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Environmental Security Risks in South America:

The Expectations and Implications of a Changing Climate

By K.R. Miner, PhD

INTRODUCTION

Continental-scale risks from climate change affect both regional communities and country dynamics across the world, with climate models forecasting an average global temperature rise of more than 1.5 degrees Celsius. This rise in global temperatures may increase South American environmental security risks through sea level rise, changing weather patterns, and extreme storms—ultimately influencing the security and health of citizens.

Over the course of the next several decades, impacts to ecosystems from climate destabilization are likely to become significant throughout the Western Hemisphere, diminishing biodiversity and natural resources. The numerous and varied natural environments found within South America, could face loss to ecosystem services or structure as climate change alters fragile ecosystems. These diverse and critical ecosystems include tropical rainforests, temperate deserts, subtropical dry forests and high-mountains.

South American biome environments span multiple countries and support a variety of diverse flora and fauna. The sustainable functioning of each of these natural environments is required to produce clean water, air and food for the population, as well as natural protection from extreme storms and land erosion. Though they are somewhat heterogeneous, a collapse in any of these environments would have resounding impacts to all of the others, as well as the rural and urban populations that rely on them.

The impact to the human population from ecosystem damage could be significant, with the risk of increased migration resulting from food and water shortages. Recognizing the likely impacts of climate change within these diverse environments can give policymakers the opportunity to plan for future scenarios affecting their countries' food and water security, migration, and natural disaster preparedness.

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This review provides a summary of the critical risks from a 1.5 to 4 degree Celsius average temperature increase in South American forest and temperate landscapes. An appreciation of the overall risks to South American countries will allow for the development of intraregional mitigation and conservation strategies. Active environmental planning will help to identify which environmental risks need to be taken into account, to further dialogue on the regional security implications of a changing climate.

THE IMPACTS OF CLIMATE CHANGE IN SOUTH AMERICA

Large-scale climate impacts seen globally are magnified on the South American continent by the natural El Niño-Southern Oscillation (ENSO) cycles (Cai et al. 2019). During an El Niño event, warmer sea surface temperatures in the Pacific Ocean, and along the Western coast of South America, cause unstable sea-air interaction that drives an increase in precipitation and decrease of ocean upwelling (Timmermann et al. 2018)affecting global climate, marine and terrestrial ecosystems, fisheries and human activities. The alternation of warm El Niño and cold La Niña conditions, referred to as the El Niño–Southern Oscillation (ENSO). During a La Niña event, the opposite is true and drying is common.

With warmer ocean temperatures from climate change, the impacts from El Niño are expected to intensify to include heavier precipitation during individual storm events (Penalba and Rivera 2016). Greater drying or drought impacts during a La Niña cycle are also anticipated, affecting South and Central America (Penalba and Rivera 2016). ENSO as a driver of flooding, erosion and drought has already affected the crop production and infrastructure of some rural populations in South America, impacting food production and fresh water availability (Vörösmarty et al. 2013). An increase of rainfall volume during each discrete rain event may cause further erosion and flooding in the future.

While precipitation events are expected to have greater volume per storm, storm variability and the time between significant rainfall events is also expected to increase, leading to long-term drying (Erfanian, Wang, and Fomenko 2017; Timmermann et al. 2018). Continental-scale precipitation is trending towards a long-term decrease, due to warmer temperatures worldwide, with fewer rain events overall (Erfanian, Wang, and Fomenko 2017).

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This decrease in overall precipitation, coupled with human development and deforestation, contributes to a high risk of large-scale vegetation loss across ecosystems. In fact, currently the loss of South American flora and fauna is outpacing biodiversity loss in the rest of the world, with potentially dire impacts (Urban 2015). The destruction of vegetation can lead to destabilized soils, landslides and erosion, causing further damage to human infrastructure during flood events (Vörösmarty et al. 2013).

