Mainstreaming climate change in the Rio Doce watershed restoration

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RIO DOCE PANEL THEMATIC REPORT NO. 2

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Acronyms

ANA	National Water Agency
APP	Permanent preservation area
C/ha	Carbon per hectare
CIF	Interfederative Committee
CO_2eq	Carbon dioxide equivalent
COP	Conference of the Parties
CT-Flor	Technical Chamber for Forest Restoration and Water Production
EE	Energy efficiency
FEAM-MG	Minas Gerais State Foundation for the Environment
GDP	Gross domestic product
GHG	Greenhouse gases
Ibama	Brazilian Institute of Environment and Renewable Natural Resources
ICMBio	Chico Mendes Institute for Biodiversity Conservation
INPE	National Institute of Space Research
ISTAP	Independent Scientific and Technical Advisory Panel
IUCN	International Union for Conservation of Nature
NbS	Nature-based Solutions
NDC	Nationally determined contribution
PES	Payment for environmental services
RE	Renewable energy
RDP	Rio Doce Panel
SEAMA-ES	Secretariat of Environment and Water Resources of the State of Espírito Santo
SEMAD-MG	Secretary of Environment and Sustainable Development of the State of Minas Gerais
SIRENE	National Emissions Register System
TTAC	Terms of Transaction and Conduct Adjustment
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

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Foreword

Healthy ecosystems and natural resources underpin livelihoods and the global economy at large. Today, however, the climate emergency is increasingly threatening human and ecosystem health. Emerging diseases, water rationing, droughts and floods are expected to occur more frequently in the coming years, and societal changes are imperative to avoid and mitigate these looming challenges. In degraded landscapes, such as the Rio Doce Basin – which is still recovering from the Fundão Dam collapse in 2015 – climate change is likely to aggravate an already fragile landscape. For example, torrential rains in the first half of 2020 caused severe landslides, leaving hundreds of people homeless and potentially churning up sediments that could expose people and the environment to the harmful effects of the dam failure five years earlier.

With this important and timely report, the independent Rio Doce Panel draws attention to the necessity for decision makers to take climate impacts into account in the ongoing and future restoration efforts of this critical watershed. With around 3.3 million people depending on the Rio Doce for their freshwater and livelihoods, urgent measures are needed to help communities mitigate and adapt to the impacts of climate change. Averting such impacts falls firmly in line with the global agenda during the forthcoming UN Decade on Ecosystem Restoration, which will seek to prevent, halt and reverse the destruction of damaged ecosystems.

The issues in this publication reflect the worldwide challenges – and solutions – when tackling climate change. The latest science published by the Intergovernmental Panel on Climate Change underscores the seriousness of the threat climate change poses to natural and human systems across the world, and we know that we must immediately take action to reduce greenhouse gas emissions. Thankfully, Nature-based Solutions and other ecosystem-based mitigation actions have proven to be an efficient and cost-effective way of responding to the challenges posed by climate change, while also providing opportunities for the conservation, restoration and sustainable management of key watersheds, such as the Rio Doce Basin.

As the Panel's report finds, local and state efforts are crucial to building adaptive capacity, which will enable vulnerable regions and communities to gain greater resilience to the changing climate. Such efforts include restoring ecosystem functions, for example by planting native trees along the riversides and on hilltops, and identifying the emissions reduction potential of these restoration programmes. For the Rio Doce Basin, more forward-looking policies and investments are needed to bolster the long-term health and well-being of its people and the environment. IUCN welcomes this timely report, which provides invaluable guidance for addressing climate challenges in the region and beyond.

Dr Grethel Aguilar
Acting Director General
IUCN, International Union for Conservation of Nature

Preface

Established in 2017, the IUCN-led Rio Doce Panel (RDP) is continuing to advise the restoration of the Rio Doce Basin affected by the collapse of the Fundão Dam in Brazil in 2015. Underpinned by its vision to bring a long-term perspective to this critically important watershed, the Rio Doce Panel aims to advise the recovery efforts of Renova Foundation and stakeholders in building a more sustainable and resilient ecosystem in the basin and adjacent coastal zone.

