IDB WORKING PAPER SERIES Nº IDB-WP-932

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April 2019

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Muñoz-Castillo, Raúl.
A CLEWS Nexus modeling approach to assess water security trajectories and infrastructure needs in Latin America and the Caribbean / Raúl Muñoz-Castillo, Fernando Miralles-Wilhelm, Kleber Machado.
p. cm. — (IDB Working Paper Series ; 932)
Includes bibliographic references.
1. Water security-Latin America. 2. Waterworks-Latin America. 3. Infrastructure (Economics)-Latin America. 4. Water resources development-Latin America. I. Miralles-Wilhelm, Fernando. II. Machado, Kleber. III. Inter-American Development Bank. Water and Sanitation Division. IV. Title. V. Series.
IDB-WP-932

JEL code: Q24, Q25, Q40, O18
Keywords: water, energy, land, nexus, infrastructure, water security, Latin America and the Caribbean.

http://www.iadb.org

A CLEWS NEXUS MODELING APPROACH TO ASSESS WATER SECURITY TRAJECTORIES AND INFRASTRUCTURE NEEDS IN LATIN AMERICA AND THE CARIBBEAN

ABSTRACT

This working paper presents an up-to-date and prospective assessment of water security throughout the Latin America and Caribbean (LAC) region, with a focus on infrastructure needs, to aid in strategic thinking towards planning and management in key water-using sectors such as agriculture, energy and water supply. This assessment is grounded on a physically-based analysis of water supply and demand, highlights the climate-land-energy-water-socioeconomics (CLEWS) nexus contributions to water security in the region and addresses uncertainty in projections and their implications through a variety of potential future scenarios of climate change and socioeconomic development in the region. This investigation can be thought of as an exercise of envisioning possible futures of water security for the LAC region, explaining existing vulnerabilities when it comes to CLEWS nexus and laying out water infrastructure needs for addressing current and likely future problems under a range of such scenarios. The analysis that leads to estimates of infrastructure needs in the water sector is based on a multi-sector nexus approach that is at the core of the methodology employed in computing water supply and demand. This is both an important distinction and a contribution of this research compared to traditional single-sector approaches to assess projected water demands and associated infrastructure needs. By providing a socioeconomic quantitative framework for integrated analysis of water supply and demand, climate scenarios, and other forcing factors such as land use change and technological developments, this research can be extended to analytically explore different types of policy and investment interventions in multiple water demand sectors.

CONTENTS

A CLEWS Nexus modeling approach to assess water security trajectories and infrastructure needs in Latin America and the Caribbean

A. INTRODUCTION

Water security is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2013). In this context, water security refers to the possibility of access to sufficient quantities of water to meet the diversity of uses, preservation of quality in the face of wastewater discharges, and consideration of climate change in water infrastructure planning.

The nexus of energy, land and water encompasses growing concerns about the availability of vital resources derived from these intertwined systems and how to manage them in response to the challenges posed by socioeconomically-driven human demands and climate change. The components of the climate-land-energy-water-socioeconomics (CLEWS) nexus affect one another in various ways. Water is frequently under stress from the agriculture sector, which is responsible for about 70% of the total global freshwater withdrawals (FAO 2011a). Food production in particular accounts for about 30% of the world's total energy consumption (FAO 2011b). Climate variability and change dictate spatial and temporal variations of water availability, with intensified fluctuations of the hydrologic cycle leading to increased flooding and drought events. This is likely to increase competition for water across sectors, such as agriculture, the biggest consumer of water worldwide, but also energy generation, potable water supply, as well as the environment. In the Latin America and Caribbean (LAC) region specifically, population and per capita income continue to grow, which in turn increases demand for water, energy and food, especially in fast-growing countries. It is becoming increasingly clear that constraints in one component of the CLEWS nexus (i.e., climate, land, energy, water, socioeconomics) can impact other components with quantifiable consequences to overall societal well-being (e.g., Bazilian et al. 2011; Miralles-Wilhelm, 2016; Perrone and Hornberger, 2014).

The LAC region has relatively plentiful surface and groundwater sources. However, these sources are under risk in many cases. For example, most countries in the Caribbean face water scarcity and/or unavailable access, because of inefficiency in the management of the resource (combined with where demands generally match or exceed supplies and increasing demand driven by population growth and development) exacerbates the problems. Some countries of the region (e.g., Suriname, Uruguay, Venezuela) still operate with no real separation between the water resource authority and the water utility which implies that the water rights and/or water abstraction permits are given by the same institution that requests the resources. There is also limited and out-of-dated catchment information that limits the decision making process in the use to water resources. A similar situation is found in many areas in larger countries such as Mexico, Brazil, Chile and Peru. Even in countries with ample water resources to supply their population, the distribution of water is carried out in an unsustainable fashion in most cases, with impacts from climate change threatening sources even more. Disputes between upstream and downstream uses are spread all over the Region indicating in some cases a lack of understanding and dialogue

between users such is the case of the Peruvian watersheds: Santa, Piura and Tacna. In Brazil, the 2013-15 drought of São Paulo brought to the discussion an old idea of reverting part of the the Paraiba do Sul river to supply the megalopolis; contention is expected since the Paraiba do Sul is used to supply most of the water to the city of Rio de Janeiro and suburbs downstream.

Given this, the CLEWS nexus in the LAC region is characterized by abundant water in total, but with large spatial and temporal heterogeneities, a critical reliance on agriculture in economic output, and diverse and a growing energy sector with a broader generation matrix; all of these increase pressure on water security. According to estimates from the Food and Agriculture Organization's (FAO) AquaStat database (which incorporates the average annual flow of rivers and recharge of aquifers generated from endogenous precipitation), about 32% of the global renewable water resources can be found in the LAC region. Nevertheless, the large spatial variability in the distribution of these resources results in striking contrasts such as the rainy pattern of the Amazon basin versus the arid or semi-arid climate conditions found in northern Chile, northern and central Mexico, and northeast Brazil. The temporal dimension relates to the natural climate variability of the region, in which strong rainfall anomalies are modulated within a range of temporal scales (Grimm and Saboia 2015; Grimm and Zilli 2009; Mo and Schemm 2008). Substantial challenges to the future water management strategies in the LAC region are imposed by the prospect of climate change with shifts in the hydrological cycle, and rising water demands driven by population and economic growth.

In this context, water security, food security, and energy security have been recognized as critical considerations for sustainable growth and social stability. Given the complex interactions among the sectors, it is imperative to move beyond traditional approaches in which decision-making is focused as if these sectors are independent of each other and towards an integrated (nexus) planning development in these sectors. Apart from promoting economic and resource efficiency, this integrated planning framework is important to avoid unintended consequences and potential conflicts regarding the utilization of the energy, land and water resources in the coming decades in the LAC region (Da Silva et al. 2018; Miralles-Wilhelm and Muñoz-Castillo, 2018).

The focus of this paper is on analyzing water security under a CLEWS nexus framework. It presents an up-to-date and prospective assessment of water security in the LAC region, with a focus on infrastructure needs, to aid in strategic thinking towards planning and management in key water-using sectors such as water supply and sanitation (WSA), energy and agriculture. This assessment is grounded on a physically-based analysis of water supply and demand, highlights the nexus contributions of each sector to water security in the region, and addresses uncertainty in projections and their implications through a variety of potential future scenarios of climate change and socioeconomic development in the region. This investigation can be thought of as an exercise of envisioning futures of water security for the LAC region, explaining the existing vulnerabilities when it comes to CLEWS nexus and laying out water infrastructure needs for addressing current and likely future problems under a range of such scenarios.

B. RESEARCH OBJECTIVES AND QUESTIONS

This research is focused on quantifying the impacts of climate and future socioeconomic development scenarios on water security throughout the LAC region. This research also lays out the ground towards an analytical thought process that can be used to support planning, identification and prioritization of water infrastructure investment purposes, not only in the scenarios documented in this document, but also other policy and intervention options that may be considered moving forward by the Inter-American Development Bank, other research and investment organizations, governments and other stakeholders in LAC countries.

Towards these overarching objectives, the following are the research questions that this paper seeks to address:

- *What is the current trajectory of water security in the LAC region over the next few decades, particularly under the impacts of climate and socioeconomic development, using a multi-sectoral nexus analysis?*
- *What are alternative trajectories of water security in the LAC region over the next few decades, under a variety of climate and socioeconomic development scenarios?*
- *How can results from this analysis be used towards assessing investment needs in water infrastructure for different uses (water supply, agricultural, energy) in order to enhance water security in countries of the LAC region?*

In analyzing these questions, the focus of this work shifts from the traditional concept of water security based on natural availability of water resources, to one focused on water security based on infrastructure for access and efficient use of water in adequate quantity and for various "nexus" sectors, e.g., agricultural production, water supply, and energy generation. This distinction is particularly important for the LAC region, as results of this analysis (as well as many other studies) show that the region is relatively well endowed with water resources, so water security then hinges on the availability of infrastructure to make use of this water in a sustainable way, with resiliency to a broad and varied set of physical (e.g., climate change), social (e.g., population and land use change) and economic (e.g., development and policy intervention) conditions.

C. METHODOLOGY

Model Description

The CLEWS nexus scenarios for water security presented in this paper were modeled using the Global Change Assessment Model (GCAM)[1], release version 4.3, a state-of-the-art Integrated Assessment Model (IAM) designed to explore interactions among critical sectors of the economy, the human and physical systems, and to support policy-relevant decisions (Edmonds and Reilly 1985, Wise et al. 2009, Clarke et al. 2014). As a leading IAM, GCAM has contributed significantly to advance the scientific understanding of climate change as the IAM selected by the

[1] GCAM is freely available as a community model and can be obtained through a widely used software repository (https://github.com/JGCRI/gcam-core). The full documentation of the model is also hosted at GitHub (http://jgcri.github.io/gcam-doc). The description presented in this subsection is a summary of key GCAM characteristics based mostly on the online documentation.

Intergovernmental Panel on Climate Change (IPCC) to model the representative concentration pathway (RCP) 4.5 (Thomson et al. 2011). More recently, GCAM became the marker model for the quantification of the Shared Socioeconomic Pathway (SSP) 4 storyline (Calvin et al. 2017) and was implemented regionally in LAC (Silva et al. 2018; Miralles-Wilhelm and Muñoz-Castillo, 2018).

The current implementation of GCAM is oriented towards the coupling of five main (CLEWS) systems: climate, land energy, water and socioeconomics. Along the socioeconomics system, assumptions for population and labor productivity are used to derive GDP in each region, which, in turn, drive the regional economic activity, as well as a large chain of interconnected processes and demand responses in the other systems. Within a market equilibrium economic framework, GCAM represents the global economy by disaggregating the world in 32 geopolitical regions. The LAC region in particular, is represented as seven distinct sub regions: Argentina, Brazil, Central America and Caribbean, Colombia, Mexico, South America Northern, and South America Southern (Figure 1).

As a long-term model, GCAM operates in 5-year time steps until 2100. The base year for the model is 2010, based on calibration to historical energy, agricultural, land, and climate data. In terms of its solution algorithm, GCAM is a dynamic-recursive model, which solves each period sequentially (based on existing information for the period being solved) through the establishment of market-clearing prices for all existing markets (energy, agriculture, land, GHG emissions). This means that, for each model period, an iterative scheme ensures convergence to final equilibrium prices such that supplies and demands are equal in all markets.

Figure 1: GCAM representation of the following 7 LAC subregions: Argentina (red), Brazil (blue), Central America and Caribbean (green), Colombia (purple), Mexico (yellow), South America Northern (brown), and South America Southern (magenta).

The energy system structure in GCAM contains explicit modeling of the energy supply and demand sectors for each region, and the trading of primary resources among regions. The model

includes representations of the availability and extraction of primary energy resources (oil, natural gas, coal, bioenergy, uranium, hydropower, geothermal, solar, and wind energy) as well as the energy transformation processes (e.g., liquid fuel refineries and power generation) that produce the final fuel carriers (refined liquids, refined gas, coal, commercial bioenergy, hydrogen, and electricity) used by the energy end-use sectors (buildings, industry, and transport). GCAM is particularly detailed in the representations of technology options (including technology evolution in the future) with more than 100 different energy supply and conversion technology representations currently available (McJeon et al. 2014).

Another key feature of GCAM is the agriculture and land-use system, which allows projections for agricultural supply (crops, livestock, forest products, and bioenergy), prices, and changes in land use and cover, considering also the trading of primary agricultural and forest goods. In this component, each of the 32 geopolitical regions can be disaggregated into up to 18 agro-ecological zones resulting in a total of 283 agriculture and land use regions. Within each of these 283 subregions, land is categorized into twelve types based on cover and use. Among the land types considered arable, non-commercial land uses such as forests, shrublands and grasslands are included, as well as commercial forestlands and croplands. Land allocation within any geopolitical region depends on the relative profitability of all possible land uses within each of the 283 land-use regions (Kyle et al., 2014). Land used for any purpose in GCAM competes economically with croplands, commercial forests, pastures, and all lands not involved in commodity production, with the exception of the land types whose land cover is assumed constant over time such as tundra, deserts, and urban lands. The profitability of any land used for commercial production is derived from the price (value) of the commodity produced, the costs of production, and the yield (Kyle et al. 2014). GCAM models the production of twelve crop categories based on exogenously specified yields that are crop-specific but vary depending on the subregion. Bioenergy production is derived from various types of dedicated bioenergy crops (e.g., switchgrass, miscanthus, willow, jatropha, and eucalyptus), food crops, residues from forestry and agriculture, municipal solid waste, and traditional bioenergy through a suite of technologies for transforming these biomass feedstocks. For example, the biomass liquids subsector within the energy module includes a number of transforming technologies for biofuels production from agricultural crops such as sugar, corn and oil crops.

The water module within GCAM provides estimates of water demands (gross water withdrawals and net consumptive use) for six sectors divided in agricultural water use (irrigation and livestock) and non-agricultural use: primary energy production and processing, electricity generation, industrial, and municipal. As described by Hejazi et al. (2014a, 2014b), the main characteristics of the GCAM water module are: (1) future agricultural water demands are driven by crop production from GCAM, the share of crop production that takes place on irrigated lands in each of the 283 subregions, and by crop type (12 categories of crops plus biomass). The estimates of water withdrawals for biomass includes a number of second-generation biomass crops (purpose-grown bioenergy crops), but crops such as corn, sugar and oil palm used for biofuel production are not included since their water demands are quantified in the irrigation category. (2) Future manufacturing and domestic water demands are driven by socioeconomic assumptions, among other factors (e.g., total industrial output, future changes in efficiency, technological improvements, and prices of goods that are water-derived); (3) the water demands for primary

energy depend on the amount of each fuel produced whereas water demands for secondary energy (electricity, refined liquid products) depend also on the specific production technologies used, which in the case of the electric-sector water use includes the types of cooling systems used during thermal power generation.

GCAM has been built and populated with global and detailed datasets for over 30 years and is extensively used to explore climate change mitigation and adaptation policies. A key advantage of GCAM over some other IAMs is that it is a Representative Concentration Pathway (RCP)-class model. This means it can be used to simulate scenarios, policies, and emission targets from various sources including the Intergovernmental Panel on Climate Change (IPCC).

GCAM is a publicly available, open source modeling tool, developed and maintained by the Pacific Northwest National Laboratory, part of the US Department of Energy. Further details about GCAM can be found on its wiki site.

Climate Scenarios: Representative Concentration Pathways (RCPs)

RCPs are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014 [Moss et al. 2008]. RCPs supersede the Special Report on Emissions Scenarios (SRES) projections published in 2000. These pathways are used for climate modeling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs: RCP2.6, RCP4.5, RCP6.0, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (increases of +2.6, +4.5, +6.0, and +8.5 W/m^2, respectively; Weyant et al. 2009).

The RCPs are consistent with a wide range of possible changes in future anthropogenic GHG emissions. RCP2.6 assumes that global annual GHG emissions (measured in CO_2-equivalents) peak between 2010-2020, with emissions declining substantially thereafter. Emissions in RCP4.5 peak around 2040, then decline. In RCP6.0, emissions peak around 2080, then decline. In RCP8.5, emissions continue to rise throughout the 21st century.

In this study, focus is placed on impacts on climate futures represented by RCPs to reflect an envelope of climate change policies throughout the world and their impacts on water availability (or scarcity) and its trajectory over the next decades. Scenario RCP6.0 is used in this work as a “reference” scenario to illustrate baseline conditions in climate. Therefore, RCP2.6 and RCP4.5 are scenarios with relatively less climate change, and RCP8.5 is a scenario with relatively more climate change compared to the reference.

