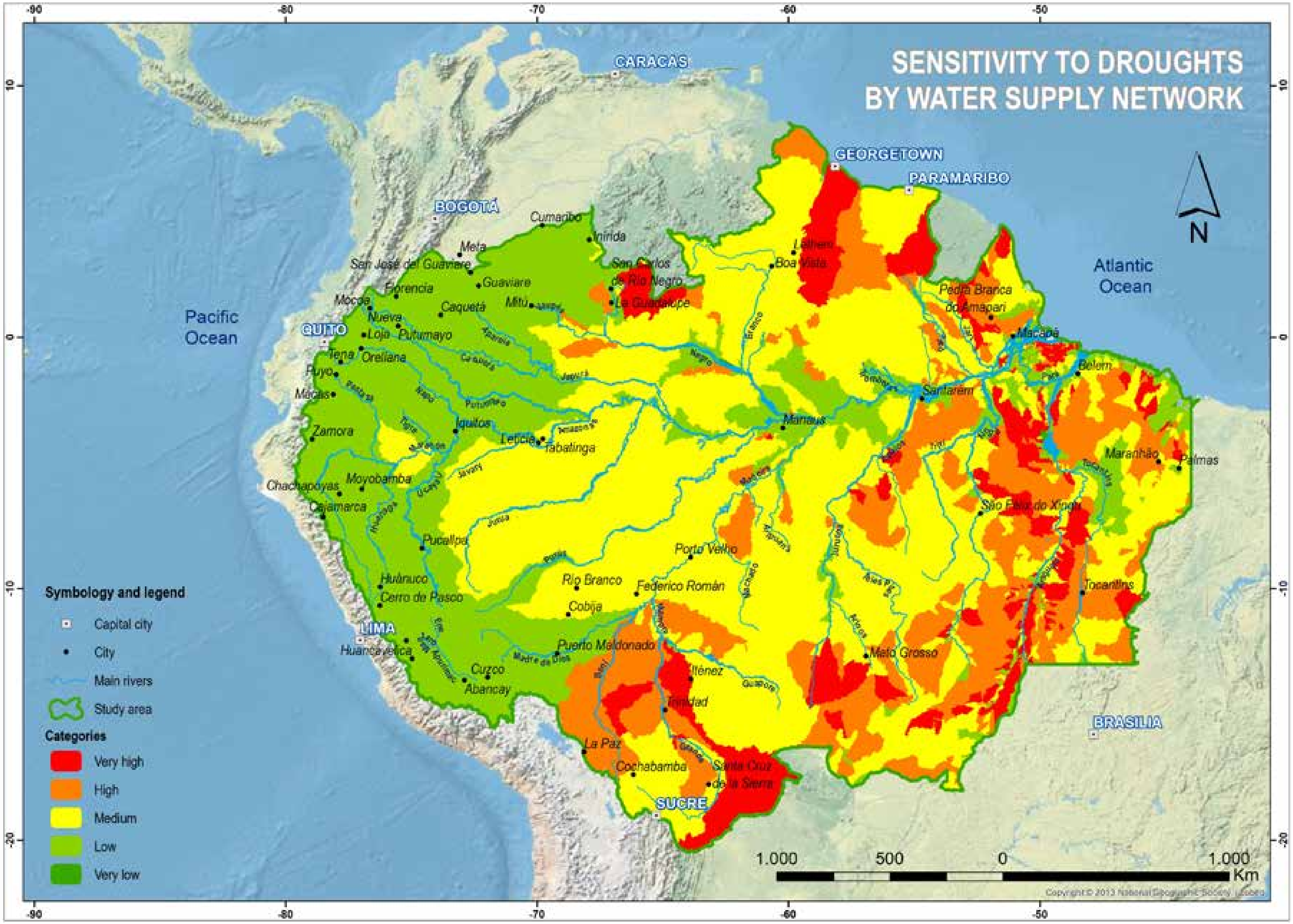
Biophysical sensitivity to floods due to the hydrographic network in the Amazon Region.



SOURCE: Sensitivity indicator elaborated from the water system information, consulted through official websites and ACTO's Focal Points.[35]

(35) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/). Ecuador: National Information System (NIS), Military Geographic Institute (https://sni.gob.ec/inicio & http://www.igm.gob.ec). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

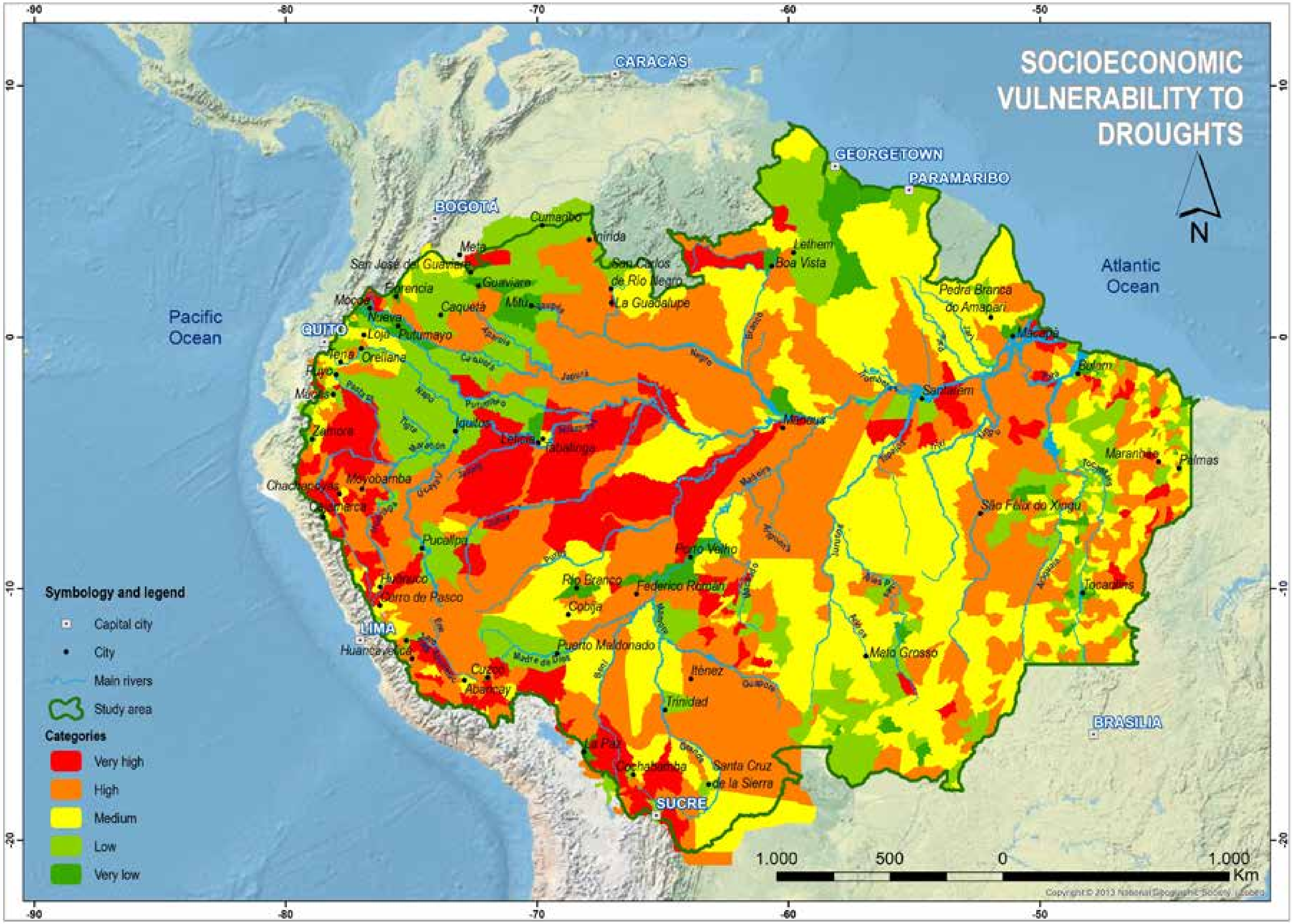
MAP 54.
Biophysical sensitivity to droughts due to the hydrographic network in the Amazon Region.