In its first report, *Impacts of the Fundão Dam failure: A pathway to sustainable and resilient mitigation*, the Panel identifies climate change as the biggest threat to natural systems, local communities and business operating in the basin. It calls on the Renova Foundation, which is responsible for implementing the restoration and compensation efforts, to include a climate perspective in its mitigation actions.

The Fundão disaster has increased the vulnerability of the region, which was already severely degraded from decades of unsustainable activities. The dam collapse resulted in 19 deaths and caused serious impacts on nature, health and livelihoods in the region. While affected communities expect a restored and safer natural and social environment, decision makers must take forward-thinking actions to ensure that socio-environmental interventions already underway contribute to a more sustainable and resilient society with greater capacity to conserve, use and protect the land.

Building on its earlier recommendations (outlined in its first report and issue papers), the Panel finds that Renova must prioritise climate mitigation and adaptation measures in its programme planning and implementation. The report identifies several ways in which the Renova Foundation can improve its ongoing efforts to build greater climate resilience, such as the use of Nature-based Solutions and maintaining natural water infrastructure, as well as strengthening cooperation to enhance institutional capacities.

Ultimately, the Panel concludes that climate action is essential to generate a positive and lasting legacy for current and future generations. What follows is an invitation for a dialogue regarding the long-term recovery of the Rio Doce Basin.

Yolanda Kakabadse
Chair
Rio Doce Panel

Executive summary

Predicted climate change may imply risks to the legacy of the programmes for Rio Doce Basin restoration underway by Renova Foundation. In this report, the Rio Doce Panel proposes that Renova, as well as stakeholder organisations and decision makers operating in the basin, initiate an action plan to address these potential risks.

The report contextualizes the climate conditions in the Rio Doce watershed and the consequences of possible changes in the current patterns of temperature and rainfall. Increased risk of climate change makes the communities in the Rio Doce more vulnerable to events, such as flooding, landslides and coastal erosion, indicating the need for policies and investments to build institutional and societal resilience for climate change adaptation, particularly in regard to human and ecosystem health. Climate scientists in Brazil affirm that recent intense rainfall events of 2020 in southeast Brazil reflect long-term shifts influenced by global warming. Adaptation to climate change brings with it the need to build institutional capacity among government agencies and social networks to respond to the challenges ahead.

While several cross-cutting restoration programmes implemented by Renova enhance climate resilience, there is an evident need for greater coordination over time among these programmes to ensure adaptive capacity. The report discusses opportunities to mitigate and reduce emissions, and the potential of financial instruments that could generate resources for their implementation (e.g. carbon pricing and green investment funds) or facilitate their uptake (e.g. payment for ecosystem services (PES) schemes). The report also urges the adoption of Nature-based Solutions (NbS) as a basis for landscape approaches for climate adaptation and mitigation at basin scale, citing Renova's exemplary actions for re-naturalisation of waterways.

The Panel recommends that Renova seek solutions to the potential threats posed by climate change for the effectiveness and sustainability of its programmes, and thereby contribute to achieving a low-carbon and resilient economy at the watershed level.

Renova should coordinate its crosscutting activities to gain greater leverage and an evidence base for climate action in the future, and work in cooperation with local and state governments to strengthen institutional capacities for climate adaptation. In this regard, the Panel recommends that Renova cooperate with its stakeholders and partner institutions, including state and local governments, public prosecutors and the judiciary to:

1) Initiate a dialogue towards the development of a Rio Doce Watershed Climate Action Plan;
2) Propose that the Inter-Federative Committee (*Comitê Interfederativo*, or CIF) and other entities mainstream climate change within a timely review of relevant programmes of the Terms of Transaction and Conduct Adjustment (*Termo de Transação e de Ajustamento de Conduta,* or TTAC)[1];
3) Adopt NbS when considering technological alternatives for remediation, restoration and compensation; and
4) Invite state and local governments to build capacity and undertake actions to prepare for climate change adaptation.