Earth System Models (CCSM, FIO, GISS)

Three different Earth System Models were selected as to represent different climate model assumptions and formulations in an effort to provide a robust envelope of impacts of climate change and variability on water resources availability and the corresponding analysis of results. This analysis employed the three Earth system models (CCSM, GISS and FIO) to assess the

level of uncertainty propagating from these models and scenarios, and their implications on water availability throughout the LAC region. The Earth system models span the range of uncertainty (wet, dry, and normal) that may be expected in the region over the coming decades (Miralles-Wilhelm et al. 2017).

The Community Climate System Model (CCSM) is a GCM developed by the University Corporation for Atmospheric Research (UCAR). The coupled components include an atmospheric model (Community Atmosphere Model), a land-surface model (Community Land Model), an ocean model (Parallel Ocean Program), and a sea ice model (Community Sea Ice Model) [e.g., Hoffman 2006].

The Goddard Institute for Space Studies (GISS) GCM is primarily aimed at the development of coupled atmosphere-ocean models for simulating Earth's climate system. Primary emphasis is placed on investigation of climate sensitivity —globally and regionally, including the climate system's response to diverse forcings such as solar variability, volcanoes, anthropogenic and natural emissions of greenhouse gases and aerosols, paleoclimate changes, etc. A major focus of GISS GCM simulations is to study the human impact on the climate as well as the effects of a changing climate on society and the environment. The GISS GCM is featured in the IPCC (AR5 as well as past reports), and over 50 TB of climate model results have been publicly archived for the CMIP5. This project has included simulations for the historic period, future simulations out to 2300, and past simulations for the last 1000 years, the last glacial maximum and the mid-Holocene.

The FIO Earth System Model (FIO-ESM) is a GCM developed by the First Institute of Oceanography in China. It includes the ocean surface wave model besides the atmosphere, ocean, land and ice components, and is coupled with the fully global carbon cycle process and its interactions with the climate system. The historical simulation of the global carbon cycle is following the CMIP5 (Climate Model Inter-comparison Project phase 5) long-term experiments design and the simulation results are used to evaluate the performance of the model including the atmosphere, ocean, land surface and biogeochemical process of ocean and terrestrial ecosystem.

Socioeconomic Scenarios: Shared Socioeconomic Pathways (SSPs)

Long-term scenarios play an important role in research on global environmental change. The climate change research community is developing new scenarios integrating future changes in climate and society to investigate climate impacts as well as options for mitigation and adaptation. One component of these new scenarios is a set of alternative futures of societal development known as the shared socioeconomic pathways (SSPs). The conceptual framework for the design and use of the SSPs calls for the development of global pathways describing the future evolution of key aspects of society that would together imply a range of challenges for mitigating and adapting to climate change.

O'Neill et al. (2015) present the "SSP narratives", a set of five qualitative descriptions of future changes in demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources. We describe the methods used to develop

the narratives as well as how these pathways are hypothesized to produce particular combinations of challenges to mitigation and adaptation. Development of the narratives drew on expert opinion to identify key determinants of these challenges that were essential to incorporate in the narratives and combine these elements in the narratives in a manner consistent with their interrelationships. The narratives are intended as a description of plausible future conditions at the level of large world regions that can serve as a basis for integrated scenarios of emissions and land use, as well as climate impact, adaptation and vulnerability analyses.

The SSPs are designed to span a relevant range of uncertainty in societal futures. Unlike most global scenario exercises, the relevant uncertainty space that the SSPs are intended to span is defined primarily by the nature of the outcomes, rather than the inputs or elements that lead to these outcomes. Therefore, the SSP outcomes are specific combinations of socioeconomic challenges to mitigation and socioeconomic challenges to adaptation. The SSPs are intended to describe worlds in which societal trends result in making mitigation of, or adaptation to, climate change harder or easier, without explicitly considering climate change itself.

The SSPs are illustrated in **Figure 2**. The implementation of SSPs in IAMs such as GCAM is described in further detail in the papers by Riahi et al. (2017) and Calvin et al. (2017). **Figure 3** and **Figure 4** show global input variables for the GCAM simulations. Population and GDP data are obtained from the SSP database, and documented in KC and Lutz (2017); Leimbach et al. 2017; Cuaresma, 2017; and Dellink et al. 2017.

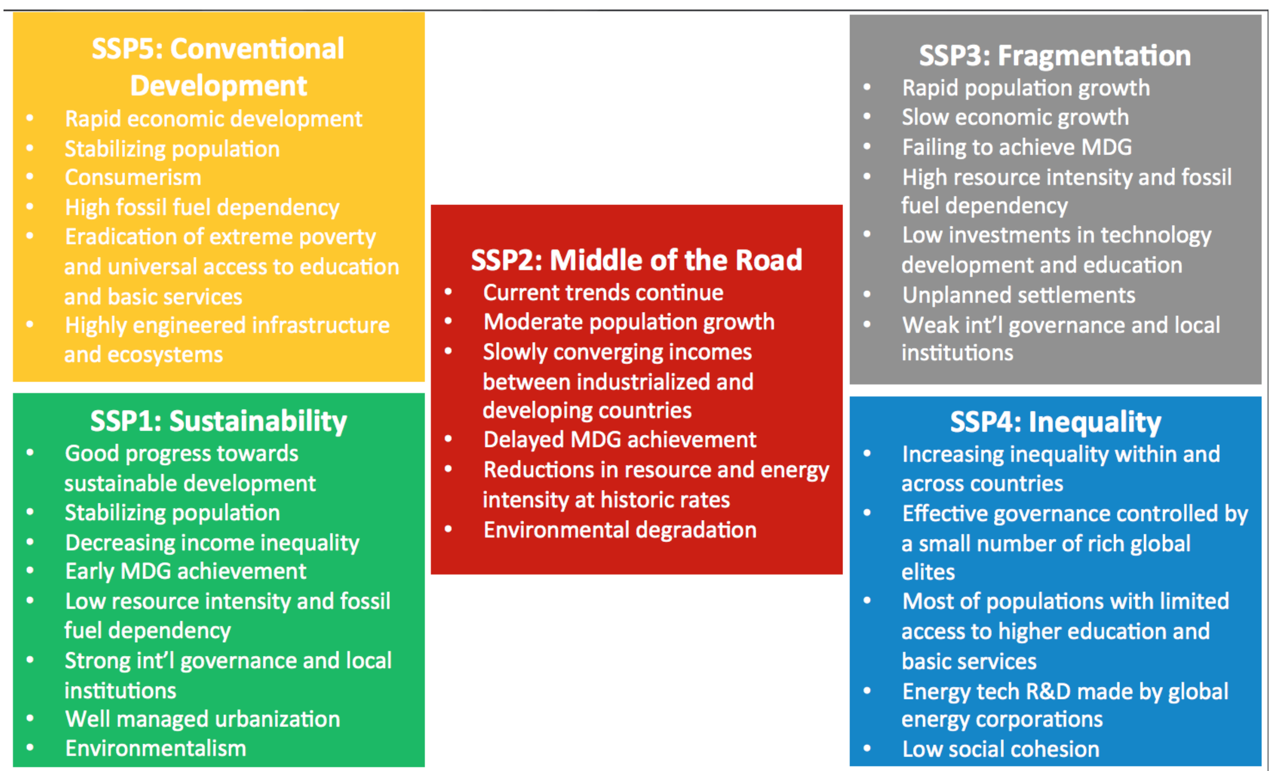

Figure 2: Shared socioeconomic pathways (SSPs) representing different combinations of challenges to mitigation and to adaptation; source: adapted from O'Neill et al. (2015).

Water Scarcity Index (WSI)

The WSI is the ratio of water extracted from sources (demand) to water available from these sources (surface runoff and renewable groundwater) at a given location, which in GCAM implies numerical grids of 0.5 degree x 0.5 degree spatial resolution. For a given simulated scenario, the WSI was determined as follows:

- Water demands (total water withdrawals) are simulated in GCAM; these results are calculated at the grid scale.
- The hydrology (water supply) module in GCAM is used to generate water supply using climate information from the 3 GCMs: CCSM, GISS, FIO-ESM at the grid level. This supply includes surface runoff plus renewable groundwater.
- The WSI for each grid is calculated as:

$$WSI = \frac{Demand}{Supply}$$

A water scarcity index value of 0.1 or lower is used in this study to denote low scarcity; values of (0.1≤ WSI< 1.0) are used to denote moderate water scarcity; and (WSI<1.0) is used to denote high and severe levels of water scarcity.

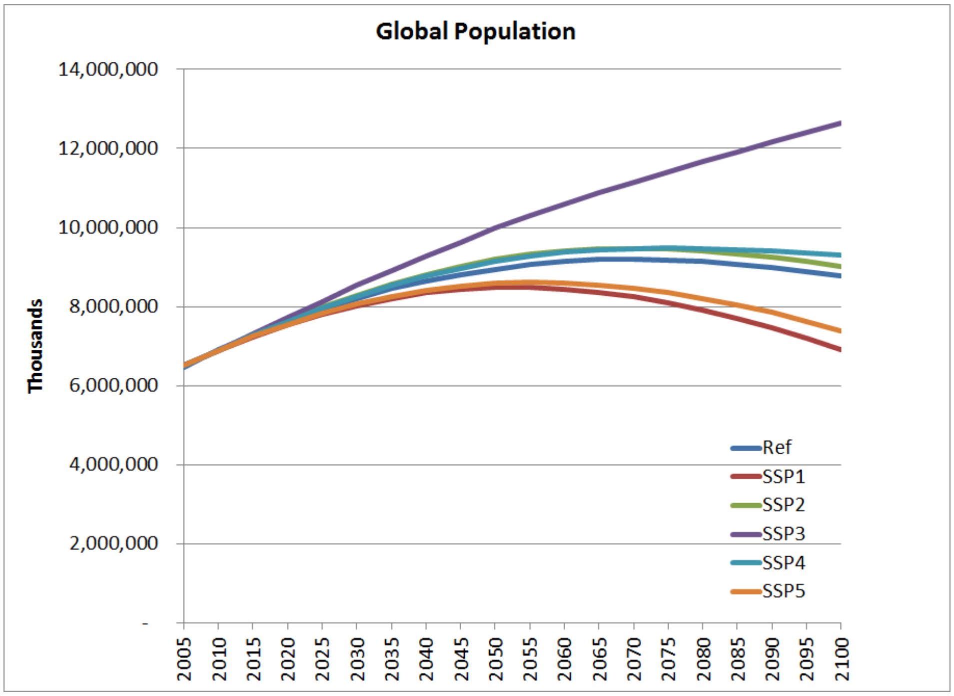

Figure 3: Global population for the GCAM reference scenario and for the five SSPs (source: SSP database[2]).

[2] SSP database: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about#intro

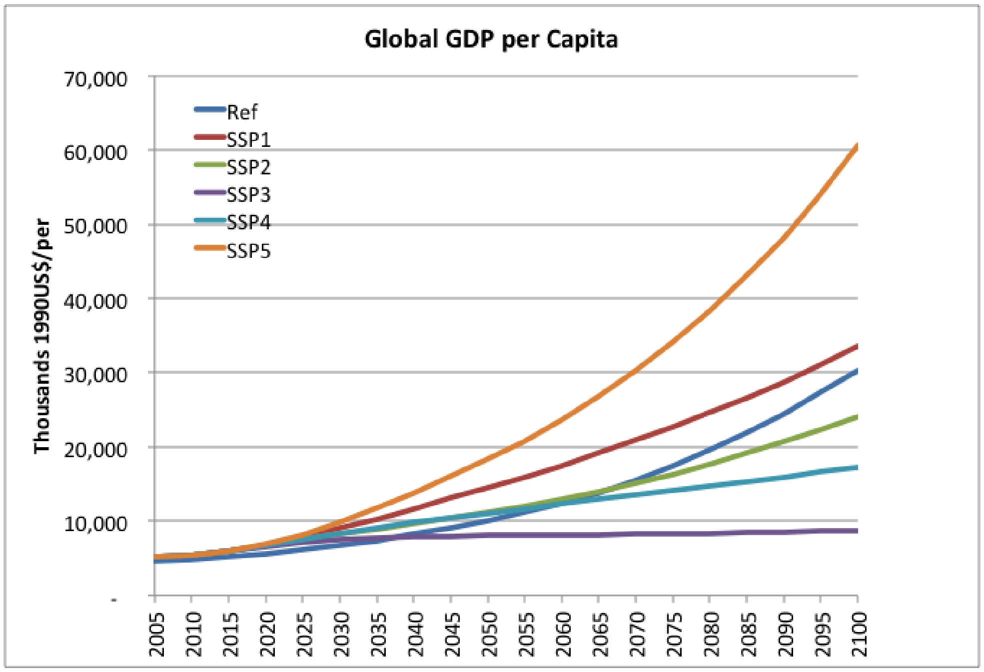

Figure 4: Global GDP per capita for the GCAM reference scenario and for the five SSPs (source: SSP database[2]).

D. RESULTS AND DISCUSSION

For the purposes of discussion, the results of the analysis conducted in this work has been divided into three categories, which are aligned with the strategic questions posed in Section B.

D.1 Current Trajectory of Water Security throughout the LAC Region

Figure 5 shows the estimates of total annual runoff volume (including renewable groundwater) for the three Earth system models under climate scenarios RCP2.6 and RCP8.5. This is the sum of the runoff volume generated for the water basins in GCAM covering the region.

The total runoff volume in the LAC region for climate scenario RCP2.6 is sensibly larger (in the order of 5 percent overall) than that for RCP8.5. This result is consistent with the notion of decreasing water availability with increasing climate change, amply documented for the global case in the literature and summarized in the IPCC's Fifth Assessment Report (Working Group II, Jimenez Cisneros et al. 2014; Magrin et al. 2014; and references therein). The different Earth system models yield runoff estimates for each climate scenario that are within close range of each other, suggesting robustness of these estimates at the regional scale in LAC.

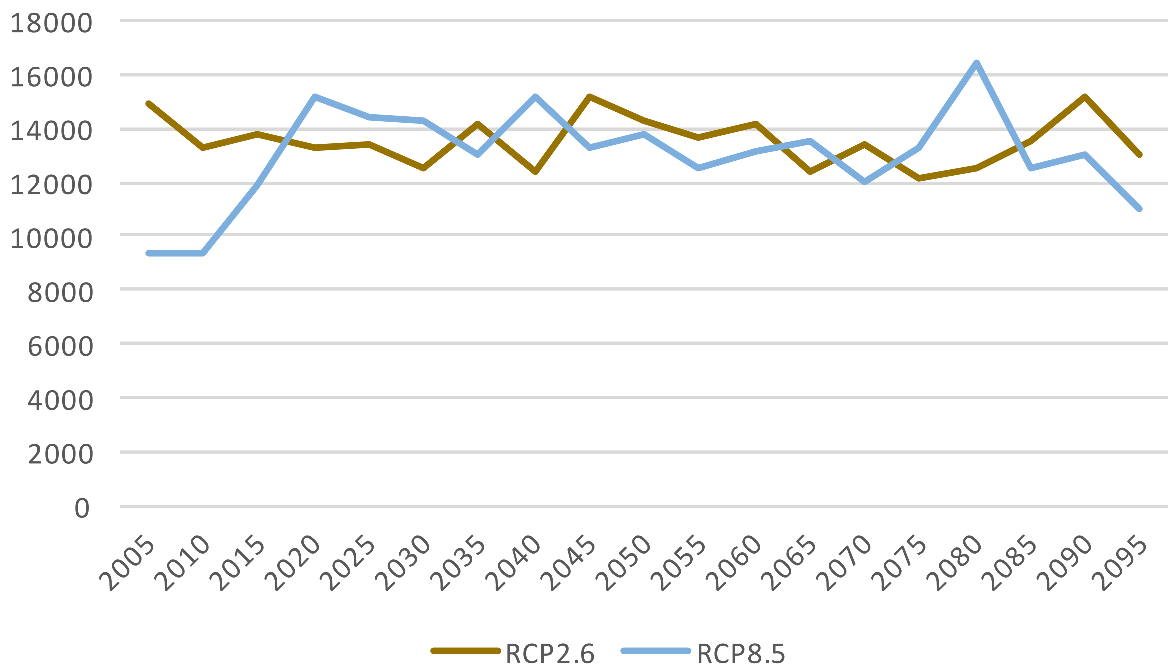

Figure 5: Estimates of LAC regional runoff generation (sum for all countries) using the GISS Earth System Models for climate scenarios RCP2.6 and RCP8.5. Values are in km^3/yr. Long term average runoff values are 13,530 km^3/yr (RCP2.6) and 12,932 km^3/yr (RCP8.5).

While the regional total runoff volume may not vary significantly over the next decades, the spatial distribution around the region shows some variations that are important to note. **Figure 6** shows the annual runoff volume generated throughout the region, for the climate scenarios RCP2.6 and RCP8.5 for the year 2050; complementary results are shown in **Appendix A**. Because the runoff volume calculated by the Earth system models used in this study are of similar order (see Figure 5), results for the GISS model are shown as representative for illustration purposes. These values of runoff volume are useful indicators of total surface water availability and facilitate inter-country or intra-region comparisons.