SOURCE: Sensitivity indicator elaborated from the water system information, consulted through official websites and ACTO's Focal Points.[36]

(36) ACTO Focal Points: Brazil, Colombia, Guyana, Peru and Suriname. Bolivia: GeoBolivia (http://geo.gob.bo/).
Ecuador: National Information System (NIS), Military Geographic Institute (https://sni.gob.ec/inicio & http://www.igm.gob.ec). Venezuela: Instituto Geográfico Simón Bolívar (http://www.igvsb.gob.ve) and CIIFEN database.

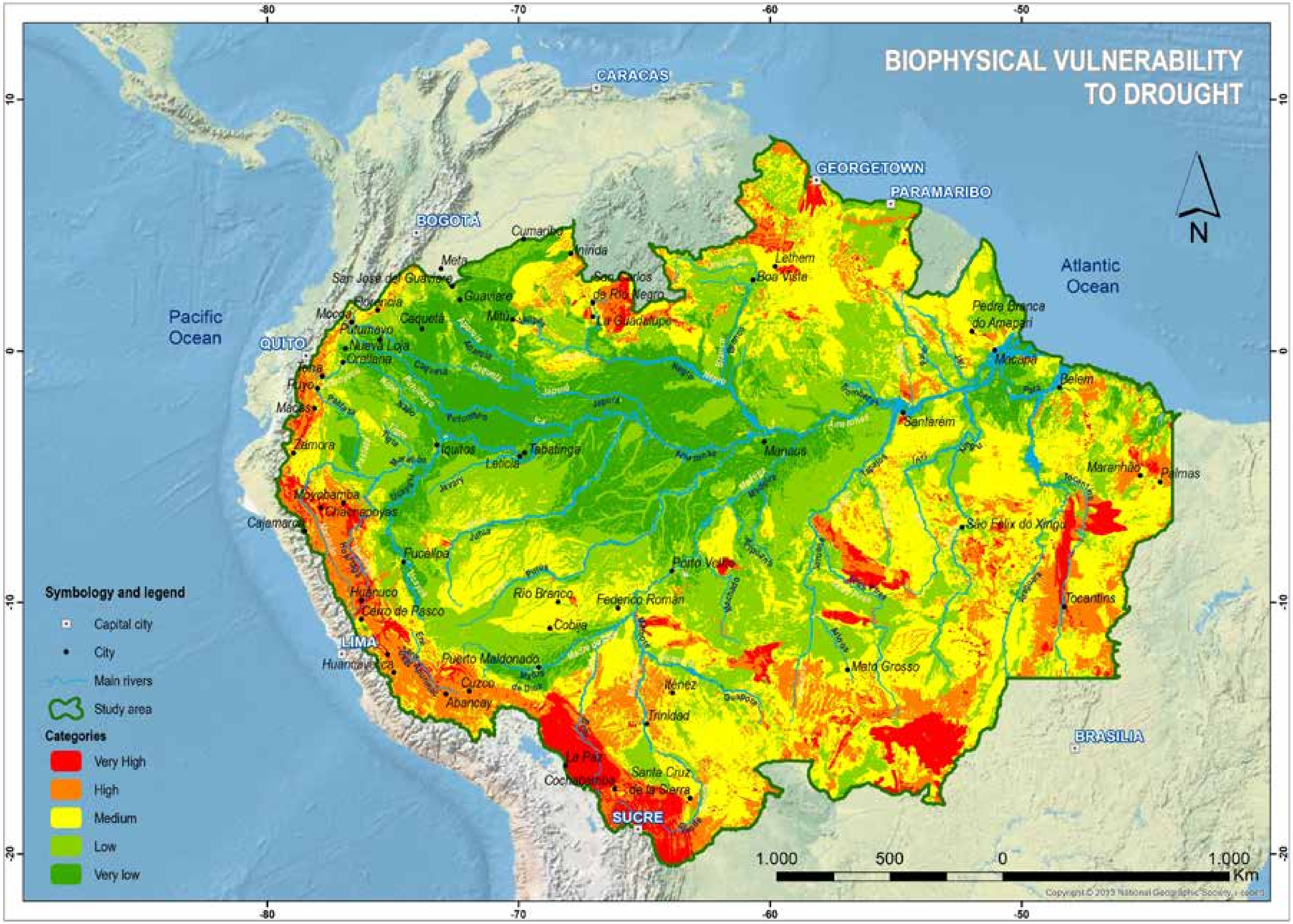
MAP 55.
Spatial distribution of socioeconomic vulnerability to droughts in the Amazon Region.



SOURCE: CIIFEN.