Loss of arable land for farming, as well as potable fresh water resources, creates risk of significant resource instability and potential migration of local populations (Salazar et al. 2015) most of the studies of the effects of LUCC on the local and regional climate have focused on the Amazon region (54 studies. This sequence of extreme weather and resultant ecosystem loss has the potential to debilitate the resilience of natural resources across the continent, and increase the financial toll to rebuild and fortify infrastructure.

FOREST ECOSYSTEMS

The recent surge in Amazonian deforestation throughout Brazil and neighboring countries is aggravating existing dynamics that may lead to large-scale vegetative loss across the tropical forest ecosystem (Wright et al. 2017). With some of the greatest taxonomic diversity in the world, the potential for irreversible animal and plant loss under intensifying weather dynamics is significant. The turning point for runaway forest decline may be as low as a 20% decrease of tree cover in 2018, with any more deforestation risking deterioration of the ecosystem as a whole (Lovejoy and Nobre 2018). Preliminary reports are already warning that in 2018 rainforest loss rose by 60% over the previous year, with total loss at the current rate within projected within 50 years.

A decreasing precipitation trend, magnified in La Niña years, has already led to water stress for many species of flora critical to the stability of the forest. Trees in the Amazon generate their own atmospheric moisture and circulation through transpiration-enabled convection. (Pöhlker et al. 2012; Wright et al. 2017).

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Therefore, a decrease in the number of trees in a forest can result in additional atmospheric drying and precipitation reduction. For example, if significant forest loss were to occur during drought or from logging, the atmospheric moisture established by the tree's evapotranspiration would decrease; leading to a further loss of rain and fog cover. This atmospheric moisture reduction would in turn exacerbate drought conditions—committing to a cycle of coupled precipitation and vegetative loss (Marengo et al. 2017).

While high-volume rainfall events are expected to replace consistent precipitation, in what can be called an 'atmospheric river' phenomenon, these rainfall events may not be evenly distributed. In the North of the continent, rainfall may increase per event within the next 10 years, but an average fall in precipitation overall is forecast in the South (Rojas et al. 2016). The continued loss of precipitation will affect the subtropical forest ecosystems similarly to tropical forests, with a decrease in vegetation as droughts stretch across a greater area and last for longer (Rojas et al. 2016).

In addition to precipitation change, a decreasing quantity of snow and ice at the high altitudes diminishes water resources to critical rivers within the Amazon (Mountain Research Initiative E D W Working 2015; Zemp et al. 2015). As glaciers continue to melt in warming temperatures, the level and supply of freshwater to the rainforest and low altitude communities will decrease, further punctuating any drought conditions. Additional land change from natural to built ecosystems will also exacerbate damage to forest structure and soil stability, further increasing the opportunity for loss of biological diversity and harm to these fragile and diverse ecosystems (Salazar et al. 2015)most of the studies of the effects of LUCC on the local and regional climate have focused on the Amazon region (54 studies.

COASTAL AND MOUNTAIN ECOSYSTEMS

Across the arid and subtropical mountain ecosystems of South America exposure to extreme weather systems may be more pronounced than at lower altitudes (Vörösmarty et al. 2013). Along the Pacific coast of the continent, sea surface temperature increase and a strengthening El Niño have already led to higher risk of landslides and soil degradation during high-volume rain showers (Penalba and Rivera 2016). Yet while rain events continue to grow in volume, snowfall at high altitudes has seen a marked decrease over the last 10 years (Mountain Research Initiative E D W Working 2015).

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Temperature increase across the high-altitude mountain ranges minimizes the potential for snowfall, and elevates the opportunity for glacier melt. This lack of winter snowfall leads to decreasing mass in the glaciers that provide a main water source to downstream cities in Peru and Chile (Schauwecker et al. 2017). Additionally, summer glacier melt pulses functionally produce short-term flood events followed by longer-term drought (Baraer et al. 2012). This lack of regular summer glacier water availability will continue to decrease the amount water available to all ecosystems, mountain smallholder farms, and cities. This loss of water availability could decrease water security in the regions effected, leading to potential social unrest and instability.