1 For further information, please visit: www.samarco.com/en/plano-de-recuperacao-macro/

1 | Introduction

Climate change is a global phenomenon that affects all life forms on Earth. The world's biodiversity and ecosystem services, and consequently, human well-being, are affected both directly and indirectly. While the world's economies and livelihoods depend on natural resources and ecosystem, it is predicted that these assets, as well as human-built infrastructure, health and food security, will continue to be affected by climate change. At the same time, a growing body of scientific research acknowledges the influence of human activities in the increasing concentration of greenhouse gases (GHGs) in the atmosphere and their role in recent trends of global climate change. Changes in rainfall, temperature patterns and the frequency of extreme events, such as floods, fires, droughts, cyclones and hurricanes, are some of the consequences of the higher concentration of GHGs in the atmosphere (IPCC, 2014a).

Although it is too early to provide published scientific verification, climate scientists in Brazil affirm that the recent intense rainfall events of 2020 in the southeast region of Brazil, accompanied by drought in other parts of the country, reflect long-term shifts in rainfall patterns that have been traced to global warming (Phillips, 2020). A changing climate has different implications for different social groups and places. Cities are without a doubt the most vulnerable to increase changes in rainfall intensity, since their infrastructure for stormwater drainage cannot be quickly adapted to respond to extreme events. Brazil's population is increasingly urban; in the Atlantic Forest biome, the urban population is even more dense. At the same time, rural areas are not spared the brunt of climatic shifts. Agriculture and forestry are among the sectors most severely affected by drought and temperature rise, while coastal tourism may be impacted by sea level rise and coastal erosion (Margulis, 2017). The need for adaptive strategies is paramount.

The collapse of Fundão Dam resulted in the need to respond in an adaptive way to material losses and human suffering, as it contributed to increase the territory's vulnerability: whether through the interruption of economic activities that sustain local livelihoods, psychological stress due to the loss of community structures and equipment that were part of the culture of the region, or environmental impacts, among other consequences. Renova Foundation was created to respond to this major disaster by making efforts to mitigate and compensate the socio-economic and environmental impacts. The foundation, working under rigorous governance provisions, is responsible for the implementation of 42 environmental and socio-economic programmes laid down in an out-of-court settlement outlined in the TTAC. The agreement also led to the establishment of CIF, which is composed of representatives of municipal, state and federal governments, regulatory agencies and more recently, representatives of affected people to monitor the progress and outcomes of the programmes. The experience accumulated by Renova in dealing with a set of complex tasks on an interdisciplinary basis, within a framework of multi-level governance, serves as part of the legacy of the programmes to the Rio Doce Basin and its peoples.

Adaptation to climate change and emissions reduction are key to sustainability and resilience of TTAC programmes' outcomes

Community garden in Povoação (ES)

Photo: NITRO (October 2018).

In line with its mandate, the Panel[2] draws attention to the need of including responses to climate change in the mitigation and compensation programmes outlined in the TTAC. Accordingly, in its first thematic report (Sánchez et al., 2018), RDP recommended that Renova and CIF review TTAC programmes in order to evaluate the possible impacts of climate change on the intended outcomes, and adapt or modify the programmes as required to reflect the Panel's main concern: mitigation and compensation efforts should generate a positive and lasting legacy for current and future generations.

This second thematic report therefore addresses the need for appropriate responses to climate change in the mitigation and compensation efforts being conducted in the Rio Doce watershed, associated with adaptation to climate change and emissions reduction, which are key to sustainability and resilience of TTAC programmes' outcomes.