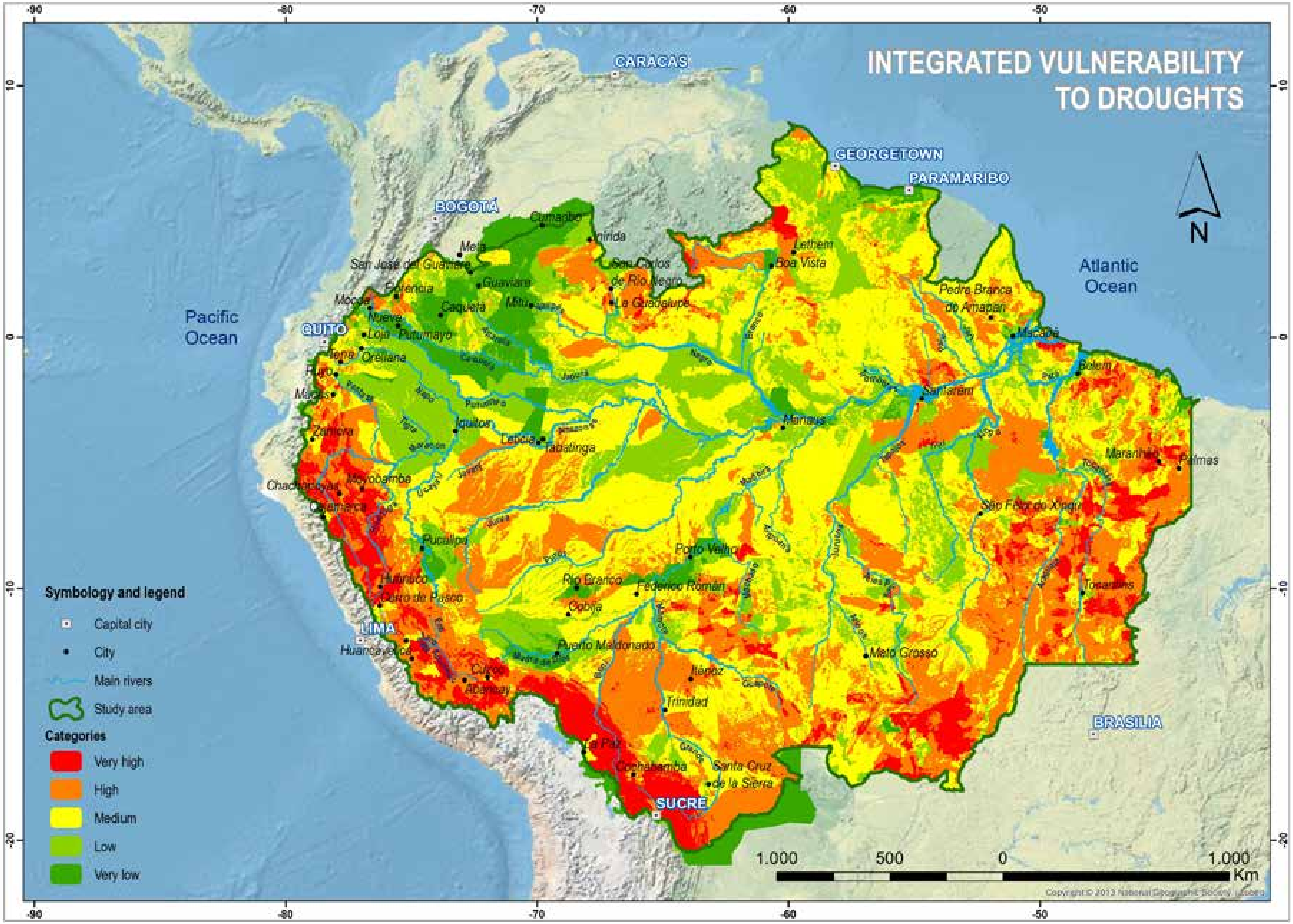
MAP 56.

Spatial distribution of biophysical vulnerability to droughts in the Amazon Region.



SOURCE: CIIFEN.

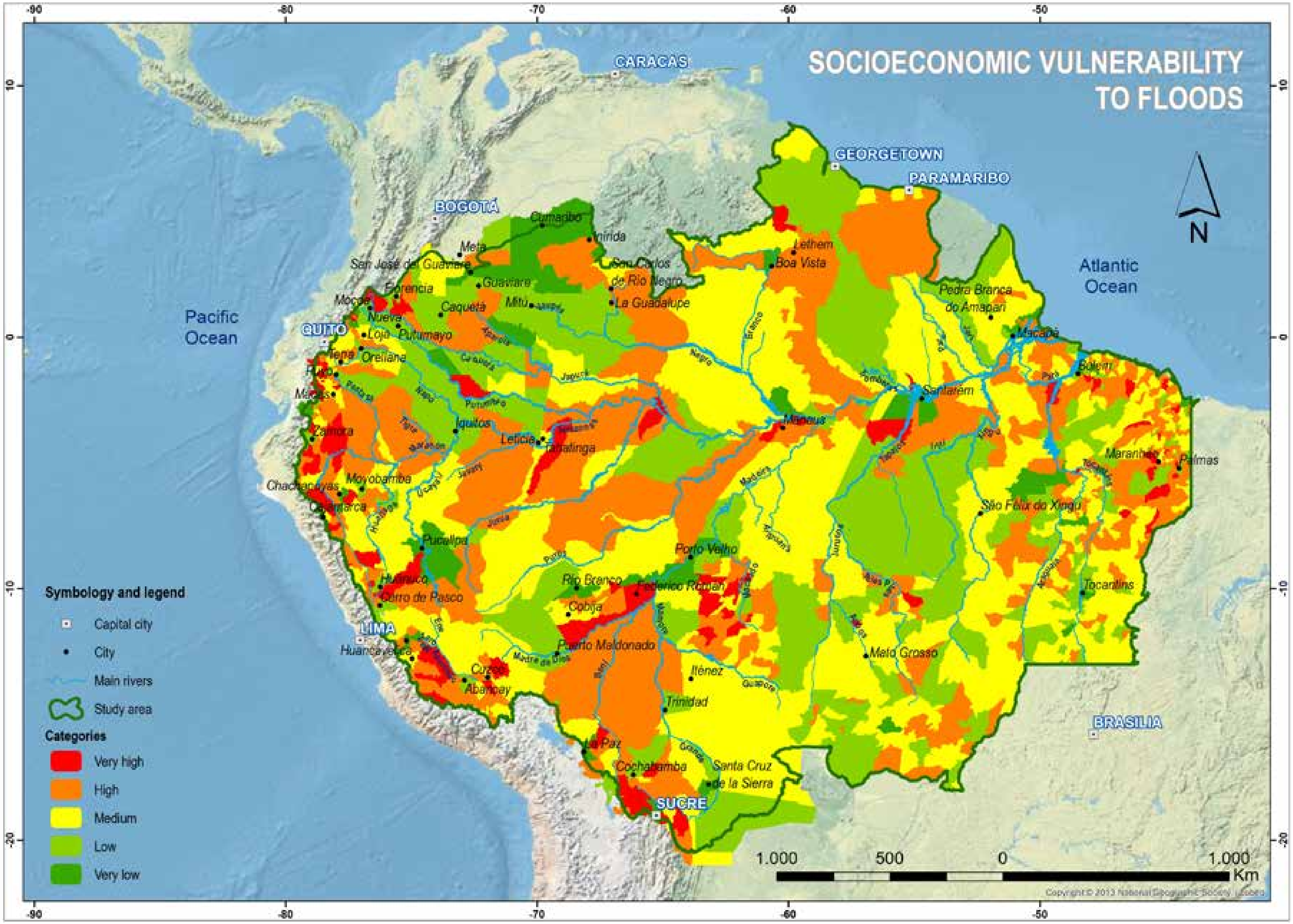
MAP 57.
Spatial distribution of integrated vulnerability to droughts in the Amazon Region.