The change in runoff for the region during the period 2015-2050 is shown on **Figure 7**. Some localized effects are noteworthy: drying of the Amazon basin, northern Mexico, northeast Brazil, the Caribbean and Central America. Glacial melting keeps runoff in the Andes relatively stable, at the expense of runoff, then progresses to drying towards the end of the century.

Some trends that these results for runoff in the LAC region show can be summarized as follows. There is drying in the Amazon basin, northern Mexico, northeast Brazil and countries in the Caribbean and Central America, which appear to have a consistent trend towards diminishing runoff, a trend that is more pronounced towards the second half of the century, particularly in Mexico. In the Andean countries, progressively glacial melting keeps runoff generation in the first half of the century (to 2050), followed by a drying trend in the second half. The Pacific coast of Peru shows a trend towards drying that is stabilized towards the end of the century (because of glacial melting draining westward to that basin). Chile shows a consistent trend towards decreased runoff in all three model simulations.

Annual Runoff (km³/yr) for the Latin America and Caribbean (LAC) Region

2050

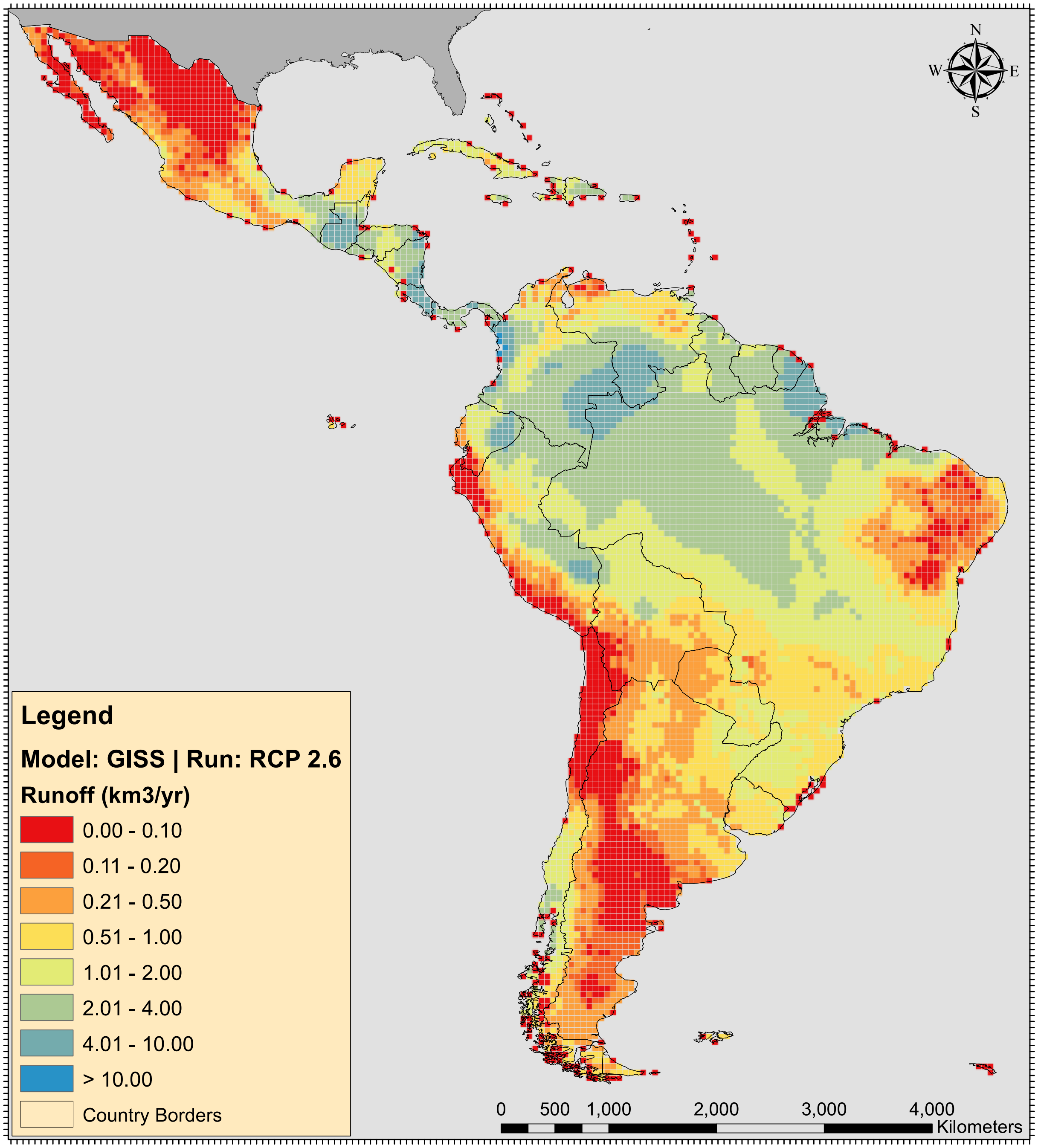

Figure 6: Runoff distribution in the LAC region in 2050 (RCP2.6).

Annual Runoff (km^3/yr) for
the Latin America and Caribbean (LAC) Region

2050

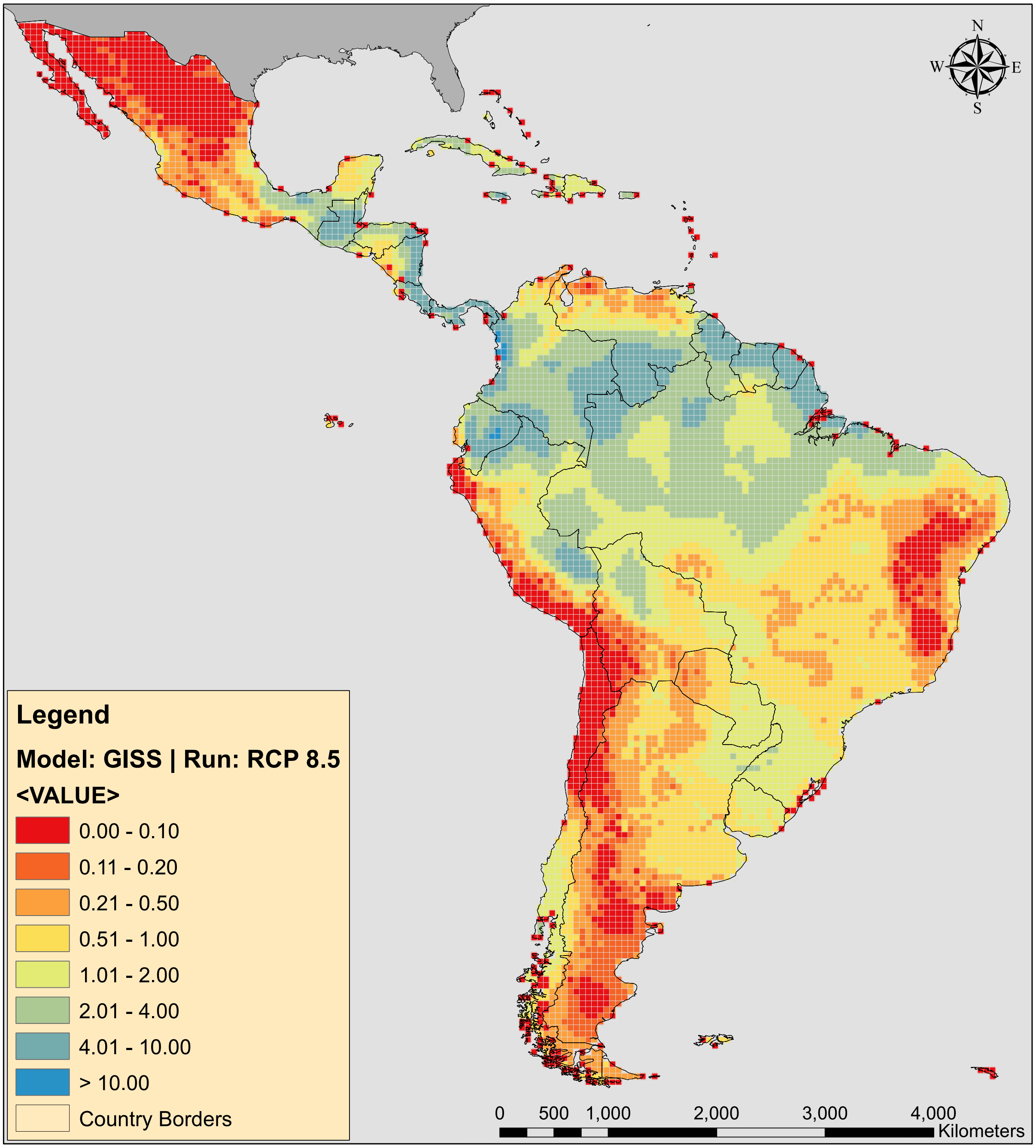

Figure 6 (cont): Runoff distribution in the LAC region in 2050 (RCP8.5).

Change in Annual Runoff (km^3/yr) for the Latin America and Caribbean (LAC) Region

2015 - 2050

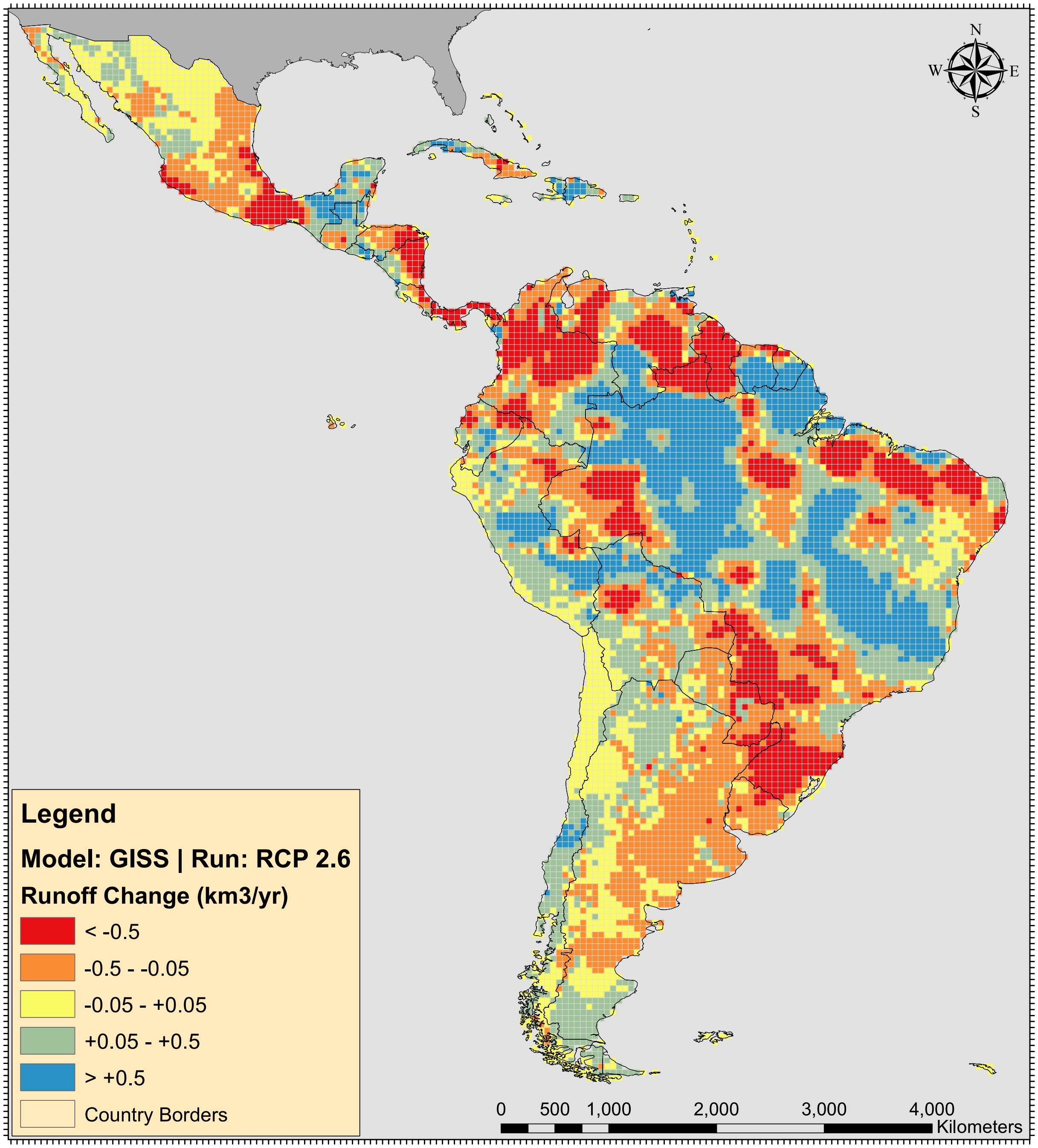

Figure 7: Change in runoff distribution in the LAC region for the period 2015-2050, projected using climate scenario RCP2.6.

Annual Runoff (km^3/yr) for
the Latin America and Caribbean (LAC) Region

2050

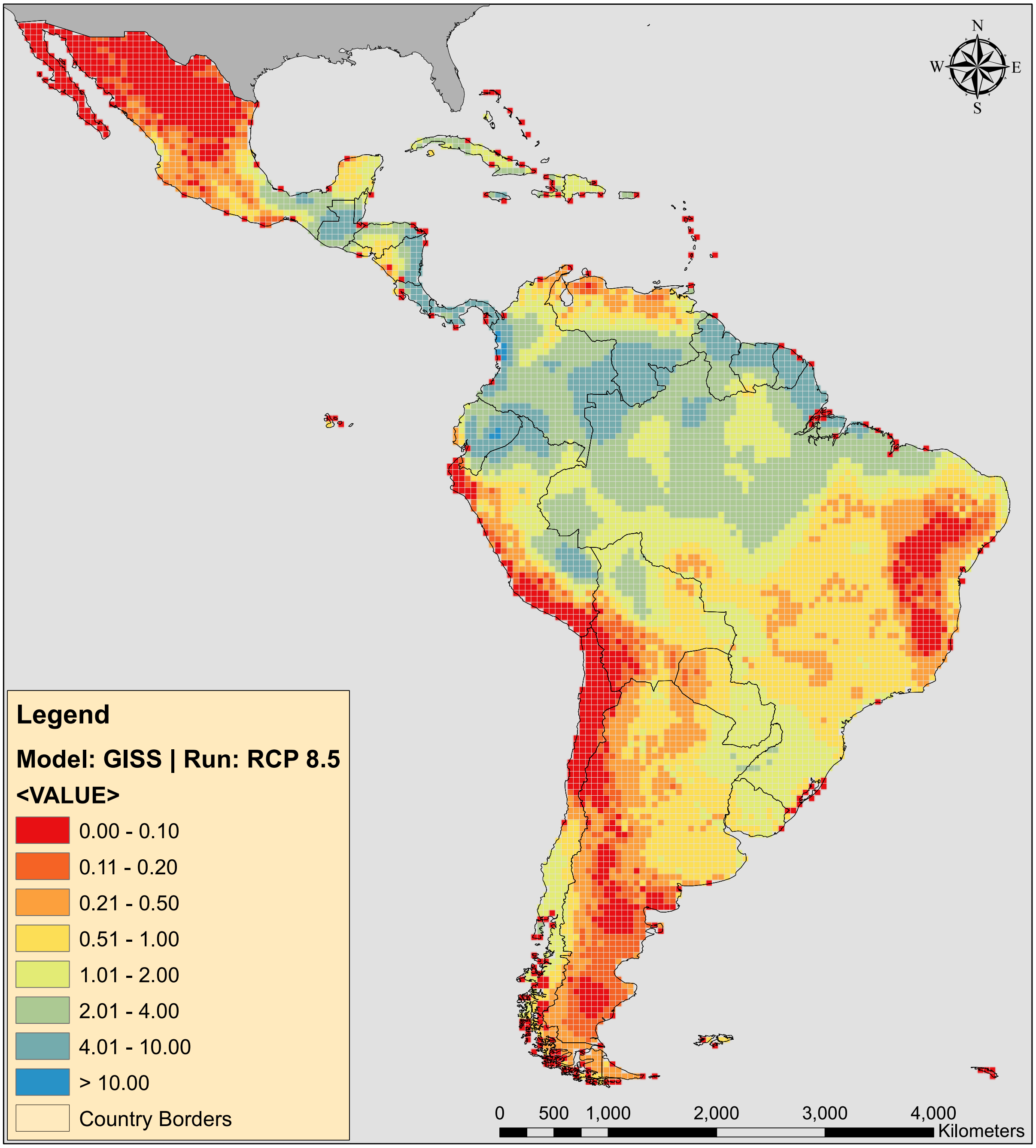

Figure 7 (cont): Change in runoff distribution in the LAC region for the period 2015-2050, projected using climate scenario RCP8.5.