The report is organized into five sections. Section 1 introduces the scope of the report and its relationship to TTAC programmes implemented by Renova following the Fundão Dam break. A climate change framework for the Rio Doce watershed is presented in section 2, as well as its vulnerability to the derived impacts and associated risks. An analysis of the extent to which climate change could affect the intended long-term outcomes of TTAC programmes is shown in section 3, followed by an assessment of the potential contributions of alternative land uses and energy alternatives for GHG emissions reduction. In section 4, some options for financing low carbon alternatives and adopting NbS are proposed. Finally, section 5 presents recommendations to Renova and partner institutions on how to improve decision-making for mainstreaming low carbon alternatives and build resilience in connection with Renova's mitigation and compensation programmes in the light of current global changes. The definition of selected terms used is provided in the annex of this report.

2 The Rio Doce Panel (RDP) was established in 2017 as an Independent Scientific Technical Advisory Panel (ISTAP) coordinated by the International Union for Conservation of Nature (IUCN). The overall goal of the Panel is to provide Renova Foundation with objective and independent advice on the recovery of the Rio Doce Basin, following the Fundão Dam failure in November 2015. For more information, please see: https://www.iucn.org/riodocepanel

2 | Assessing the vulnerability of the Rio Doce watershed

In terms of climate change, vulnerability can be defined as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007a, p. 883). In general, the most vulnerable are the ones critically exposed to enduring sources of socio-environmental stress.

In 2011, the Minas Gerais State Foundation for the Environment (Fundação Estadual do Meio Ambiente, or FEAM) conducted an assessment[3] of the predicted changes in the climate in Minas Gerais state, including the Rio Doce watershed, and concluded that significant changes are anticipated over the coming decades. These changes in climate patterns would themselves increase the vulnerability of the Rio Doce watershed and its people.

In addition to the threat already posed by climate change, the Fundão Dam failure – as a large-scale and high-impact event with long-term repercussions – further exacerbated the pre-existent vulnerability of the Rio Doce watershed and adjacent coastal zone. While some of the most critical immediate effects, for example, fisheries bans, worker layoffs and household relocation, have been partially compensated by payments to affected parties, other less tangible effects, such as human and ecosystem health, are difficult to ascribe with a causal nexus. Moreover, heavy rainfall events have reportedly dislocated sediments deposited along the river (Queiroz et al., 2018) and could have stirred up tailings deposited by the Fundão Dam collapse, indicating that intensified events associated with climate change may continue to affect conditions in the basin. In such circumstances, it is therefore important to ensure that TTAC programmes, as well as complementary governmental investments, be adapted and resilient to the potential impacts of climate change.

This section describes the basin from a climatological perspective, identifying the changes in temperature and rainfall that are projected globally and regionally over the coming decades. Likewise, environmental and socio-economic factors that are likely to be affected by such changes within the Rio Doce watershed are presented as a basis for a preliminary review of TTAC programmes and their potential to contribute to the region's resilience to a changing climate.