SOURCE: CIIFEN.

MAP 58.

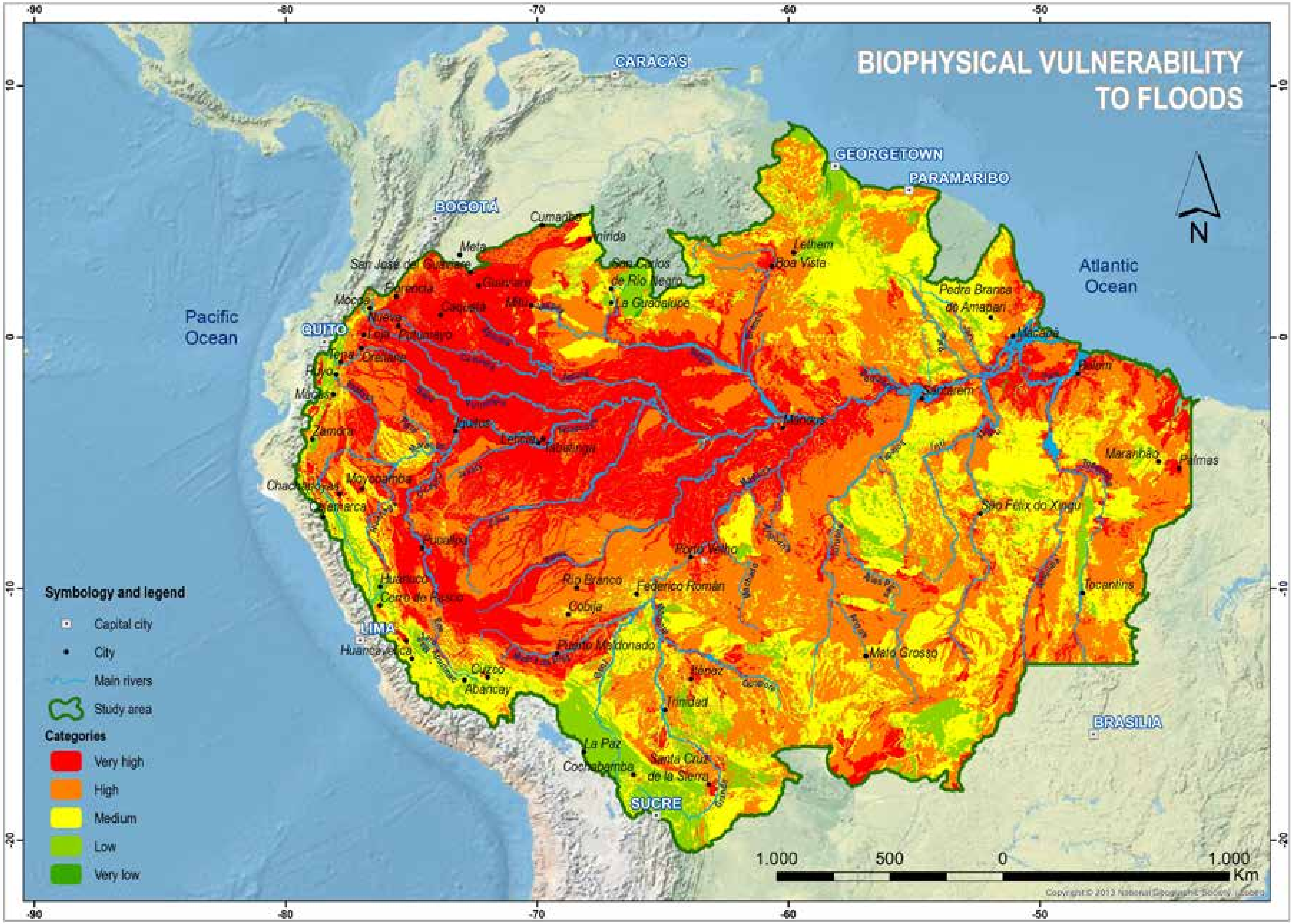
Spatial distribution of socioeconomic vulnerability to floods in the Amazon Region.



SOURCE: CIIFEN.

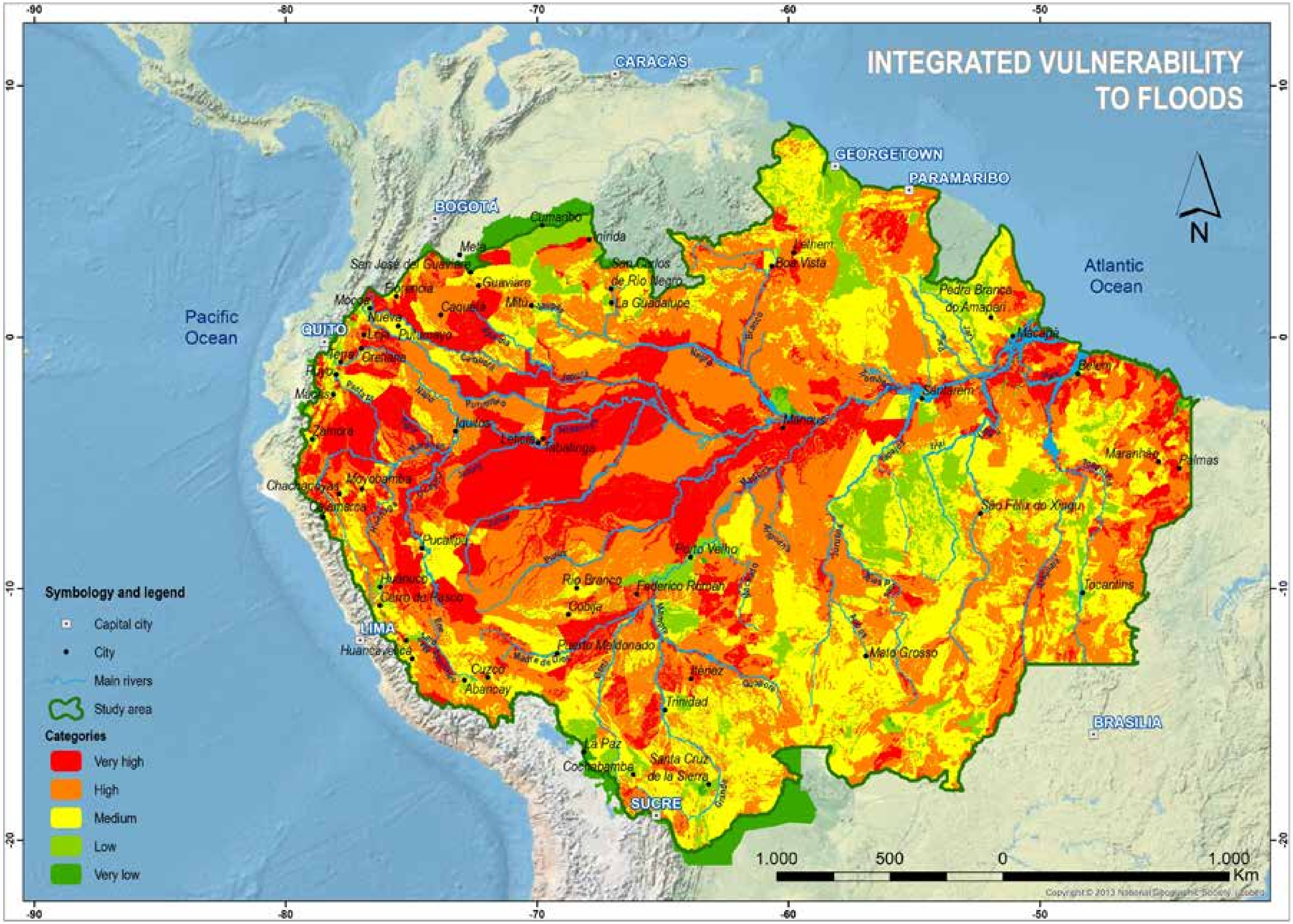
MAP 59.