Water demand is estimated using population, land use (including urbanization), agricultural (FAO) and major energy demand (IEA) locations using the methodology described in Hejazi et al. (2013, 2014ab). **Figure 8** presents the water demand in the LAC region for the reference scenario for the year 2050; complementary results are shown in **Appendix B**.

The reference scenario for these GCAM simulations is used to portray the current and future status of water scarcity in the LAC region. **Figure 9** shows the simulation results for the WSI in the reference (RCP6.0) scenario for the year 2050.

These results illustrate four key trends in the WSI for the LAC region:

- First, the region, with abundant water resources availability compared to demand of water for different uses, exhibits overall low water scarcity values. This is characteristic of a region that is relatively water-rich and is consistent with numerous studies of water availability in the LAC region.
- Second, water scarcity has different trends throughout in the region; in some parts of the region, water availability (expressed as runoff plus renewable groundwater) may increase over time, while in other parts of the region the trend is decreasing. This is reasonable to be expected given the combination of changes in rainfall and temperature, and the dynamics of different biomes across the region, i.e., coastal areas, high mountain Andean glaciers, wetlands, dry savannas and other ecosystems.
- Third, the WSI results appear to be fairly consistent among the 3 climate models used; this suggests that *water scarcity is dominated by water demands* (numerator of the WSI) rather than by the climate-influenced water supply (surface runoff and groundwater). This is an important finding that suggests that the human influence, rather than that posed by climate, drives water scarcity in the region.
- Fourth, it appears that *severe and moderate water scarcity in the region advance significantly within the next few decades*, and particularly towards the second half of the century. Severe water scarcity is projected primarily in Mexico, Haiti and the Dominican Republic; while moderate water scarcity advances in Chile, in parts of Central America (Nicaragua and El Salvador), particularly around larger urban areas.

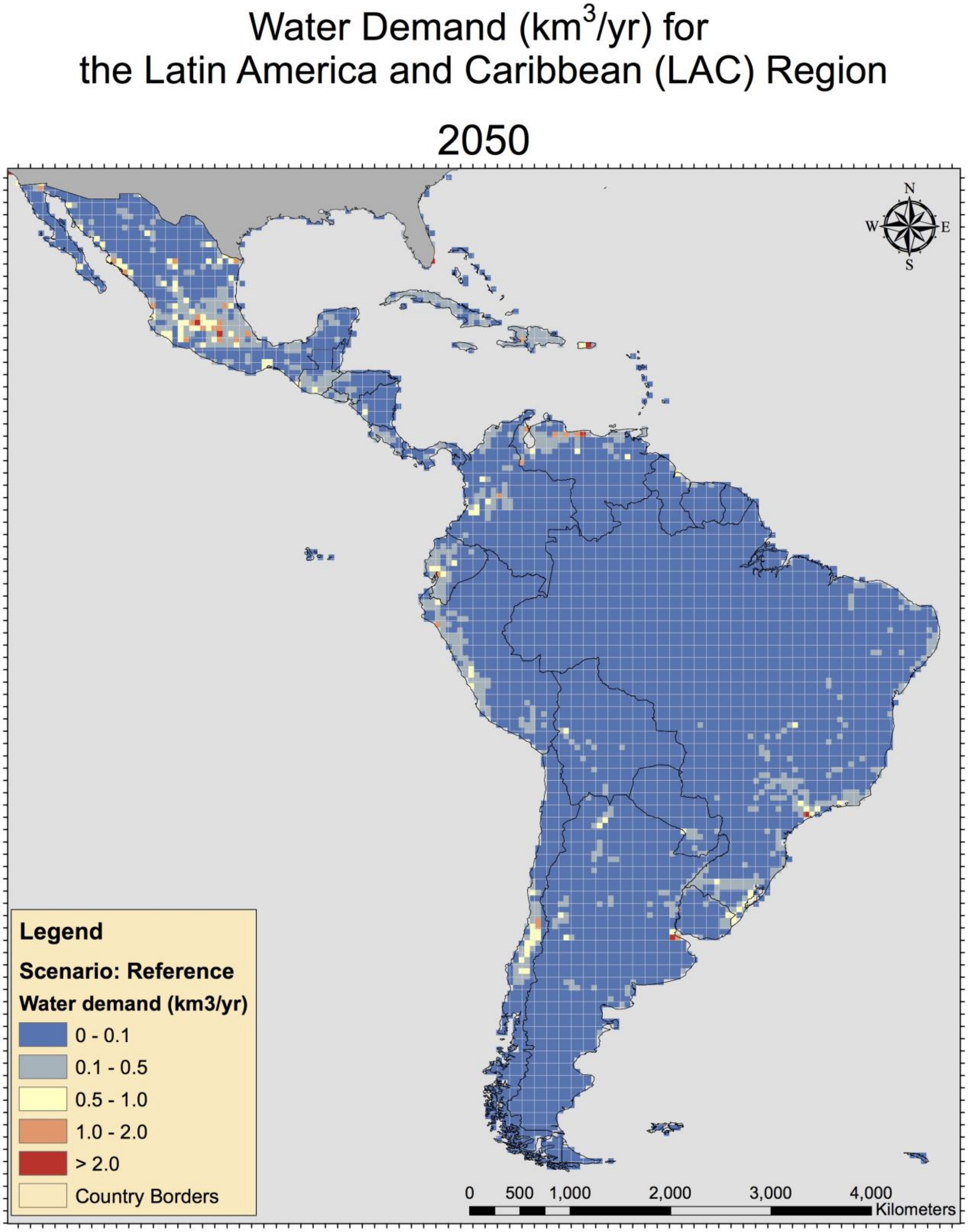

Figure 8: Water demand in the LAC region for the year 2050.

Figure 9: Water Scarcity Index (WSI) in the LAC region for the year 2050.

D.2: Water Security in LAC under a variety of Socioeconomics Scenarios

This part of the analysis provides an assessment of the impact of several Shared Socioeconomic Pathway (SSP[3]) scenarios on water security throughout the LAC region. These results show how socioeconomic and technological development might affect water demands and consequently water security in different basins, helping to illustrate tradeoffs between sectoral water usage and identify potential mitigation and adaptation effects on water security. These scenarios also highlight the roles of infrastructure-based measures (e.g., storage, irrigation efficiency, water reuse, dry cooling for energy generation). The results are also useful to compare the relative effects of socioeconomics and technological changes to the effects of climate change (Section D.1).

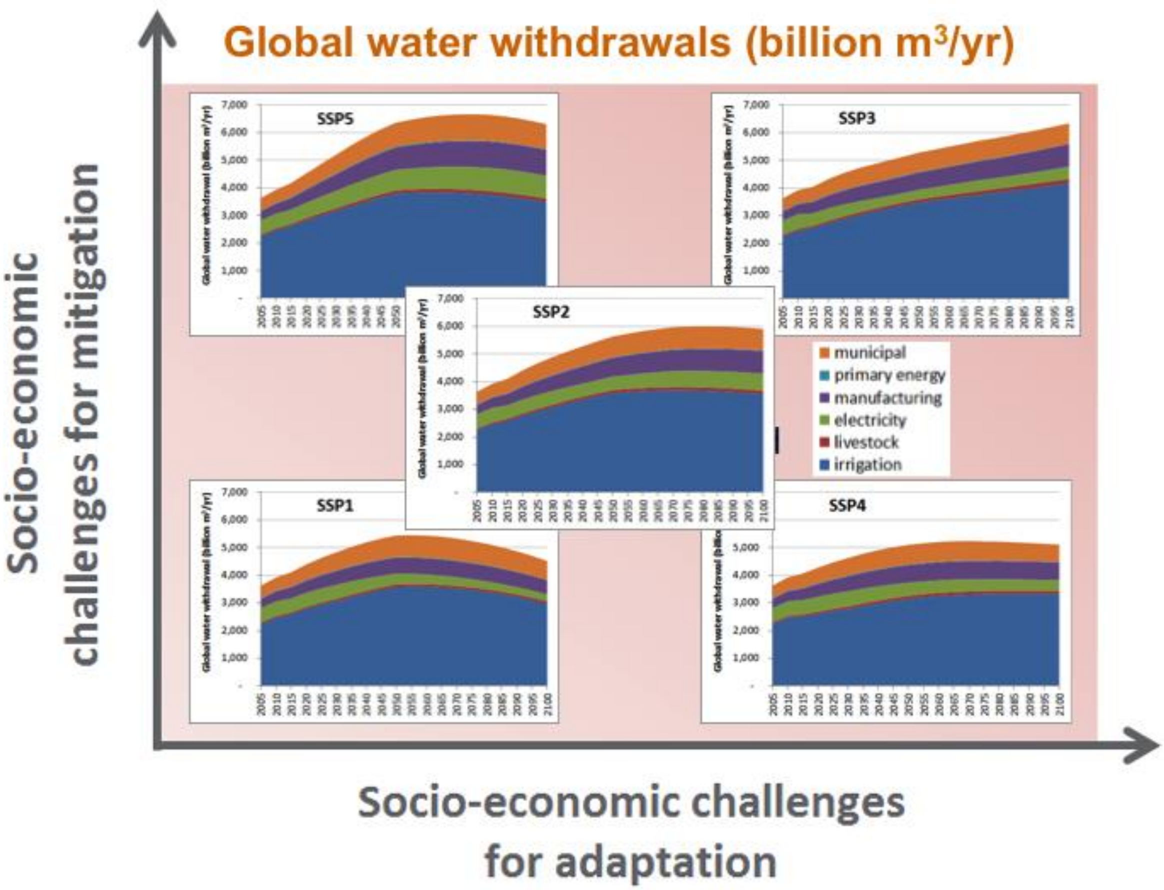

Figure 10: Global water demands for the five SSPs and broken down by major water using sectors.

[3] e.g., See O'Neill et al. 2015, The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century, Global Environmental Change, doi:10.1016/j.gloenvcha.2015.01.004

Because SSPs are global socioeconomic development scenarios which affect the demand side of water security, it is useful to understand how water demands vary between these scenarios. This comparison is shown on **Figure 10**. SSP 1 exhibits a strong focus on sustainability, reducing water demand for both adaptation and mitigation of climate change. This results in water demand being curbed significantly towards the middle of the century and reduced onwards. SSP4 shows a water demand that plateaus starting in 2060, a similar trend to that found in SSP2. However, SSP4 stabilizes at lower values than those in SSP2, reflecting the lesser energy generation in SSP4 with a resulting reduction in water use; increased efforts on mitigation reduce the pressure over water resources across all sectors. The scenario posed by SSP5 is characterized by increased water demand from energy generation and agricultural production activities, driven by a much larger size of the economy. Similarly, to scenarios SSP2 and SSP4, the increase in water demand over time reaches a plateau towards 2050, followed by a slight decreasing trend that starts in 2080. Scenario SSP3 is reflective of business-as-usual, and results in a continuous increase in water use across all sectors, with no curbing at all.

Figure 11 shows the water scarcity results for scenario SSP2 (moderate efforts in climate mitigation and adaptation) for the year 2050; results for the remaining SSPs are shown in **Appendix C**. Countries in the LAC region with tendencies towards water scarcity are:

- Mexico: severe scarcity in SSP2, SSP3 and SSP5; moderate scarcity in SSP1 and SSP4.
- Chile: severe scarcity in SSP1, SSP2, SSP4 and SSP5; high scarcity in SSP3.
- Dominican Republic: moderate scarcity in SSP1, SSP2, SSP4 and SSP5; severe scarcity in SSP3.
- Haiti: moderate scarcity in SSP1, severe scarcity in SSP2, SSP3, SSP4, SSP5.

The rest of the LAC region appears to exhibit low scarcity for all SSP scenarios.

Figure 11: Water Scarcity Index (WSI) in the LAC region for the year 2050; Scenario SSP2.

D.3 Assessing Water Infrastructure Needs in Nexus Sectors

Given the relative abundance of water availability (supply) compared to the demand for water for different uses, in the LAC region water security is driven by access to water resources, which requires infrastructure, and associated measures such as efficiency in the use of water, sustainability of this infrastructure, governance and institutional strengthening, and appropriate financing and participation by societal stakeholders, including the private sector.

To further emphasize this finding, a calculation can be made of the gap between water availability and projected demand of water for different uses. This is shown in **Table 2**. These results can be directly obtained from the preceding analysis for every scenario simulated. For any given country, the availability of water is given by its generated runoff plus the net inflow received from other countries (i.e., the denominator of the WSI); the demand is given by projected withdrawals of water for different uses, chiefly agriculture, energy and water supply and sanitation services (i.e., the numerator of the WSI).

Table 2: Values of Water Demand (D) in the LAC Region for the Period 2015-2050; Reference Scenario

TOTAL WATER DEMAND				
		D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2050	2015-2100
ARG	Argentina	48.27	73.87	53%
BLZ	Belize	0.23	0.36	53%
BOL	Bolivia	3.63	7.27	100%
BRA	Brazil	103.14	152.60	48%
CHL	Chile	65.06	108.12	66%
COL	Colombia	13.68	25.60	87%
CRI	Costa Rica	2.73	4.02	48%
DOM	Dom Rep	6.72	9.83	46%
ECU	Ecuador	18.59	32.86	77%
GTM	Guatemala	5.04	7.65	52%
GUY	Guyana	2.94	4.78	63%
HND	Honduras	2.34	3.55	52%
HTI	Haiti	2.04	3.08	51%
JAM	Jamaica	1.70	2.65	56%
MEX	Mexico	107.35	168.56	57%
NIC	Nicaragua	2.22	3.34	50%
PAN	Panama	0.71	1.08	51%
PER	Peru	21.39	39.17	83%
PRY	Paraguay	2.73	5.15	89%
SLV	El Salvador	3.25	4.91	51%
SUR	Suriname	1.17	1.89	62%
URY	Uruguay	7.29	13.90	91%
VEN	Venezuela	38.02	58.37	54%
REGIONAL LAC		**460.26**	**732.62**	59%

Some key results can be inferred from this calculation:

- Water demand increases significantly over the period of analysis; the result overall for the region indicates an almost 60% increase over this period.
- At the country level, some of the relative increases in water demand are even more significant. In Bolivia, Colombia, Perú, Paraguay and Uruguay, the increases are practically two-fold.

This implies that water security at the regional level in LAC is driven not only by water availability (and factors affecting it such as climate and land use changes), but also by demand (which is population and use driven). So, the results suggest that water security in the LAC region, as an important resource management problem beyond a physical scarcity problem. A large part of this management problem is developing and investing in the necessary infrastructure to deliver water for this growing demand, in an efficient and sustainable way. Even in countries with notable water availability variations such as Brazil, Chile and Mexico, investments in infrastructure combined with demand-based measures in water scarce locations, can provide water security and higher reliability of supply systems.

It is also useful to understand how this growing demand is broken down between major water use sectors, which provides an indication of magnitude of needed investments in infrastructure for the different sectors. These results are presented in **Table 3** for the Reference Scenario and **Appendix D** for the series of SSP scenarios analyzed. These values of projected demand can be used to assess water infrastructure needs at the country level for different development trajectories over the next few decades. These infrastructure needs can be used to evaluate existing gaps in infrastructure in the different sectors and prioritize investments based on needs, gaps and national priorities in food production, energy generation and water and sanitation.

It is important to note that although infrastructure needs are broken down here into sectors, the analysis that led to these estimates is based on a multi-sector CLEWS nexus approach that is at the core of the methodology employed by GCAM in computing supply and demand of water. This is an important distinction contributed by this work compared to traditional single-sector approaches to assess projected water demands and the associated infrastructure needs.