2.1 Climate conditions in the Rio Doce

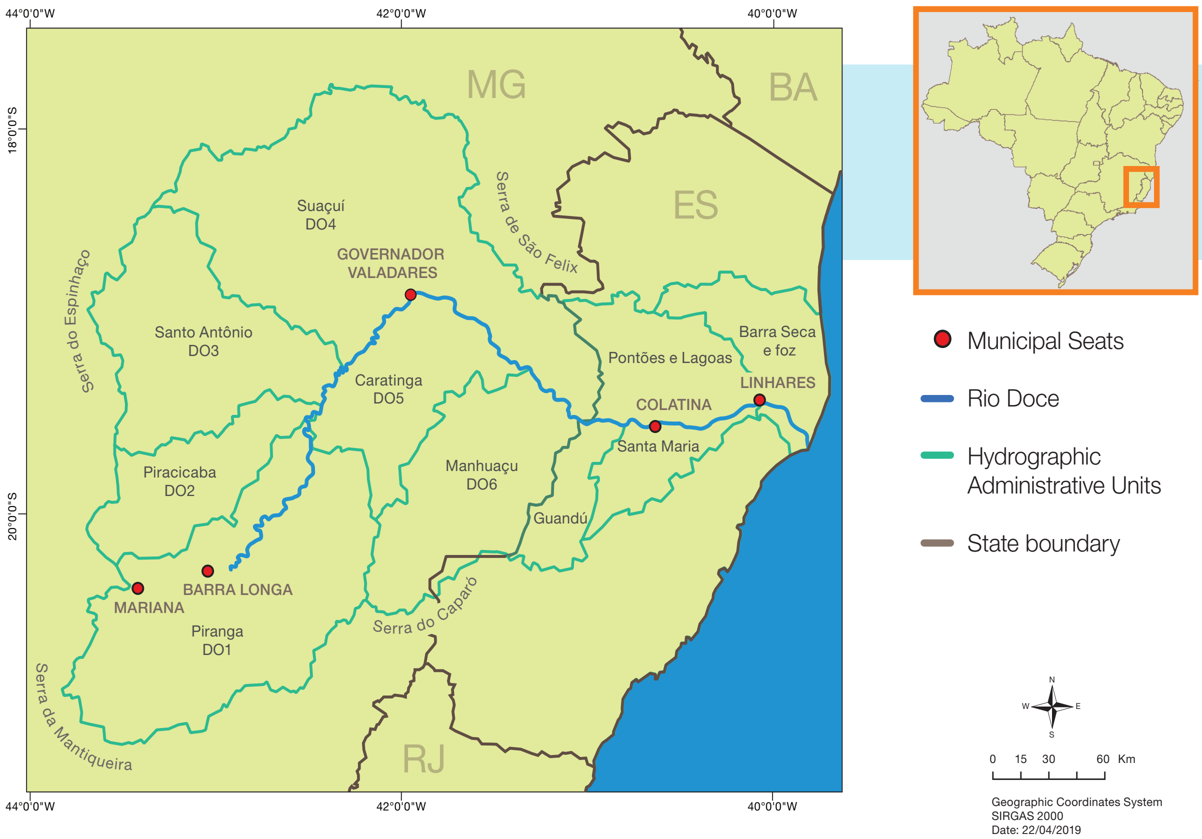
The Rio Doce watershed (Figure 1) comprises approximately 86,715 km^2. Around 86% of the watershed is located in Minas Gerais state, while the remaining 14% lies within Espírito Santo state.[4] The headwaters of the river lie in Minas Gerais, in the Mantiqueira and Espinhaço mountains, and its waters flow over approximately 850 km until reaching the Atlantic Ocean, in the town of Regência, Espírito Santo.[5]

The pluviometry regime of Rio Doce Basin is characterized by two very distinct periods. The rainy period, during which total rainfall ranges from 800 to 1300 mm, extends from October to March, with the highest rates in the month of December. The dry period, during which total rainfall varies from 150 to 250 mm, extends from April to September, with a more critical deficit from June to August.

3 See sections 2.2 and 2.3 for further details on the results of the FEAM assessment.
4 For further information, please see: http://www3.ana.gov.br/portal/ANA/panorama-das-aguas/divisoes-hidrograficas
5 For further information, please see National Water Agency website: https://www.ana.gov.br/sala-de-situacao/rio-doce/rio-doce-saiba-mais

Figure1

Rio Doce watershed hydrographic region and state borders



Source: Renova Foundation.

According to Nimer (1989), the diversity of climate types and sub-types is intrinsic to Minas Gerais and Espírito Santo due to their position in a tropical climate transition region. In this part of southeast Brazil, the climate is characterized by average temperatures higher than 18°C even during the colder months. In areas with elevation higher than 300 m, however, the average temperatures during the colder months may decline below 18°C (Figure 2).