Spatial distribution of biophysical vulnerability to floods in the Amazon Region.



SOURCE: CIIFEN.

MAP 60.
Spatial distribution of integrated vulnerability to floods in the Amazon Region.



SOURCE: CIIFEN.

PART III

Information Sources

Focal Points from the ACTO/UN Environment Programme/GEF Amazon-Water Resources and Climate Change Project

BOLIVIA

- Ministry of Foreign Affairs, Vice Minister, Ambassador **Juan Carlos Alurralde**.
- Ministry of Foreign Affairs, Limits, Borders and International Transboundary Waters, General Director, **Juan Carlos Segurola Tapia**.
- Ministry of Foreign Affairs, Unit for Borders and Transboundary International Waters, Head, **Mayra Briseida Montero Castillo**.
- Ministry of Environment and Water (MMAYA), General Director, **Oscar Céspedes Montaño**.

BRAZIL

- National Water Agency, Superintendent of Program and Project Implementation - SIP, Superintendent, **Ricardo Medeiros de Andrade**.
- National Water Agency, Superintendent of Program and Project Implementation - SIP, Deputy Superintendent, **Tiberio Magalhães Pinheiro**.
- National Water Agency, Superintendent of Program and Project Implementation - SIP, Water Resources Specialist, **Diana Leite Cavalcanti**.
- Special Recognition to Mr. **Humberto Cardoso Gonçalves**, co-manager of this regional initiative, current Superintendent, Superintendence of Support and Implementation of the National Water Resources Management System -SAS/ SINGREH, National Water Agency.

COLOMBIA

- Ministry of Environment and Sustainable Development, Board of Integrated Water Resource Management, Technical Director, **Luz Hicela Mosquera**.
- Ministry of Environment and Sustainable Development, Board of Integrated Management of Water Resources, Professional Specialist in Water Resources, **Martha Cristina Barragán Acosta**.
- Ministry of Environment and Sustainable Development, Office of International Affairs, Advisor on Borders and Sub-Regional Organizations, **Mauricio Molano Cruz**.

ECUADOR

- Ministry of Water, Under-Secretary for Social and Water Resources Articulation, Under-Secretary, **Helder Ernesto Solís Carrión**.
- Director of Territorial and Intersectoral Articulation, **Bertha Concepción Andrade Velasco**.
- Water Resources Technical Analyst, **María Belén Benítez Carranco**.

GUYANA

- Ministry of Public Works and Department of Communication, Works Service Group, Senior/Superior Engineer, **Jermaine Braithwaite**.
- Guyana Water Incorporated, Division Manager (Operations-DIV2), **Marlon Daniels**.

PERU

- National Water Authority, Head, **Ing. Abelardo De la Torre Villanueva**.
- Director of Conservation and Water Resources Planning, **Ing. Paola Chinen Guima**.
- Head of Water Resources Management and Transboundary Basins, **Ing. Adolfo Polidoro Toledo Parreño**.
- Specialist in Water Resources Management in Transboundary Basins, **Ing. Fanny María Quispe Guzmán**.

SURINAME

- Ministry of Foreign Affairs, ACTO Focal Point, **Marlena Wellis**.

VENEZUELA

- Ministry of People's Power for Foreign Affairs, ACTO Office, Office of Multilateral and Integration Affairs, **Mariana Milagros Orta Osorio**.
- Ministry of the People's Power for Ecosocialism and Water, General Board of Basins, General Director of Basins, **Adrián Alberto León Cedeno**.

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF MAPS

INFORMATION SOURCES

BOLIVIA

» **GeoBolivia:** (http://geo.gob.bo/)
» **Centro Digital de Recursos Espaciales de Bolivia:** (http://cdrnbolivia.org/geografia-fisica-nacional.htm)
» **Instituto Nacional de Estadística de Bolivia–INE:** (www.ine.gob.bo)

BRAZIL

» **Ministerio de Medio Ambiente de Brasil, MMA:** (http://mapas.mma.gov.br/i3geo/datadownload.htm)
» **Instituto Brasileiro de Geografía y Estadística de Brasil-IBGE:** (www.ibge.gov.br)
» **Sistema Integrado de Información sobre Desastres, Defensa Civil de Brasil:** (https://s2id.mi.gov.br/)

COLOMBIA

» **Instituto Geográfico Agustín Codazzi-IGAC:** (www.igac.gov.co)
» **Instituto de Hidrología, Meteorología y Estudios Ambientales-IDEAM:** (www.ideam.gov.co)
» **Departamento Administrativo Nacional de Estadística–DANE, Censo Ampliado/ Censo Básico:** (www.dane.gov.co)

ECUADOR

» **Instituto Geográfico Militar-IGM:** (www.igm.gob.ec)
» **Sistema Nacional de Información–SNI:** (http://sni.gob.ec)
» **Instituto Nacional de Estadísticas y Censos–INEC:** (www.ecuadorencifras.gob.ec)

VENEZUELA

» **Instituto Nacional de Estadística de Venezuela–INE:** (www.ine.gov.ve)
» **Instituto Geográfico de Venezuela Simón Bolívar–IGVSB:** (www.ine.gov.ve)

GUYANA

» **Guyana Bureau of Statistics:** (www.statisticsguyana.gov.gy)
» **Guyana Geology and Mines Commission:** (www.ggmc.gov.gy)
» **Office of the Commissioner Guyana Lands and Surveys Commission:** (www.glsc.gov.gy)
» **Environmental Protection Agency Guyana:** (www.epaguyana.org)