Table 3: Water Demand for Agriculture, Energy and Water Supply and Sanitation (2015-2050), Reference Scenario

AGRICULTURAL WATER DEMAND					
		D (km3)	D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2025	2050	2015-2050
ARG	Argentina	14.88	17.75	22.77	53%
BLZ	Belize	0.04	0.04	0.06	53%
BOL	Bolivia	2.55	3.42	5.10	100%
BRA	Brazil	29.64	34.34	43.85	48%
CHL	Chile	11.19	13.50	18.60	66%
COL	Colombia	5.23	6.77	9.79	87%
CRI	Costa Rica	0.63	0.67	0.93	48%
DOM	Dom Rep	2.05	2.18	3.01	46%
ECU	Ecuador	5.94	7.26	10.49	77%
GTM	Guatemala	1.85	1.99	2.81	52%
GUY	Guyana	1.14	1.39	1.86	63%
HND	Honduras	1.38	1.48	2.09	52%
HTI	Haiti	1.59	1.71	2.40	51%
JAM	Jamaica	0.26	0.28	0.40	56%
MEX	Mexico	57.44	65.64	90.19	57%
NIC	Nicaragua	1.06	1.14	1.59	50%
PAN	Panama	0.36	0.38	0.54	51%
PER	Peru	11.27	14.49	20.63	83%
PRY	Paraguay	1.37	1.76	2.59	89%
SLV	El Salvador	0.69	0.74	1.04	51%
SUR	Suriname	0.32	0.39	0.53	62%
URY	Uruguay	2.12	2.67	4.05	91%
VEN	Venezuela	12.00	13.74	18.42	54%
REGIONAL LAC		**164.99**	**193.73**	**263.72**	**60%**

Table 3 (cont): Water Demand for Agriculture, Energy and Water Supply and Sanitation (2015-2050), Reference Scenario

ENERGY WATER DEMAND					
		D (km3)	D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2025	2050	2015-2050
ARG	Argentina	2.40	2.86	3.67	53%
BLZ	Belize	0.01	0.01	0.02	53%
BOL	Bolivia	0.05	0.07	0.10	100%
BRA	Brazil	9.48	10.98	14.03	48%
CHL	Chile	1.80	2.18	3.00	66%
COL	Colombia	1.20	1.56	2.25	87%
CRI	Costa Rica	0.12	0.13	0.18	48%
DOM	Dom Rep	0.04	0.04	0.06	46%
ECU	Ecuador	0.40	0.49	0.71	77%
GTM	Guatemala	0.59	0.64	0.90	52%
GUY	Guyana	0.02	0.02	0.03	63%
HND	Honduras	0.13	0.14	0.20	52%
HTI	Haiti	0.08	0.08	0.12	51%
JAM	Jamaica	0.07	0.07	0.10	56%
MEX	Mexico	6.85	7.82	10.75	57%
NIC	Nicaragua	0.07	0.07	0.10	50%
PAN	Panama	0.03	0.03	0.05	51%
PER	Peru	0.27	0.35	0.49	83%
PRY	Paraguay	0.12	0.15	0.22	89%
SLV	El Salvador	0.10	0.11	0.15	51%
SUR	Suriname	0.10	0.12	0.17	62%
URY	Uruguay	0.05	0.07	0.10	91%
VEN	Venezuela	0.57	0.65	0.87	54%
REGIONAL LAC		**24.56**	**28.67**	**38.28**	**56%**

Table 3 (cont): Water Demand for Agriculture, Energy and Water Supply and Sanitation (2015-2050), Reference Scenario

WSS WATER DEMAND					
		D (km3)	D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2025	2050	2015-2050
ARG	Argentina	3.26	3.89	4.99	53%
BLZ	Belize	0.01	0.01	0.01	53%
BOL	Bolivia	0.18	0.25	0.37	100%
BRA	Brazil	15.17	17.58	22.45	48%
CHL	Chile	0.48	0.58	0.80	66%
COL	Colombia	2.59	3.35	4.85	87%
CRI	Costa Rica	0.36	0.38	0.53	48%
DOM	Dom Rep	0.75	0.80	1.10	46%
ECU	Ecuador	0.95	1.16	1.68	77%
GTM	Guatemala	0.82	0.88	1.24	52%
GUY	Guyana	0.05	0.06	0.08	63%
HND	Honduras	0.37	0.40	0.56	52%
HTI	Haiti	0.38	0.41	0.58	51%
JAM	Jamaica	0.13	0.15	0.21	56%
MEX	Mexico	10.58	12.09	16.62	57%
NIC	Nicaragua	0.21	0.22	0.31	50%
PAN	Panama	0.44	0.47	0.66	51%
PER	Peru	1.17	1.50	2.13	83%
PRY	Paraguay	0.28	0.36	0.53	89%
SLV	El Salvador	0.23	0.24	0.34	51%
SUR	Suriname	0.04	0.04	0.06	62%
URY	Uruguay	0.27	0.35	0.52	91%
VEN	Venezuela	3.68	4.21	5.65	54%
REGIONAL LAC		**42.41**	**49.40**	**66.28**	**56%**

The values of water demand can be used to estimate infrastructure needs to meet that demand, chiefly as water storage (reservoir volume needed), as well as provide estimated costs to build this infrastructure. A simple calculation procedure has been employed here, multiplying storage volume deficit, i.e., the difference between the currently-built storage volume and the estimated demand, at the country level, by a unit cost of storage, to obtain an estimate of investment costs of water infrastructure required to fill this deficit.

The unit cost used in these calculations is 1 USD/cubic meter of water storage. This value was found to be a conservative estimate (upper bound) over a review of costs of projects financed by the IDB and other sources and should be only seen as an approximation that would need to be refined based on more accurate estimations that are place-based.

The estimates of water storage infrastructure investment needs on a country basis through the year 2050 are included in **Appendix E**. The existing water storage infrastructure per country was obtained from the AquaStat database referenced earlier. Under the reference scenario simulated with GCAM (**Table 4**), water infrastructure investment needs to meet the projected demand in 2025 are found to be in the range of 24-31 billion USD, increasing to 43-57 billion USD in 2050. These investment values are all additional to the currently existing infrastructure.

Table 4: Water Storage Infrastructure Cost Estimate, Reference Scenario

	Reservoir	D (km3)	(R-D) km3	Est Cost	D (km3)	(R-D) km3	Est Cost
COUNTRY	**Capacity (R; km3)**	**2025**	**2025**	**2025**	**2050**	**2050**	**2050**
Argentina	131.60	24.51	107.10	0.00	31.44	100.17	0.00
Belize	0.12	0.06	0.06	0.00	0.08	0.04	0.00
Bolivia	0.60	3.74	-3.14	3.14	5.58	-4.98	4.98
Brazil	700.40	62.90	637.50	0.00	80.32	620.08	0.00
Chile	14.44	16.26	-1.82	1.82	22.40	-7.96	7.96
Colombia	11.28	11.69	-0.41	0.41	16.89	-5.61	5.61
Costa Rica	2.00	1.19	0.81	0.00	1.65	0.35	0.00
Dom Rep	2.30	3.02	-0.72	0.72	4.16	-1.86	1.86
Ecuador	7.70	8.92	-1.22	1.22	12.88	-5.18	5.18
Guatemala	0.46	3.51	-3.05	3.05	4.95	-4.49	4.49
Guyana	0.81	1.46	-0.65	0.65	1.96	-1.15	1.15
Honduras	5.80	2.02	3.78	0.00	2.85	2.95	0.00
Haiti	0.30	2.21	-1.91	1.91	3.10	-2.80	2.80
Jamaica	0.01	0.50	-0.49	0.49	0.72	-0.71	0.71
Mexico	150.00	85.56	64.44	0.00	117.56	32.44	0.00
Nicaragua	32.00	1.43	30.57	0.00	2.00	30.00	0.00
Panama	9.14	0.89	8.25	0.00	1.25	7.89	0.00
Peru	5.77	16.33	-10.56	10.56	23.25	-17.48	17.48
Paraguay	33.53	2.27	31.26	0.00	3.34	30.19	0.00
El Salvador	3.88	1.09	2.79	0.00	1.53	2.35	0.00
Suriname	20.00	0.56	19.44	0.00	0.75	19.25	0.00
Uruguay	17.20	3.09	14.11	0.00	4.67	12.53	0.00
Venezuela	157.60	18.60	139.00	0.00	24.94	132.66	0.00
	1306.94	**271.79**	**1035.14**	**23.96**	**368.28**	**938.65**	**52.23**

E. LIMITATIONS OF THIS ANALYSIS

Water security is understandably a highly complex problem, and the focus of this work is to provide a quantitative framework, through Integrated Assessment Modeling, to explore aspects and implications of the CLEWS nexus on this problem. There are necessarily resulting limitations on any exercise like this, and this section points to some of these limitation and potential further work along this line of research.

A first area of limitations has to do with the data used in this analysis. Data on future projections of water supply and demand for different climate and socioeconomic development scenarios generated through this analytical work need to be validated at the regional and country levels so they can provide reliable intelligence for water security assessment, planning and management purposes, particularly for the purposes of prioritizing investments in water infrastructure throughout the region.

The level of detail in the assessment of inventory and costing of infrastructure for water security in the LAC region is fairly simplified in this paper, and it should only be understood as illustrative of the CLEWS framework rather than a sophisticated approach to make this assessment. We have limited our analysis to an assessment of water storage infrastructure aggregated to the country level; this aspect of the work deserves more detailed analysis. Sustainable provision of water resources in a demographically and economically dynamic growing region like LAC hinges on adequate financing of water resources management infrastructure. Problems found here are widespread throughout the region as well, ranging from aging conveyance, drainage and treatment systems to inadequate operation and maintenance practices, energy efficiency, to insufficient and poor-quality data and decision support tools, to planning, design and financing of new facilities. Every year, destructive floods inflict harm and stifle development. Here too, the problems are largely present in poor regions of higher population density (e.g. Rio de Janeiro, Recife, São Paulo, Buenos Aires, Nicaragua and throughout Haiti). Inadequate infrastructure also affects lesser developed rural areas, which become more vulnerable to natural disaster events and climate change. There is a growing need to attract public and private investments to the sector and the correspondent generation of revenues to support the water security activities in a sustainable manner.

Another aspect worth mentioning, beyond of the scope of this analytical investigation, but of key importance nonetheless, is that the economic value of water is intrinsically linked to governance and management issues. Conventional wisdom in the LAC region dictates that the problem of water is not one of physical shortage but, rather, one of governance as indicated above. This is not entirely correct. The physical lack of surface or groundwater may not be an issue in many areas of the region, but the widespread notion that the LAC region is water-rich is far from accurate. For instance, two thirds of the region are classified as arid and semi-arid such as the center and northern part of Mexico, the Brazilian northeast, Argentina, Chile, Bolivia and Peru (IWMI, 2007). In fact, the problem is one of matching demand with supply, of ensuring that there is water at the right location, and the right time of year, and at a cost that people can afford and are willing to pay for. The difficulty in accomplishing this is partly institutional and certainly includes issues of governance. However, the problems of governance have to some extent an economic explanation, because the capital intensity and longevity of water and the significant economies of

scale create a need for collective action in the provision and financing of water supply, and the looming presence of fixed costs make cost allocation among individual beneficiaries highly problematic. In short, while there clearly are some distinctive emotive and symbolic features of water that make the demand for water different from most other commodities, there are also some distinctive physical and economic features that make the supply of water different and more complex than that of other goods (Hanemann, 2006). Sustainability of provision and as a consequence of service is tied to the adequate management of the upper watersheds adding a retinue of benefits to the water and sanitation value chain (OECD, 2011). The experience of financing IWRM at upper or whole watersheds varies from country to country and in cases of large countries like Brazil it may vary according to the diversity of the water users in the watershed (e.g., ANA, 2009) The revised methodologies do not take into consideration the intrinsic or value of no use of the water and neither the scarcity. The Nature Conservancy (TNC) has proposed a methodology that incorporates the value of scarcity, costs of upstream watershed conservation and payment for ecosystem services in the water tariffs in Latin America (TNC, 2013). The implementation of such approaches is still to be seen.

Across the LAC region, incipient or poorly funded water resources management institutions (e.g., ministries, national and local water authorities and river basin commissions) struggle with the finer details of water security challenges. Although many countries have made significant progress in institutional strengthening (e.g., Colombia, Brazil, Mexico, Peru, Venezuela), the need for further capacity building efforts is necessary to develop proactive actions to implement water resources management at the watershed level and address adaptation to climate change. Furthermore, even though most of the LAC countries have developed water resources legislation tuned to the idea of water security using the watershed as management unit (Brazil, Peru, Mexico etc), there is still a need to consolidate the concept in some countries and to harmonize water resources with environmental legislation and the respective institutional responsibilities (e.g., Brazil, Panama, Argentina). Lack of clear responsibilities and effective coordination between institutions have been the causes for poor implementation of many water resources management projects in LAC, which in most cases is due to a lack of an integrated, multi-sectoral and cutting-edge approach by decisions makers when planning water resources and designing the related water infrastructure. In addition, there is a need to strength the technical capacity of institutions and sector’s decision makers (human and technical resources).

While problems of water availability afflict a subset of countries in semi-arid and arid regions, problems of poor water quality afflict widely all countries of the region. Many more insidious problems exist as well, revealed in degraded freshwater that constantly undermines public health, threatens the ecological integrity and the very life support ecosystems on which people of the region depend, e.g., wetlands in the Amazon river basin and a large fraction of the Atlantic and Pacific coastlines of countries in the region. Examples include pollution caused by inadequate wastewater disposal system, groundwater pollution due to agricultural and industrial practices and salinization of near coastal aquifers. The urban rivers of the Region’s metropolis are heavily polluted by untreated or poorly treated sewage, urban runoff and improper solid waste disposal. Urban rivers Such as Tiete in São Paulo, Guaire in Caracas, Bogotá in Bogotá, Rimac in Lima, Reconquista y Matanza-Riachuelo in Buenos Aires represent a complex challenge for action since it requires efficient management of the upper watershed, extensive coordination between

institutions and different levels of governments, revision of urban planning paradigms, expensive engineering solutions and clever financing mechanisms to regain their quality and ability to supply water for different uses including scenic appreciation by the population. This is an aspect not covered in this work, but that merits further investigation as it is also related to the CLEWS nexus.

F. CONCLUDING REMARKS

This working paper presents an up-to-date and prospective assessment of water security throughout the LAC region. with a focus on infrastructure needs, to aid in strategic thinking towards planning and management in key water-using sectors such as water supply and sanitation, energy and agriculture. This assessment is grounded on a physically-based analysis of water supply and demand, highlights the multi-sector CLEWS nexus contributions to water security in the region, and addresses uncertainty in projections and their implications through a variety of potential future scenarios of climate change and socioeconomic development in the region.

The focus of this work shifts from the traditional concept of water security based on availability of water resources, to one focused on water security based on infrastructure for access and efficient use of water in adequate quantity and quality for various sectors, e.g., agricultural production, water supply and sanitation, and energy generation. This distinction is particularly important for the LAC region, as results of this analysis (as well as many other studies) show that the region is relatively well endowed with water resources, so water security then hinges on the availability of infrastructure to make use of this water in a sustainable way, with resiliency to a broad and varied set of physical (e.g., climate change), social (e.g., population and land use change) and economic (e.g., development and policy intervention) conditions.

The analytical work supporting the finding documented in this working paper is based on the application of an Integrated Assessment Model (GCAM: Global Change Assessment Model) to quantify these impacts for a wide range of scenarios of socioeconomic development that offer a mix of possible futures for the availability, use and management of water resources. The understanding gained through this analysis is expected to contribute to the ongoing dialog on sustainability among the multiple human activities and their trajectories towards global development pathways. Through this research and analysis, this working paper provides an integrated qualitative and quantitative understanding of the implications of several selected potential future scenarios for water security, including climate change and mitigation, socioeconomic and technological developments, and water demand for water-energy-food interactions at the country level and within a regional context.

A key finding that can be extracted from these results is that at a regional scale, water availability, expressed as a combination of surface runoff and renewable groundwater, will not vary significantly over the next decades. While the total available water volume may not vary as a whole, the spatial distribution across the region does show some variations worth noting among and within countries.

In general, water scarcity projection results show different trends throughout the LAC region; in some parts of the region, water availability (expressed as runoff plus renewable groundwater) may increase over time, while in other parts of the region the trend is decreasing. This is reasonable to be expected given the combination of changes in rainfall and temperature, and the dynamics of different biomes across the region, i.e., coastal areas, high mountain Andean glaciers, wetlands, dry savannas and other ecosystems. The WSI results appear to be fairly consistent among the 3 climate models used, suggesting that water scarcity is dominated by water demands rather than by the climate-influenced water availability (surface and groundwater). It appears that severe and moderate water scarcity advances within the next few decades (i.e., between now and 2050), in countries where water is already somewhat scarce. Notably, water security appears to severely threatened in Mexico, Chile, Hispaniola (Dominican Republic and Haiti) and to a lesser degree in Nicaragua and El Salvador.

These findings imply that water security at the regional level is not dominated by water availability (nor factors affecting it such as climate and land use changes), but rather by demand (which is population and use driven). So, water security in the LAC region is a management and access (through infrastructure and improved policies for water management) problem for the most part and not a physical scarcity problem. A large part of this management problem is developing and investing in the necessary infrastructure to deliver water for this growing demand, in an efficient and sustainable way. Even in countries with notable water availability variations such as Brazil, Chile and Mexico, investments in infrastructure combined with demand-based measures in water scarce locations, can provide water security and higher reliability of supply systems.