Rural communities with established mountain livelihoods such as smallholder farmers and herders can often be the most vulnerable to temperature increases, droughts and flooding (Salazar et al. 2015). Small communities with less wealth and access to government services in mountainous regions may experience significant hardship. The capability of mountain ecosystems to thrive and support both farming communities and downstream cities may continue to decrease, with significant risk to the human and natural populations reliant on the fresh water and food the mountains provide. Loss of access to food and water on the regional level has historically precipitated migration to more stable regions, increasing the risk of social unrest.

For coastal communities, sea level rise will continue to be a growing risk. With unprecedented sea ice melt in 2018-2019, sea levels may rise faster than the projected 26 cm by 2100 (Bamber et al. 2019). In Brazil, projected sea level rise is up to a meter in some locations, risking infrastructure loss and ocean pollution from sewage and chemical overflow (Marengo Orsini et al. 2018; Lovejoy and Nobre 2018). Although there are some 'hard' infrastructure resources, such as dams, in place to mitigate flooding issues, further glacier melt or sea level rise will require additional capacity and hardening. These infrastructure changes can be costly and disruptive, only fully functioning after years of work.

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Sea level rise also has the potential to negatively impact fishing communities that have homes and processing facilities in close proximity to the coastline. Due to a decrease in fish population from overfishing and warming ocean temperatures, a critical livelihood for many families may be at risk (Timmermann et al. 2018; Cleber JR 2017). The magnification of climate impacts from El Niño and La Niña events is also notable within these coastal ecosystems, with the combination of sea level rise and stronger storms increasing the risk of debilitating storm surge (Cai et al. 2019).

Without significant infrastructure adaptation within coastal towns, the potential loss of facilities, roads and houses during storms is great. Additionally, the risk of soil salinification from both sea level rise and storm surge may make a growing area unsuitable for farming (Silva et al. 2018; Neves et al. 2017) limiting the opportunity for either fishing or farming, the two most important livelihoods, in these local communities (Bell, Watson, and Ye 2017; Vörösmarty et al. 2013). As South America may be risking the greatest loss of biodiversity in the world, it is notable that this damage will occur across both the land and sea, potentially impacting food security for numerous communities.

TOWARD A SUSTAINABLE FUTURE

Currently, the most pressing issue for South American ecosystems may be active deforestation. The continued loss of the Amazonian rainforest degrades the ecosystem services it provides, including potable water and arable soil, and has the potential to devastate weather patterns internationally. Combined with the stressors to forest ecosystems from a changing climate, ongoing deforestation will overwhelm the forests' ability to survive. Moving towards sustainable land, agriculture and water management will be critical if this globally important resource is to be preserved.

On the continental scale, the loss of glacier water and regular precipitation may create water stress across borders, taxing existing infrastructure and leading to human migration. While some of the impacts of climate change are already in motion, continued security risk forecasting at both regional and global scales offers governments the opportunity to prepare.

It may be possible to preserve forests through tree reforestation programs, minimizing consumer meat and palm oil consumption, choosing sustainable coffee and cacao cultivation. Ensuring coastal stability may require the prioritization of soft infrastructure such as wetlands and functioning watersheds, preemptively hardening or moving coastal communities, and closely regulating commercial and artisan fishing. Mountain ecosystems may be strengthened by replanting native grasses and trees, and moving dense, mixed-use agriculture.

Increasing the sustainability of human land use practices may be able to prevent the worst impacts from climate change across the continent. The diversity of life in South America has sustained and supported the human populations for generations; it is now time for the humans to do the same by protecting these fragile ecosystems under a changing climate.

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Dr. Kimberley R. Miner is a Research Assistant Professor at the University of Maine's Climate Change Institute, focusing on global risks from climate change. In this capacity, she recently managed pollution research on the 2019 National Geographic trip to take ice cores from Mt. Everest. She is a graduate of Columbia's School of International and Public Affairs (MPA) and University of Maine's Climate Change Institute (PhD). She also serves as a Fellow at the Center for Climate and Security in Washington, D.C. and as Co-chair of the NASA Interagency Forum on Climate Risks, Impacts and Adaptation.

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