PERU

» **Ministerio de Agricultura y Riego de Perú**
» **Ministerio del Ambiente–MINAM:** (www.minam.gob.pe)
» **Instituto Nacional de Estadística e Informática de Perú–INEI:** (www.inei.gob.pe)
» **Servicio Nacional de Meteorología e Hidrología del Perú, SENAMHI:** (www.senamhi.gob.pe)
» **Instituto Nacional de Recursos Naturales–INRENA:** (www.minagri.gob.pe)
» **Organismo de Evaluación y Fiscalización Ambiental, OEFA Amazonas:** (www.oefa.gob.pe)
» **Ministerio de Transportes y Comunicaciones:** (www.mtc.gob.pe)
» **Ministerio de Energía y Minas–MINEM:** (www.minem.gob.pe)

SURINAME

» **General Bureau of Statistics:** (www.statistics-suriname.org)
» **The Embassy of the Republic of Suriname:** (www.surinameembassy.org)
» **Ministry of Agriculture, Animal Husbandry and Fisheries:** (http://www.fao.org/pgrfa-gpa-archive/sur/nieuws/en/The-Ministry-Of-Agriculture-Animal-Husbandry-And-Fisheries.html)
» **National Master Plan for Agricultural Development of Suriname:** (http://www.gov.sr/)
» **United Nations Development Programme–UNDP:** (www.sr.undp.org)

ACRONYMS

Acronyms	
ANA	Agencia Nacional de Aguas, Brazil
ANA	Autoridad Nacional del Agua, Peru
AR5	Fifth Assessment Report
IDB	Inter-American Development Bank
CAN	Comunidad Andina de Naciones
ECLAC	Economic Commission for Latin America and the Caribbean
LACDC	Latin American and Caribbean Demographic Center
ICTA	International Center for Tropical Agriculture
CIIFEN	International Center for Research on the El Niño Phenomenon
UNFCCC	United Nations Framework Convention on Climate Change
COSIPLAN	Consejo Suramericano de Infraestructura y Planeamiento
CRED	Centre for Research on the Epidemiology of Disasters
DANE	Departamento Administrativo Nacional de Estadística
DESINVENTAR	Database for Bolivia, Colombia, Ecuador, Guyana and Venezuela
ISDR	International Strategy for Disaster Reduction
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
IBGE	Instituto Brasileiro de Geografia e Estatística
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales
IGAC	Instituto Geográfico Agustín Codazzi, Colombia
IGM	Instituto Geográfico Militar, Ecuador
IGVSB	Instituto Geográfico de Venezuela Simón Bolívar
IPCC	Intergovernmental Panel on Climate Change
IIRISA	Initiative for the Integration of Regional Infrastructure in South America
INE	Instituto Nacional de Estadística, Bolivia
INEI	Instituto Nacional de Estadística e Informática, Peru
INEC	Instituto Nacional de Estadísticas y Censos, Ecuador
INRENA	Instituto Nacional de Recursos Naturales, Peru
IRI	International Research Institute for Climate and Society
ISRIC	International Soil Reference and Information Centre
MMA	Ministerio de Medio Ambiente, Brazil
MMAyA	Ministerio de Medio Ambiente y Agua, Bolivia
MINAM	Ministerio del Ambiente, Peru

Acronyms	
MINEM	Ministerio de Energía y Minas, Peru
NASA	National Aeronautics and Space Administration, Estados Unidos
NOAA	National Oceanic and Atmospheric Administration, United States
NRCS	National Resources Conservation Services, United States
OEFA	Organismo de Evaluación y Fiscalización Ambiental Amazonas, Peru
MDG	Millennium Development Goals
SDG	Sustainable Development Goals
WHO	World Health Organization
WMO	World Meteorological Organization
UN	United Nations
PAHO	Panamerican Health Organization
ACTO	Amazon Cooperation Treaty Organization
SAP	Strategic Action Program (Project ACTO/UNEP/GEF-Water resources and climate change)
MP	ACTO Member Countries
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
S2ID	Sistema Integrado de Informações sobre Desastres, Brazil
SENAGUA	Secretaría del Agua, Ecuador
SENAMHI	Servicio Nacional de Meteorología e Hidrología del Perú
GIS	Geographic Information System
ETISLA	Educational Trends Information System in Latin America
SRTM	Shuttle Radar Topography Mission (of NASA)
SREX	Special Report on Managing the Risks of Extreme Weather Events
TRMM	Tropical Rainfall Measuring Mission
EU	European Union
UNASUR	Union of South American Nations
UNAL	Universidad Nacional de Colombia
UNODRR	United Nations Office for Disaster Risk Reduction
USDA	U.S. Department of Agriculture
WWF	World Wildlife Fund
SACZ	South Atlantic Convergence Zone
ICZ	Intertropical Convergence Zone

SYMBOLS AND ABBREVIATIONS

Symbols and Abbreviations	Meaning
A2	High emissions
B2	Low emissions
CA	Ability to adapt
CO_2	Carbon dioxide
CH_4	Methane
CMIP5	Coupled Model Intercomparison Project Phase 5
DE	Age Dependency
DJF	December-January-February
E	Exposure
ETR	Actual evapotranspiration
ºN	North grades
ºS	South grades
ºW	West grades
ºE	East grades
JJA	June-July-August
Km^2	Square Kilometers
MAM	March-April-May
MDE	Digital Elevation Model
mm/h	Millimeters per hour

Symbols and Abbreviations	Meaning
m^3/s	Cubic meters per second
mm/month	Millimeters per month
msnm	Meters above sea level
UBN	Unsatisfied Basic Needs
ONI	El Niño Ocean Index
PD	Dependent Population
PDO	Pacific Decadal Oscillation
EAP	Economically Active Population
P.hour	Precipitation per hour
P.monthly	Monthly precipitation
PND	Non Dependent Population
PostGreSQL	Database management system
RCP	Representative Concentration Pathway
Mentioned	RCP 2.6; RCP 4.5 and RCP 8.5 (high emissions)
S	Sensitivity
SON	September-October-November
SPI	Standard Precipitation Index
V	Vulnerability