The values of projected demand under different scenarios were used in this work to assess water infrastructure needs at the country level for different development trajectories over the next few decades. The results obtained suggest investment needs in the region of approximately 40-60 billion USD towards 2050, while increasing to different degrees depending on socioeconomic trajectories thereafter. Even though the range of investment needs found in this work vary in a wide range, the value of these investments is relatively manageable when compared to national budgets, investment needs in other infrastructure areas and international financing available. These infrastructure needs can be used to evaluate existing gaps in infrastructure in the different sectors and prioritize investments based on needs, gaps and national priorities in food production, energy generation and water and sanitation.

Data on future projections of water supply and demand for different climate and socioeconomic development scenarios generated through this analytical work need to be validated at the regional and country levels so they can provide reliable intelligence for water security assessment, planning and management purposes, particularly for the purposes of prioritizing investments in water infrastructure throughout the region.

It is important to note that although infrastructure needs are broken down here into sectors, the analysis that led to these estimates is based on a multi-sector CLEWS nexus approach between that is at the core of the methodology employed by GCAM in computing supply and demand of water. This is an important distinction contributed by this work compared to traditional single-sector approaches to assess projected water demands and the associated infrastructure needs.

By providing an economic quantitative framework for integrated analysis of water supply and demand, multiple demand sectors, climate inputs, and other forcing factors such as land use change, policy interventions and technological developments, IAMs such as GCAM provide a viable tool to explore additional issues related to water security such as the CLEWS nexus. Further research along these lines can be focused on such issues as: (i) the implications of groundwater availability and changes in pumping costs on future water supply and its effect on urban services, energy and food security; (ii) the repercussions of removing existing distortions (i.e., subsidies) in water availability and distribution in the future; (iii) the economic costs (of inaction) of non-cooperation across basins/countries/regions and the potential benefits of cooperation; (iv) quantify tradeoffs in water availability and its impact on major economic sectors; (v) define effective adaptation strategies/investments that are necessary to mitigate the lessen water scarcity and stress; (vi) identify and plan key investments at regional and country levels to address economic water scarcity.

This working paper has been written to reach a broad audience. In addition to serving as a guide for strategic thinking purposes within the Bank, the document can be used as input to the Bank's dialog with countries in LAC, as well as sector strategies at the regional and country levels, done either by the Bank or its government clients in the region. It can serve as a reference to other units across the Bank with interests in water resources in the LAC region, and as a potential template to conduct similar analyses in other regions of the world. For the reader outside of the Bank, across sectors and a variety of institutions and organizations, this document aims to provide insight into water security issues in the LAC region, particularly with a focus on infrastructure needs and within a multi-sector "nexus" perspective.

As highlighted in this work, water security encapsulates complex and interconnected challenges and highlights the importance of water in achieving a larger sense of security, sustainability, development and human well-being. Many factors contribute to water security, ranging from biophysical to infrastructural, institutional, political, social and financial, many of which lie outside the water space. In this respect, water security lies at the center of many other security areas, e.g., energy, food, environmental, each of which is intricately linked to water. Management and investment approaches must incorporate a goal and related targets for achieving water security, as this will address multiple priority development areas of pressing interest: conflict and fragility; environmental sustainability; growth and employment; health, hunger, food and nutrition; inequities; energy, among others.

In a region such as LAC with relative abundance of water resources, several issues that have not yet been resolved with respect to water security relate to the development, planning and management aspects of water infrastructure. These include the economic assessment of ecosystem services in relation to the availability and regulation of water resources, the establishment of ecological flows, groundwater management (particularly at the transboundary level), water property right regimes, the scope and restrictions for sharing water among users within or between watersheds, valuation and pricing of water, multipurpose storage, infrastructure investments for producing water for different uses, taking the impacts of climate change into account in the design and operation of water infrastructure, the location of water in transboundary

watersheds, and variability in the quality and availability of water. Such areas require more information gathering, research, and analytical work.

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H. APPENDICES

Appendix A: Runoff distribution in the LAC region for the period 2015-2050

Appendix B: Water demand in the LAC region for the period 2015-2050

Appendix C: Water Scarcity Index (WSI) in the LAC region for the period 2015-2050 for SSP Scenarios

Appendix D: Values of Demand (D) and gap between Supply (S) and Demand in the LAC region for the period 2015-2050

Appendix E: Water Storage Infrastructure Cost Estimate for SSP Scenarios

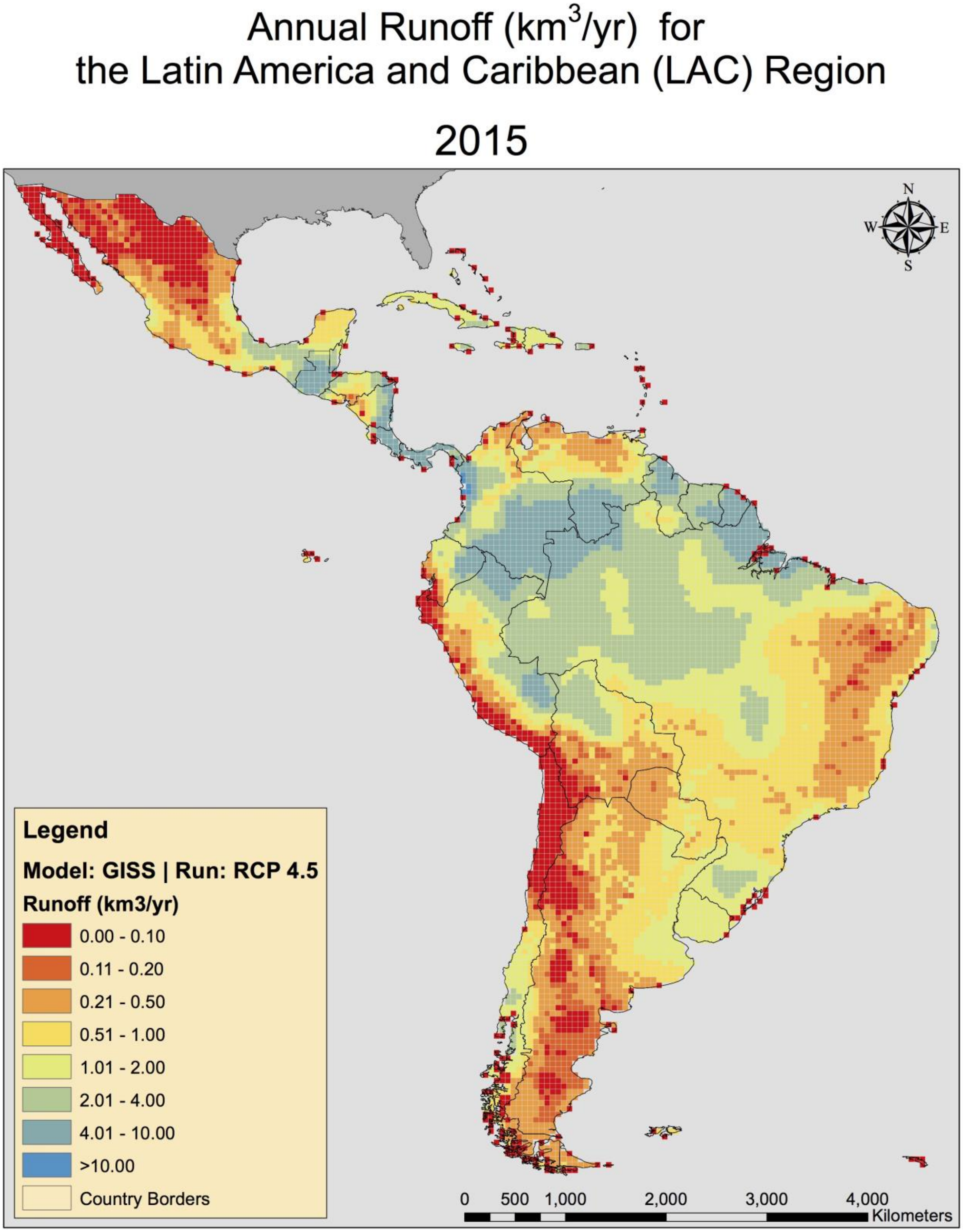

Figure A-1: Runoff distribution in the LAC region for the period 2015-2050 (RCP4.5).

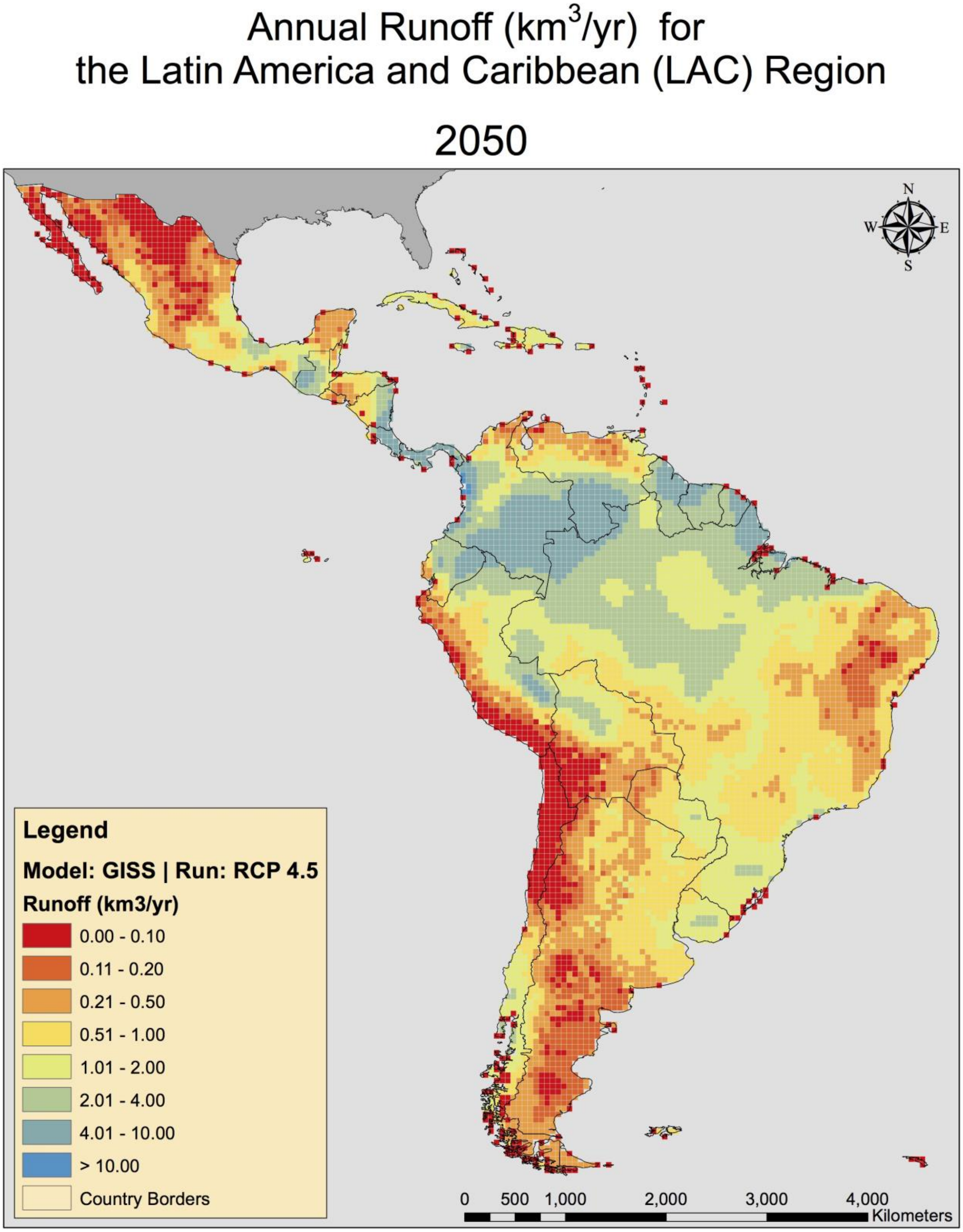

Figure A-2: Runoff distribution in the LAC region for the period 2015-2050 (RCP4.5).

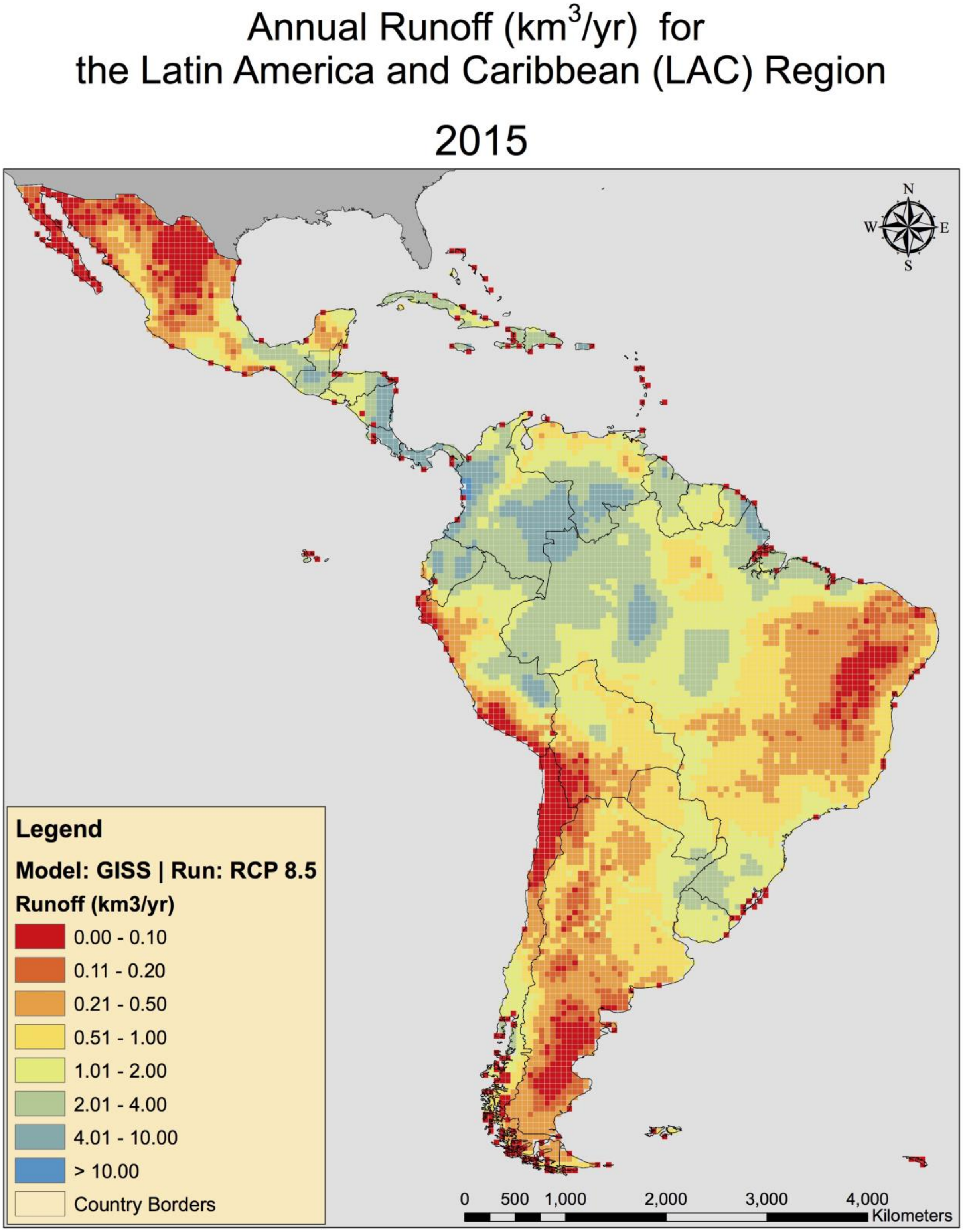

Figure A-3: Runoff distribution in the LAC region for the period 2015-2050 (RCP6.0).