Cupolillo et al. (2008) identified a west-east rainfall pattern: in the western portion of the basin where the rainy season is longer and the dry season shorter. The opposite is observed in the east, where the rainy season is shorter and the dry season longer. The occurrence of *veranicos* (dry spells during the rainy season) is also reported for the whole basin. They are more intense near the coast, where they often occur over a 10-day period in February.

According to the National Water Agency (*Agência Nacional de Água*, or ANA), the basin is susceptible to the occurrence of floods, especially in urban areas along the course of the Rio Doce and some of its tributaries. This flooding is recorded in the rainy season, mainly in the months of December to February.

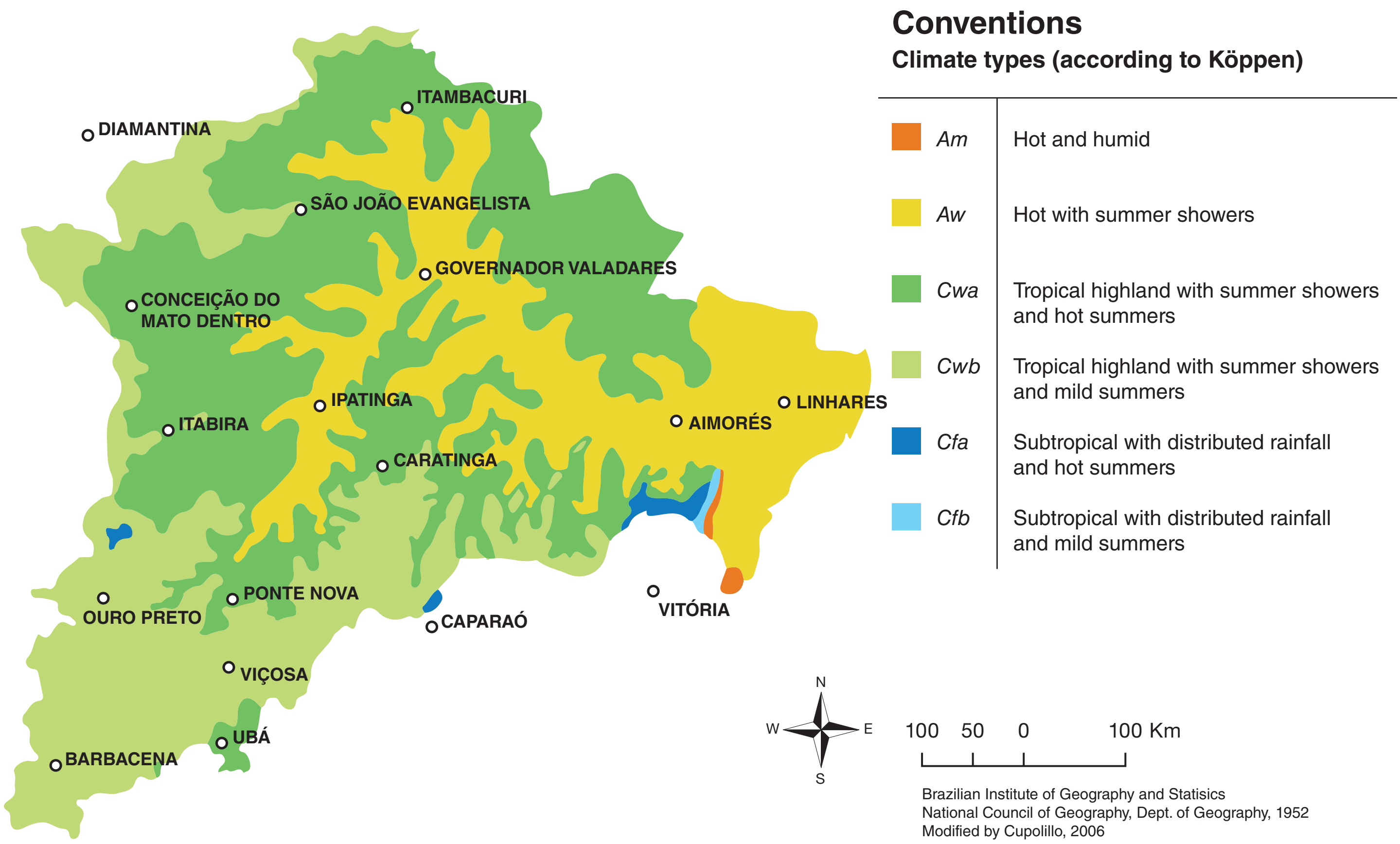
Such a climate profile provides the setting within which climate change effects may occur, with varying degrees of impact determined by the relative dependence of economic activities and human settlements on a stable temperature and rainfall regime.