GLOSSARY

Words/concepts	Definition	Source
Albedo	Fraction of solar radiation reflected by a surface and object, expressed as a percentage Light surfaces have more albedo than dark surfaces (e.g., snow has more albedo than oceans or vegetation, thus reflecting a greater percentage of the solar radiation received.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Hydroclimatic hazards	Extreme events related to the climate and hydrology of a region that may cause physical impacts and losses.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.) IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Atlas	Set of maps of different regions of the planet that have been edited and published jointly in a book or collection.	IGAC. (2019). ¿Qué es un atlas? Obtenido de https://www.igac.gov.co/es/contenido/que-es-un-atlas
Atlas of Hydroclimatic Vulnerability of the Amazon Region	Compendium of maps representing the vulnerability of the socioeconomic and biophysical characteristics of the Amazon Region to droughts and floods, as part of the extreme hydroclimatic events of greatest incidence and impact in the Region.	Atlas of Hydroclimatic Vulnerability of the Amazon Region
Atmosphere	Atmosphere: gaseous layer that surrounds the Earth, composed mainly of nitrogen and oxygen, other gases such as argon, helium and certain greenhouse gases (carbon dioxide and ozone; also contains water vapor, clouds and aerosols) It is divided into five layers: the troposphere, which contains half of the Earth's atmosphere, the stratosphere, the mesosphere, the thermosphere, and the exosphere, which is the outer limit of the atmosphere.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.) IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Water balance	Evaluation of the inputs, outputs and variations in the storage of a mass of water in a certain period of time.	OMM-UNESCO. (2012). Glosario Hidrológico Internacional. Organización Meteorológica Mundial, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura.

GLOSSARY

Words/concepts	Definition	Source
Geographical database/geodatabase	Set of geographic data organized in such a way that they allow the analysis and management of the territory within Geographic Information Systems (GIS) applications	IGN. (2020). Instituto Gegráfico Nacional de España. Retrieved from Centro Nacional de Información Geográfica: https://www.ign.es/web/resources/docs/IGNCnig/CBG-BD.pdf
Biosphere	Part of the Earth system that includes all ecosystems and living organisms in the atmosphere and on land (terrestrial biosphere) or in the atmosphere and oceans (marine biosphere), including dead organic matter resulting from them, in particular debris, soil organic matter, and oceanic debris.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Ability to adapt	Capacity of systems, institutions, humans and other agencies to adapt to possible damage, take advantage of opportunities or deal with consequences.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Climate	Climate in a limited sense is generally defined as the average climate, or more narrowly, as the statistical description in terms of the mean and variability of relevant quantities over a period of time varying from months to thousands or millions of years. The classic period for averaging these variables is 30 years, as defined by the World Meteorological Organization.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Climate Change	Climate change refers to a change in the state of the climate that may be identified (for example, through the use of statistical tests) through changes in the mean and/or variability of its properties and that persists over an extended period, usually decades or more. Climate change may be due to natural internal processes or external forcings such as modulations of solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Climate change that is directly or indirectly attributed to human activity that alters the composition of the global atmosphere and that adds to natural climate variability observed over comparable periods of time.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Global water cycle	Cycle in which water evaporates from the oceans and the surface of the earth, is transported over the earth by atmospheric circulation in the form of water vapor, condenses to form clouds, and precipitates as rain or snow over the ocean and land, where it can be intercepted by trees and vegetation, generates runoff on the earth's surface, infiltrates the soils, recharges the groundwater, flows into the river currents and, in the final stage, ends up in the oceans, where it evaporates again.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.

Words/concepts	Definition	Source
Global climate	Climate system of the planet. See Climate.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Watershed	A topographically defined area that drains through a river system, i.e., the total area of land that drains at a certain point from a watercourse or river; an area that has a single outlet for its surface runoff (RT).	OMM - UNESCO. (2012). Glosario Hidrológico Internacional. Organización Meteorológica Mundial, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. T.C. Sheng. (1992). Manual de campo para la ordenación de cuencas hidrográficas. Estudio y planificación de cuencas hidrográficas. Organización de las Naciones Unidas para la Agricultura y la Alimentación, Roma.
Cryosphere	All regions above and below the land and ocean surface where water is in a solid state, such as in sea ice, lake ice, river ice, snow cover, glaciers and ice sheets, and frozen ground (including permafrost).	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Disaster	Severe disruptions in the normal functioning of a community or society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to meet critical human needs and may require recovery support.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Carbon dioxide	Natural gas, also a by-product of the combustion of fossil fuels from fossil carbon deposits such as oil, gas or coal, from the burning of biomass, and from land use changes and other industrial processes (e.g. cement production). It is the main anthropogenic greenhouse gas affecting the radiative balance of the Earth. It is the gas used as a reference to measure other greenhouse gases, so its global warming potential is equal to 1.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Tropical Atlantic Dipole	Mode of large-scale inter-annual variability of sea surface temperature in the Atlantic Ocean	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social or cultural assets in places that could be negatively affected.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.

GLOSSARY

Words/concepts	Definition	Source
Evapotranspiration	Process by which water passes from liquid to vapour at a temperature lower than the boiling point.	OMM-UNESCO. (2012). Glosario Hidrológico Internacional. Organización Meteorológica Mundial, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura.
Radiative Forcing Factors	Externally imposed disturbance to the radiative energy budget of the Earth's climate system It may be caused by secular changes in the concentrations of radioactive active species (e.g., CO2, aerosols), changes in the solar radiation incident on the planet, and other changes that affect the radiative energy absorbed by the surface.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
El Niño Phenomenon	Water heating throughout the tropical ocean basin Pacífico east of the international date change line (180° meridian). This phenomenon is associated with some fluctuation of a global pattern of pressures on the tropical and subtropical surface called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, whose most common time scale ranges from 2 to approximately 7 years, is known as El Niño-Southern Oscillation (ENSO).	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
La Niña Phenomenon	Cold phase of ENSO. See El Niño Phenomenon.	IPCC. (2018). In: Global Warming of 1.5°C. Glossary SR1.5. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response... (J. B. (UK), V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, . . . T. Waterfield, Eds.)
Climatic phenomena	Unusual events or changes in climate in a given site or region.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Meteorological phenomena	Atmospheric phenomenon that characterizes the state of weather conditions in a given place and time. It is a natural phenomenon of nature that happens by itself and may transform it, may also influence human life (epidemics, weather conditions, natural disasters, etc.).	OMM. (2017). Manual del Sistema Mundial de Observación. OMM-N° 544. Actualización 2017. Programa Regional de Meteorología. (2019). Fenómenos Meteorológicos. Retrieved from Programa Regional de Meteorología / IANIGLA - CONICET: http://www.prmarg.org/fenomenos-meteorologicos
Extreme hydroclimatic phenomena	Changes in natural events related to the climate and hydrology of a region that may cause physical impacts and losses.	IPCC. (2013). Cambio climático 2013: Bases físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)

Words/concepts	Definition	Source
Greenhouse gases (GHG)	Gaseous component of the atmosphere, natural or anthropogenic, which absorbs and emits radiation at certain wavelengths of the spectrum of terrestrial radiation emitted by the Earth's surface, by the atmosphere itself and by the clouds. This property causes the greenhouse effect. Water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the earth's atmosphere.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Hydrosphere	Component of the climate system that includes the surfaces in liquid state and the underground waters, and that includes oceans, seas, rivers, freshwater lakes, phreatic waters, etc.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Holocene	Last of the two epochs of the Quaternary system, which spans 11,650 years to the present (defined as 1950). It is also known as marine isotopic stage 1 or current interglacial.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Climate change impacts	Effects on natural and human systems from the effects of extreme weather and climate events and climate change The impacts of climate change on geophysical systems, including floods, droughts and sea level rise, are a subset of the impacts called physical impacts.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Standardized Precipitation Index	The Standard Precipitation Index (SPI) is based on the probability of precipitation for any time scale. Taking into account the observed precipitation, the probability of precipitation is transformed into an index, which is currently used in research or in operational mode in more than 70 countries.	WMO (2012). Standardized Precipitation Index User Guide. World Meteorological Organization.