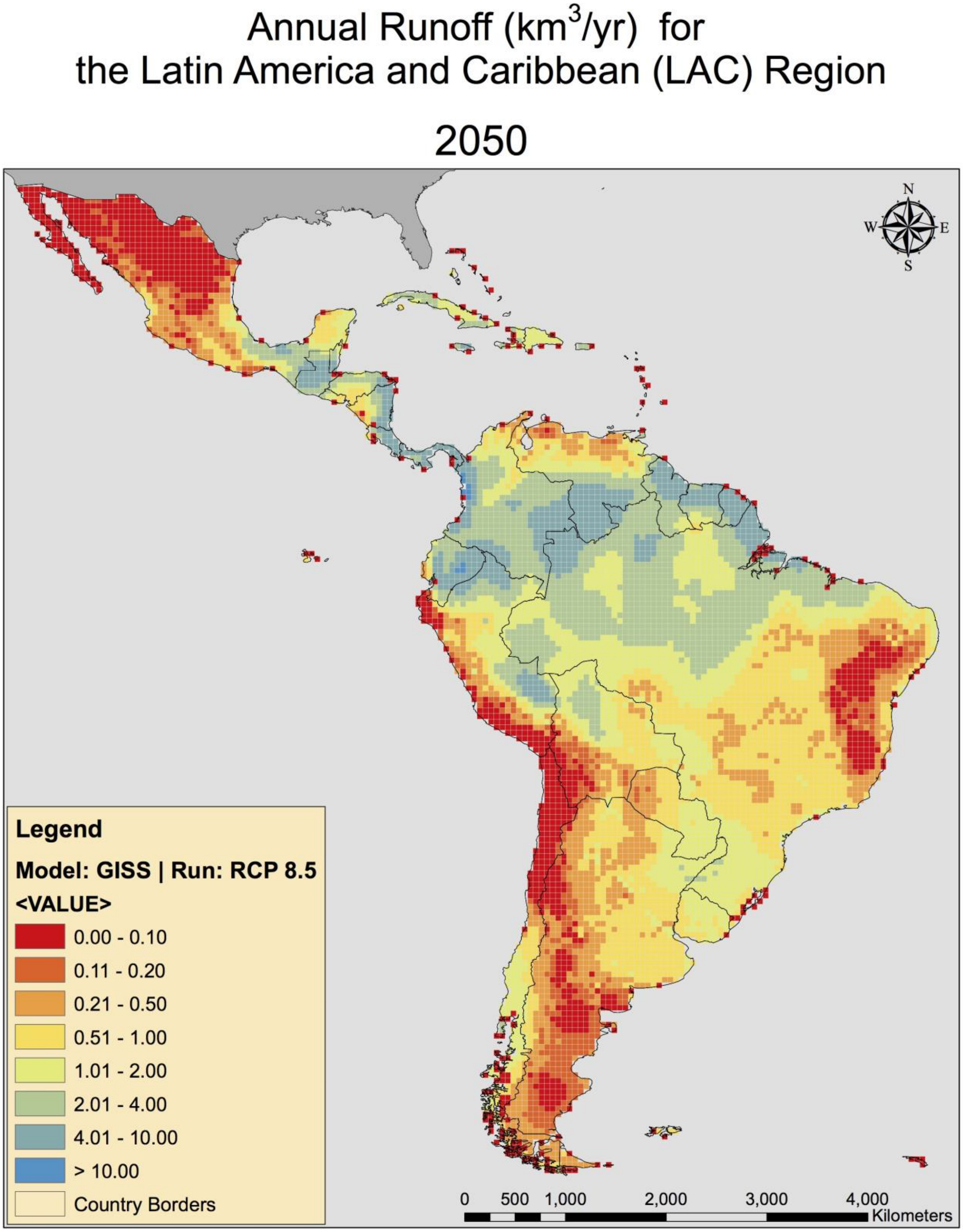

Figure A-4: Runoff distribution in the LAC region for the period 2015-2050 (RCP6.0).

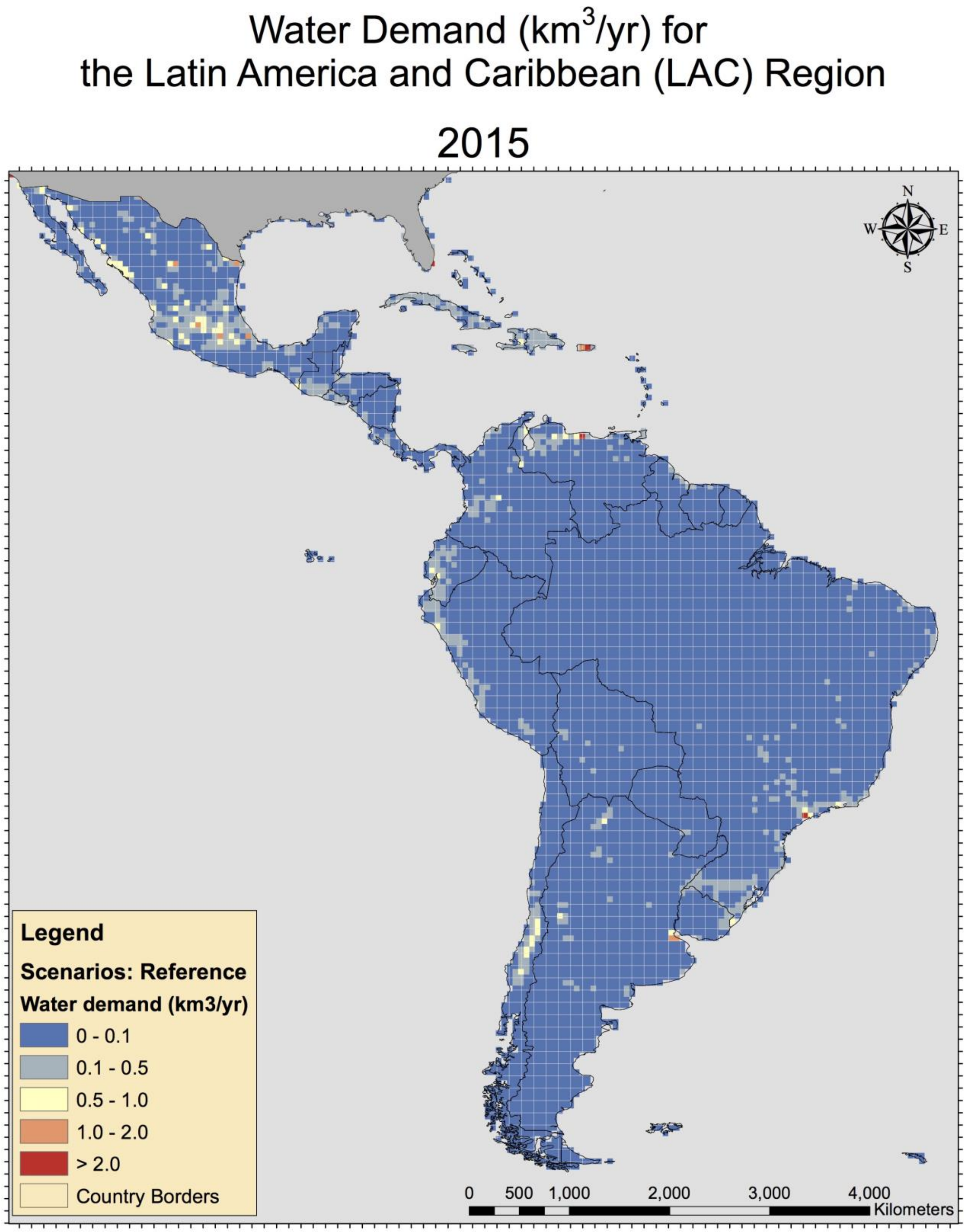

Figure B-1: Water demand in the LAC region for the period 2015-2050.

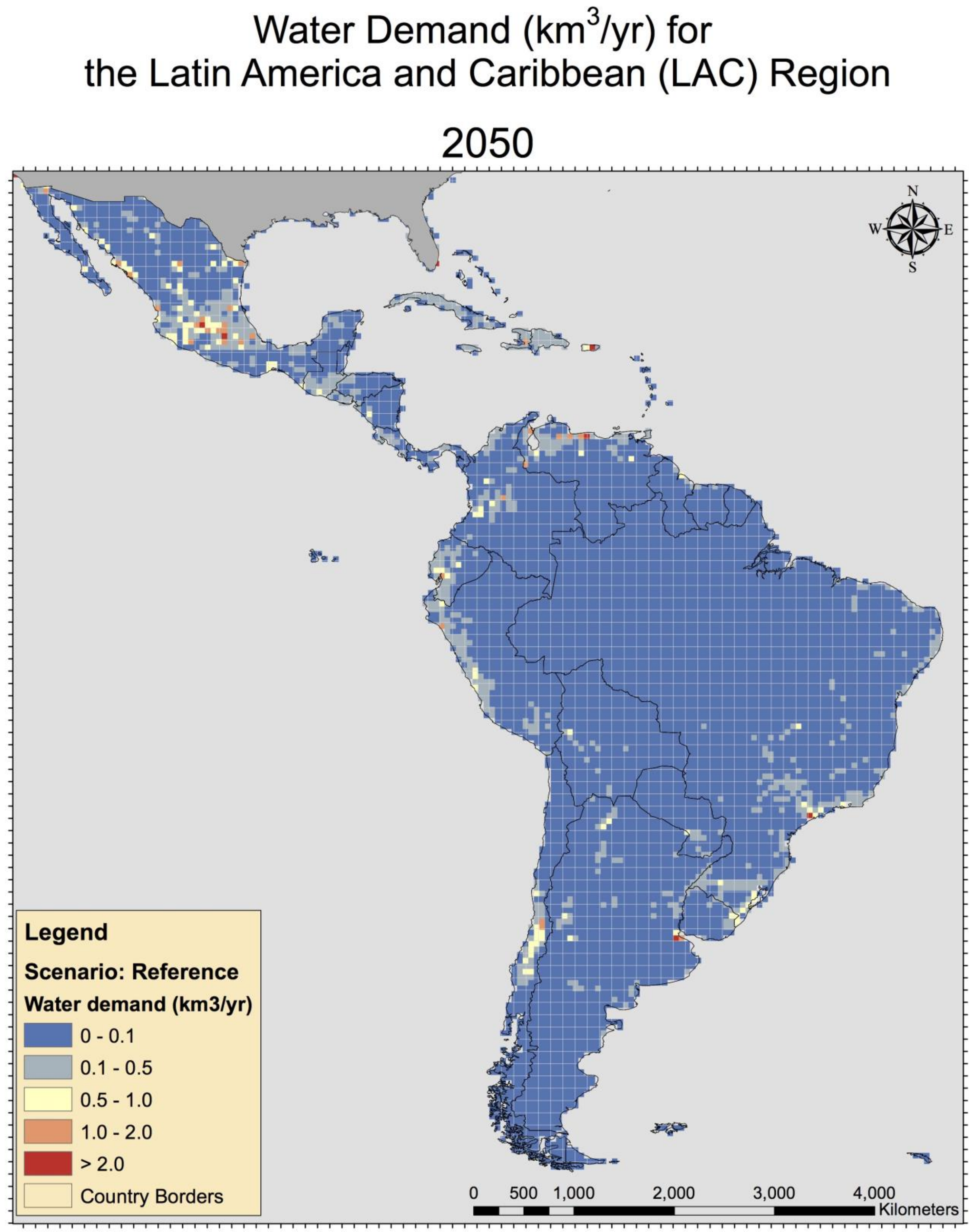

Figure B-2: Water demand in the LAC region for the period 2015-2050.

Figure C-1: Water Scarcity Index (WSI) in the LAC region for the period 2015-2050; Scenario SSP1.

Water Scarcity Index (WSI) for the Latin America and Caribbean (LAC) Region

2050

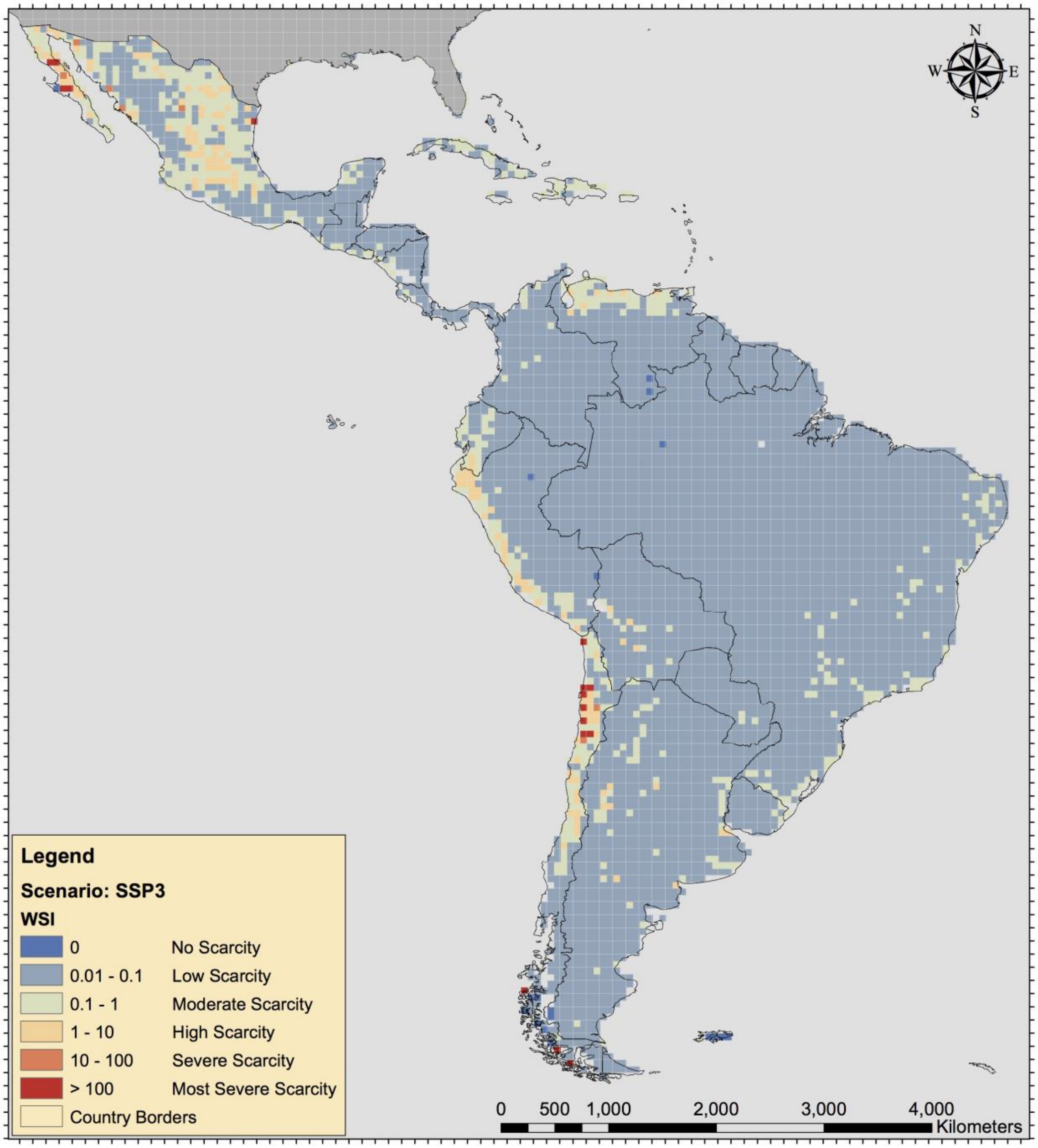

Figure C-2: Water Scarcity Index (WSI) in the LAC region for the period 2015-2050; Scenario SSP3.

Figure C-3: Water Scarcity Index (WSI) in the LAC region for the period 2015-2050; Scenario SSP4.

Figure C-4: Water Scarcity Index (WSI) in the LAC region for the period 2015-2050; Scenario SSP5.

Table D-1: Values of Demand (D) and gap between Supply (S) and Demand in the LAC Region for the Period 2015-2050; Scenario SSP1.

TOTAL WATER DEMAND				
		D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2050	2015-2050
ARG	Argentina	21.59	28.39	31%
BLZ	Belize	0.06	0.08	46%
BOL	Bolivia	3.12	5.32	70%
BRA	Brazil	57.63	75.32	31%
CHL	Chile	13.93	19.77	42%
COL	Colombia	9.92	14.57	47%
CRI	Costa Rica	1.15	1.62	41%
DOM	Dom Rep	2.90	4.05	40%
ECU	Ecuador	7.72	11.23	46%
GTM	Guatemala	3.41	4.95	45%
GUY	Guyana	1.31	1.59	21%
HND	Honduras	1.95	2.83	45%
HTI	Haiti	2.14	3.10	44%
JAM	Jamaica	0.49	0.73	49%
MEX	Mexico	78.95	116.02	47%
NIC	Nicaragua	1.39	2.00	44%
PAN	Panama	0.86	1.24	44%
PER	Peru	14.15	21.97	55%
PRY	Paraguay	1.94	2.91	50%
SLV	El Salvador	1.06	1.54	45%
SUR	Suriname	0.51	0.63	24%
URY	Uruguay	2.65	3.99	50%
VEN	Venezuela	17.40	22.28	28%
REGIONAL LAC		**246.22**	**346.09**	**41%**

Table D-2: Values of Demand (D) and gap between Supply (S) and Demand in the LAC Region for the Period 2015-2100; Scenario SSP2.

TOTAL WATER DEMAND				
		D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2050	2015-2050
ARG	Argentina	21.65	30.42	41%
BLZ	Belize	0.06	0.09	61%
BOL	Bolivia	3.12	5.77	85%
BRA	Brazil	58.06	80.20	38%
CHL	Chile	14.11	22.63	60%
COL	Colombia	10.04	16.49	64%
CRI	Costa Rica	1.15	1.78	55%
DOM	Dom Rep	2.91	4.47	53%
ECU	Ecuador	7.76	12.60	62%
GTM	Guatemala	3.42	5.48	60%
GUY	Guyana	1.31	1.86	42%
HND	Honduras	1.96	3.13	60%
HTI	Haiti	2.15	3.42	59%
JAM	Jamaica	0.49	0.81	65%
MEX	Mexico	79.22	123.67	56%
NIC	Nicaragua	1.39	2.21	58%
PAN	Panama	0.86	1.38	59%
PER	Peru	14.04	23.41	67%
PRY	Paraguay	1.96	3.27	66%
SLV	El Salvador	1.07	1.70	60%
SUR	Suriname	0.51	0.73	44%
URY	Uruguay	2.67	4.48	68%
VEN	Venezuela	17.50	25.37	45%
REGIONAL LAC		**247.42**	**375.36**	**52%**

Table D-3: Values of Demand (D) and gap between Supply (S) and Demand in the LAC Region for the Period 2015-2100; Scenario SSP3.

TOTAL WATER DEMAND				
		D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2050	2015-2050
ARG	Argentina	21.51	30.46	42%
BLZ	Belize	0.06	0.09	62%
BOL	Bolivia	3.10	5.72	85%
BRA	Brazil	57.93	80.69	39%
CHL	Chile	14.17	24.36	72%
COL	Colombia	10.09	17.33	72%
CRI	Costa Rica	1.16	1.81	57%
DOM	Dom Rep	2.93	4.57	56%
ECU	Ecuador	7.73	13.26	72%
GTM	Guatemala	3.43	5.50	60%
GUY	Guyana	1.31	2.18	67%
HND	Honduras	1.97	3.16	60%
HTI	Haiti	2.16	3.43	59%
JAM	Jamaica	0.49	0.80	64%
MEX	Mexico	78.85	124.32	58%
NIC	Nicaragua	1.40	2.22	59%
PAN	Panama	0.87	1.39	60%
PER	Peru	13.84	23.47	70%
PRY	Paraguay	1.97	3.35	70%
SLV	El Salvador	1.07	1.70	59%
SUR	Suriname	0.50	0.84	67%
URY	Uruguay	2.66	4.77	79%
VEN	Venezuela	17.61	28.96	64%
REGIONAL LAC		**246.79**	**384.39**	**56%**

Table D-4: Values of Demand (D) and gap between Supply (S) and Demand in the LAC Region for the Period 2015-2100; Scenario SSP4.

TOTAL WATER DEMAND				
		D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2050	2015-2050
ARG	Argentina	21.84	29.11	33%
BLZ	Belize	0.06	0.09	49%
BOL	Bolivia	3.16	5.45	72%
BRA	Brazil	58.68	78.71	34%
CHL	Chile	14.22	21.17	49%
COL	Colombia	10.20	16.34	60%
CRI	Costa Rica	1.17	1.70	45%
DOM	Dom Rep	2.96	4.30	45%
ECU	Ecuador	7.86	12.46	59%
GTM	Guatemala	3.47	5.11	47%
GUY	Guyana	1.34	1.92	44%
HND	Honduras	1.99	2.95	48%
HTI	Haiti	2.18	3.20	47%
JAM	Jamaica	0.50	0.74	50%
MEX	Mexico	79.42	117.08	47%
NIC	Nicaragua	1.41	2.07	47%
PAN	Panama	0.88	1.29	48%
PER	Peru	14.20	22.68	60%
PRY	Paraguay	1.99	3.27	64%
SLV	El Salvador	1.08	1.59	47%
SUR	Suriname	0.52	0.73	42%
URY	Uruguay	2.73	4.71	73%
VEN	Venezuela	17.70	24.06	36%
REGIONAL LAC		**249.54**	**360.72**	**45%**

Table D-5: Values of Demand (D) and gap between Supply (S) and Demand in the LAC Region for the Period 2015-2100; Scenario SSP5.

TOTAL WATER DEMAND				
		D (km3)	D (km3)	Total Change
ISO	COUNTRY	2015	2050	2015-2050
ARG	Argentina	21.87	31.89	46%
BLZ	Belize	0.06	0.10	69%
BOL	Bolivia	3.18	6.11	92%
BRA	Brazil	58.24	88.63	52%
CHL	Chile	14.17	22.24	57%
COL	Colombia	10.04	17.90	78%
CRI	Costa Rica	1.16	1.86	61%
DOM	Dom Rep	2.92	4.63	59%
ECU	Ecuador	7.84	12.92	65%
GTM	Guatemala	3.44	5.81	69%
GUY	Guyana	1.32	1.80	36%
HND	Honduras	1.97	3.30	67%
HTI	Haiti	2.16	3.62	67%
JAM	Jamaica	0.49	0.87	76%
MEX	Mexico	79.98	128.92	61%
NIC	Nicaragua	1.40	2.34	67%
PAN	Panama	0.87	1.45	67%
PER	Peru	14.34	24.92	74%
PRY	Paraguay	1.98	3.42	73%
SLV	El Salvador	1.07	1.80	68%
SUR	Suriname	0.51	0.73	42%
URY	Uruguay	2.69	4.45	65%
VEN	Venezuela	17.55	27.05	54%
REGIONAL LAC		**249.24**	**396.73**	**59%**

Table E-1: Water Storage Infrastructure Cost Estimate, Scenario SSP1

COUNTRY	Reservoir Capacity (km3)	D (km3) 2025	(R-D) km3 2025	Est Cost 2025	D (km3) 2050	(R-D) km3 2050	Est Cost 2050
Argentina	131.60	24.67	106.93	0.00	28.39	103.21	0.00
Belize	0.12	0.06	0.06	0.00	0.08	0.04	0.00
Bolivia	0.60	4.12	-3.52	3.52	5.32	-4.72	4.72
Brazil	700.40	66.90	633.50	0.00	75.32	625.08	0.00
Chile	14.44	16.68	-2.24	2.24	19.77	-5.33	5.33
Colombia	11.28	11.52	-0.24	0.24	14.57	-3.29	3.29
Costa Rica	2.00	1.28	0.72	0.00	1.62	0.38	0.00
Dom Rep	2.30	3.21	-0.91	0.91	4.05	-1.75	1.75
Ecuador	7.70	9.30	-1.60	1.60	11.23	-3.53	3.53
Guatemala	0.46	3.86	-3.40	3.40	4.95	-4.49	4.49
Guyana	0.81	1.53	-0.72	0.72	1.59	-0.78	0.78
Honduras	5.80	2.20	3.60	0.00	2.83	2.97	0.00
Haiti	0.30	2.42	-2.12	2.12	3.10	-2.80	2.80
Jamaica	0.01	0.56	-0.55	0.55	0.73	-0.72	0.72
Mexico	150.00	93.15	56.85	0.00	116.02	33.98	0.00
Nicaragua	32.00	1.57	30.43	0.00	2.00	30.00	0.00
Panama	9.14	0.97	8.17	0.00	1.24	7.90	0.00
Peru	5.77	18.19	-12.42	12.42	21.97	-16.20	16.20
Paraguay	33.53	2.29	31.24	0.00	2.91	30.62	0.00
El Salvador	3.88	1.20	2.68	0.00	1.54	2.34	0.00
Suriname	20.00	0.58	19.42	0.00	0.63	19.37	0.00
Uruguay	17.20	3.16	14.04	0.00	3.99	13.21	0.00
Venezuela	157.60	19.34	138.26	0.00	22.28	135.32	0.00
	1306.94	**288.75**	**1018.19**	**27.71**	**346.09**	**960.84**	**43.60**

Table E-2: Water Storage Infrastructure Cost Estimate, Scenario SSP2

	Reservoir	D (km3)	(R-D) km3	Est Cost	D (km3)	(R-D) km3	Est Cost
COUNTRY	Capacity (km3)	2025	2025	2025	2050	2050	2050
Argentina	131.60	25.02	106.58	0.00	30.42	101.18	0.00
Belize	0.12	0.07	0.05	0.00	0.09	0.03	0.00
Bolivia	0.60	4.13	-3.53	3.53	5.77	-5.17	5.17
Brazil	700.40	68.47	631.93	0.00	80.20	620.20	0.00
Chile	14.44	17.38	-2.94	2.94	22.63	-8.19	8.19
Colombia	11.28	12.07	-0.79	0.79	16.49	-5.21	5.21
Costa Rica	2.00	1.32	0.68	0.00	1.78	0.22	0.00
Dom Rep	2.30	3.33	-1.03	1.03	4.47	-2.17	2.17
Ecuador	7.70	9.51	-1.81	1.81	12.60	-4.90	4.90
Guatemala	0.46	3.98	-3.52	3.52	5.48	-5.02	5.02
Guyana	0.81	1.55	-0.74	0.74	1.86	-1.05	1.05
Honduras	5.80	2.27	3.53	0.00	3.13	2.67	0.00
Haiti	0.30	2.49	-2.19	2.19	3.42	-3.12	3.12
Jamaica	0.01	0.58	-0.57	0.57	0.81	-0.80	0.80
Mexico	150.00	94.63	55.37	0.00	123.67	26.33	0.00
Nicaragua	32.00	1.62	30.38	0.00	2.21	29.79	0.00
Panama	9.14	1.00	8.14	0.00	1.38	7.77	0.00
Peru	5.77	17.81	-12.04	12.04	23.41	-17.64	17.64
Paraguay	33.53	2.39	31.14	0.00	3.27	30.26	0.00
El Salvador	3.88	1.24	2.64	0.00	1.70	2.18	0.00
Suriname	20.00	0.59	19.41	0.00	0.73	19.27	0.00
Uruguay	17.20	3.25	13.95	0.00	4.48	12.72	0.00
Venezuela	157.60	19.87	137.73	0.00	25.37	132.23	0.00
	1306.94	**294.53**	**1012.41**	**29.14**	**375.36**	**931.57**	**53.27**

Table E-3: Water Storage Infrastructure Cost Estimate, Scenario SSP3

	Reservoir	D (km3)	(R-D) km3	Est Cost	D (km3)	(R-D) km3	Est Cost
COUNTRY	Capacity (km3)	2025	2025	2025	2050	2050	2050
Argentina	131.60	24.82	106.78	0.00	30.46	101.14	0.00
Belize	0.12	0.07	0.05	0.00	0.09	0.03	0.00
Bolivia	0.60	4.06	-3.46	3.46	5.72	-5.12	5.12
Brazil	700.40	68.62	631.79	0.00	80.69	619.71	0.00
Chile	14.44	17.75	-3.31	3.31	24.36	-9.92	9.92
Colombia	11.28	12.42	-1.14	1.14	17.33	-6.05	6.05
Costa Rica	2.00	1.35	0.65	0.00	1.81	0.19	0.00
Dom Rep	2.30	3.42	-1.12	1.12	4.57	-2.27	2.27
Ecuador	7.70	9.55	-1.85	1.85	13.26	-5.56	5.56
Guatemala	0.46	4.06	-3.60	3.60	5.50	-5.04	5.04
Guyana	0.81	1.57	-0.76	0.76	2.18	-1.37	1.37
Honduras	5.80	2.32	3.48	0.00	3.16	2.64	0.00
Haiti	0.30	2.54	-2.24	2.24	3.43	-3.13	3.13
Jamaica	0.01	0.59	-0.58	0.58	0.80	-0.80	0.80
Mexico	150.00	94.41	55.59	0.00	124.32	25.68	0.00
Nicaragua	32.00	1.65	30.35	0.00	2.22	29.78	0.00
Panama	9.14	1.02	8.12	0.00	1.39	7.75	0.00
Peru	5.77	17.26	-11.49	11.49	23.47	-17.70	17.70
Paraguay	33.53	2.42	31.11	0.00	3.35	30.18	0.00
El Salvador	3.88	1.26	2.62	0.00	1.70	2.18	0.00
Suriname	20.00	0.60	19.40	0.00	0.84	19.16	0.00
Uruguay	17.20	3.30	13.90	0.00	4.77	12.43	0.00
Venezuela	157.60	20.45	137.15	0.00	28.96	128.64	0.00
	1306.94	**295.52**	**1011.41**	**29.55**	**384.39**	**922.54**	**56.96**

Table E-4: Water Storage Infrastructure Cost Estimate, Scenario SSP4

COUNTRY	Reservoir Capacity (km3)	D (km3) 2025	(R-D) km3 2025	Est Cost 2025	D (km3) 2050	(R-D) km3 2050	Est Cost 2050
Argentina	131.60	25.12	106.48	0.00	29.11	102.50	0.00
Belize	0.12	0.07	0.05	0.00	0.09	0.03	0.00
Bolivia	0.60	4.14	-3.54	3.54	5.45	-4.85	4.85
Brazil	700.40	69.49	630.91	0.00	78.71	621.69	0.00
Chile	14.44	17.25	-2.81	2.81	21.17	-6.73	6.73
Colombia	11.28	12.41	-1.13	1.13	16.34	-5.06	5.06
Costa Rica	2.00	1.34	0.66	0.00	1.70	0.30	0.00
Dom Rep	2.30	3.38	-1.08	1.08	4.30	-2.00	2.00
Ecuador	7.70	9.70	-2.00	2.00	12.46	-4.76	4.76
Guatemala	0.46	4.00	-3.54	3.54	5.11	-4.65	4.65
Guyana	0.81	1.63	-0.82	0.82	1.92	-1.11	1.11
Honduras	5.80	2.29	3.51	0.00	2.95	2.85	0.00
Haiti	0.30	2.51	-2.21	2.21	3.20	-2.90	2.90
Jamaica	0.01	0.58	-0.57	0.57	0.74	-0.74	0.74
Mexico	150.00	93.38	56.62	0.00	117.08	32.92	0.00
Nicaragua	32.00	1.63	30.37	0.00	2.07	29.93	0.00
Panama	9.14	1.01	8.13	0.00	1.29	7.85	0.00
Peru	5.77	17.95	-12.18	12.18	22.68	-16.91	16.91
Paraguay	33.53	2.44	31.09	0.00	3.27	30.26	0.00
El Salvador	3.88	1.24	2.64	0.00	1.59	2.29	0.00
Suriname	20.00	0.62	19.38	0.00	0.73	19.27	0.00
Uruguay	17.20	3.42	13.79	0.00	4.71	12.49	0.00
Venezuela	157.60	20.08	137.52	0.00	24.06	133.54	0.00
	1306.94	**295.67**	**1011.26**	**29.88**	**360.72**	**946.21**	**49.71**

Table F-5: Water Storage Infrastructure Cost Estimate, Scenario SSP5

COUNTRY	Reservoir Capacity (km3)	D (km3) 2025	(R-D) km3 2025	Est Cost 2025	D (km3) 2050	(R-D) km3 2050	Est Cost 2050
Argentina	131.60	25.60	106.00	0.00	31.89	99.71	0.00
Belize	0.12	0.07	0.05	0.00	0.10	0.02	0.00
Bolivia	0.60	4.34	-3.74	3.74	6.11	-5.51	5.51
Brazil	700.40	69.60	630.80	0.00	88.63	611.77	0.00
Chile	14.44	17.50	-3.06	3.06	22.24	-7.80	7.80
Colombia	11.28	12.08	-0.80	0.80	17.90	-6.62	6.62
Costa Rica	2.00	1.32	0.68	0.00	1.86	0.14	0.00
Dom Rep	2.30	3.32	-1.02	1.02	4.63	-2.33	2.33
Ecuador	7.70	9.74	-2.04	2.04	12.92	-5.22	5.22
Guatemala	0.46	4.02	-3.56	3.56	5.81	-5.35	5.35
Guyana	0.81	1.56	-0.75	0.75	1.80	-0.99	0.99
Honduras	5.80	2.28	3.52	0.00	3.30	2.50	0.00
Haiti	0.30	2.51	-2.21	2.21	3.62	-3.32	3.32
Jamaica	0.01	0.58	-0.58	0.58	0.87	-0.86	0.86
Mexico	150.00	96.70	53.30	0.00	128.92	21.08	0.00
Nicaragua	32.00	1.63	30.37	0.00	2.34	29.66	0.00
Panama	9.14	1.01	8.13	0.00	1.45	7.69	0.00
Peru	5.77	18.97	-13.20	13.20	24.92	-19.15	19.15
Paraguay	33.53	2.42	31.11	0.00	3.42	30.11	0.00
El Salvador	3.88	1.25	2.63	0.00	1.80	2.08	0.00
Suriname	20.00	0.60	19.40	0.00	0.73	19.27	0.00
Uruguay	17.20	3.28	13.92	0.00	4.45	12.75	0.00
Venezuela	157.60	19.94	137.66	0.00	27.05	130.55	0.00
	1306.94	**300.30**	**1006.64**	**30.95**	**396.73**	**910.20**	**57.15**