2,0 and above	Extremely humid
1.5 to 1.99	very humid
1.0 to 1.49	moderately humid
-0.99 to 0.99	normal or approximately normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Words/concepts	Definition	Source
Floods	Overflowing above the normal confines of a stream or other body of water, or the accumulation of water above areas that are not normally submerged. The different types of floods include river floods, flash floods, urban floods, rainwater floods, sewage floods, coastal floods and glacial lake overflows.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Lithosphere	The upper layer of the solid part of the Earth, both continental and oceanic, which includes all the rocks of the crust and the cold, mostly elastic, part of the upper mantle. Volcanic activity, despite taking place in the lithosphere, is not considered a part of the climate system, although it acts as an external forcing factor.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Climate maps	Cartographic representation of the geospatial distribution of elements of the territory	
Methane (NH_4)	One of the six greenhouse gases that the Kyoto Protocol aims to reduce. It is the main component of natural gas, and is associated with all hydrocarbons used as fuel, livestock and agriculture.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Precipitation	Hydrometeorite consisting of the fall of a set of particles. The forms of precipitation are: rain, drizzle, snow, pine forest, granulated snow, diamond dust or ice prisms, hail and ice granules.	OMM. (2017). Manual del Sistema Mundial de Observación. OMM-N° 544. Actualización 2017.
Monthly precipitation	Estimation of monthly precipitation in a given site. See Precipitation.	OMM. (2017). Manual del Sistema Mundial de Observación. OMM-N° 544. Actualización 2017.
Droughts	A period of abnormally dry conditions for a period of time sufficient to cause a serious hydrological imbalance. The term drought is relative and, therefore, no review of rainfall deficits should refer to the particular activity related to the rainfall under review. For example, low rainfall during the growing season affects crop production or ecosystem function in general (due to soil moisture deficit, also called agricultural drought), and during the runoff and percolation season it mainly affects water inputs (hydrological drought).	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.

Words/concepts	Definition	Source
Sensitivity/susceptibility	Degree to which a system or species is affected, positively or negatively, due to climate variability or change.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Ecosystem Services	Ecological processes or functions that have a value, monetary or not, for individuals or for society in general. They are generally classified as: 1) supporting services, e.g. maintaining productivity or biodiversity; 2) provisioning services, e.g. food, fibre or fish; 3) regulating services, e.g. climate regulation or carbon sequestration; and 4) cultural services, e.g. tourism, or spiritual or aesthetic enjoyment.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Biophysical sensitivity	Degree to which a territory's biophysical system is affected, positively or negatively, due to climate variability or change. See Sensitivity/Susceptibility.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Socioeconomic Sensitivity	Degree to which a socioeconomic system is affected, positively or negatively, due to climate variability or change. See Sensitivity/Susceptibility.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Carbon Dioxide Sink	Process activity or mechanism that removes a greenhouse gas, in this case carbon dioxide, from the atmosphere.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Air temperature	Temperature read on a thermometer exposed to the air, protected from direct sunlight.	OMM. (2017). Manual del Sistema Mundial de Observación. OMM-N° 544. Actualización 2017.

GLOSSARY

Words/concepts	Definition	Source
Global average air temperature (global average surface temperature)	Estimation of the global average air temperature at the surface For variations over time, however, only the anomalies (e.g., deviations from the climate) are used, usually in the form of an area-weighted global average of the sea surface temperature anomaly and the land surface air temperature anomaly.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.) IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Sea Surface Temperature (SST)	Mass temperature of the first meters of thickness of the surface of the ocean measured by means of ships, buoys or boats.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Atmospheric weather	State of the atmosphere at a given moment, defined by the various meteorological elements.	OMM-UNESCO. (2012). Glosario Hidrológico Internacional. Organización Meteorológica Mundial, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura.
Troposphere	The lower part of the atmosphere, between the surface and about 10 km of altitude in medium latitudes (varying, on average, between 9 km in high latitudes and 16 km in the tropics), where the clouds are found and "meteorological" phenomena occur. In the troposphere, temperatures usually decrease with altitude.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Climate Variability	It denotes variations in the mean state and other statistical characteristics (standard deviation, extreme events, etc.) of the climate on all spatial and temporal scales larger than those of meteorological phenomena. Variability may be due to natural internal processes in the climate system (internal variability) or to variations in natural or anthropogenic external forcing. (External Variability).	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Inter-annual climatic variability	Analysis of the variations of the average state and other statistical characteristics of the climate year by year. See Climate Variability.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)

Words/concepts	Definition	Source
Intra-seasonal variability	Analysis of the variations of the average state and other statistical characteristics of the climate between climatic stations. See Climate Variability.	IPCC. (2013). Cambio Climático 2013: Bases Físicas. Resumen para responsables de políticas. Informe del Grupo de trabajo I del IPCC, Resumen técnico y preguntas frecuentes. (Thomas F. Stocker, Dahe Qin, Gian-Kasper Plattner, Melinda M.B. Tignor, Simon K. Allen, Judith Boschung, . . . Pauline M. Midgley, Eds.)
Vulnerability	Propensity or predisposition to be negatively affected. Vulnerability comprises a variety of concepts including sensitivity or susceptibility to damage and lack of responsiveness and adaptability. See also Contextual vulnerability and outcome vulnerability.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Biophysical vulnerability	Propensity of the biophysical system of a territory to be negatively affected. See Vulnerability.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Hydroclimatic Vulnerability	Analysis of the propensity of a territory to be negatively affected by extreme events related to climate and hydrology See Vulnerability.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Full vulnerability	Analysis of the interaction of socioeconomic and biophysical vulnerability of a territory, and its propensity to be negatively affected. See Vulnerability.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.
Socioeconomic Vulnerability	Propensity of the social and economic system of a territory to be negatively affected. See Vulnerability.	IPCC. (2014). Climate Change 2014. Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1132 pp. (Field, C.B, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, . . . L.L. White, Eds.) United Kingdom and New York, NY, USA: Cambridge University Press, Cambridge.

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