2.2 Climate modelling projections in the Rio Doce watershed

Enormous progress has been made in the past few decades in the understanding and long-term forecasting of weather conditions and atmospheric phenomena, notably by the Intergovernmental Panel on Climate Change (IPCC, 2007b; 2014a; 2018a). Today, forecasting and projections are outcomes of numerical climate models developed in supercomputer environments. In the field of climate modelling with its inherent uncertainties, the continuous use of a robust scientific approach and new technologies, such as artificial intelligence (Voosen, 2018), have allowed meaningful progress in reducing those uncertainties. However, the effective implementation of climate policy agreements has the potential to reduce the anthropogenic forcing of climate change. Thus, expectations for climate policy adoption are also incorporated in models, which lead to scenarios of more or less intense global warming conditions.[6]

In tune with the global efforts to understand the impacts of climate change and challenges in adapting to its effects, the Brazilian National Institute of Space Research (*Instituto Nacional de Pesquisas Espaciais*,

Figure 2
Climate classification of the Rio Doce watershed



Source: Cupolillo et al. (2008, p. 34)

6 Since its creation in 1988, the IPCC has addressed uncertainty through the construction of a series of scenarios regarding the relationship between human economy and climate change, which trace the intensity of GHG emissions to economic growth as well as the impact of policies designated to reduce anthropogenic GHG emissions. The worst-case scenario is that of ‘business-as-usual’, which unfortunately appears to be the most likely, given insufficient corrective action in compliance with national commitments to the goals of the UNFCCC. For further information, see https://www.ipcc.ch/report/emissions-scenarios/.

Models consistently predict positive temperature anomalies of between 2°C and 4°C in the most optimistic scenario for the Rio Doce watershed

or INPE), has periodically downscaled global models to the whole or parts of South America.[7] As pointed out by leading INPE climatologist José Marengo, climate modelling for future scenarios in Brazil shows a strong consensus for a rise in temperature during the current century (Piveta, 2018). Models consistently predict positive mean temperature anomalies of between 2°C and 4°C by the end of the 21st century in the most optimistic scenario for the area originally covered by the Atlantic Forest Biome (IPCC, 2014b), where the Rio Doce watershed is located.

In 2011, FEAM published a study which generated climate forecasts for 2080 using the regional climatic model developed by the UK Meteorological Office Hadley Centre, called Providing Regional Climates for Impacts Studies, or PRECIS[8] (FEAM, 2011). The study produced maps which included each of the economic sub-regions of the state, from which projections for the Rio Doce watershed in Minas Gerais were obtained. Two emissions scenarios were considered: (i) business-as-usual (A2-BR)[9]; and ii) response to society's concerns, attitudes and behaviour related to climate change (B2-BR) (see Figure 3). Both scenarios were adjusted to reflect IPCC's global scenarios.

So far, it appears that similar climate change projections were not carried out in Espírito Santo, although inferences can be drawn.[10] The importance of such projections to climate change adaptive capacity leads the Panel to recommend that such studies be extended to include the Rio Doce watershed as a whole (see section 5).

Recovery of springs (Colatina (ES), October 2018)

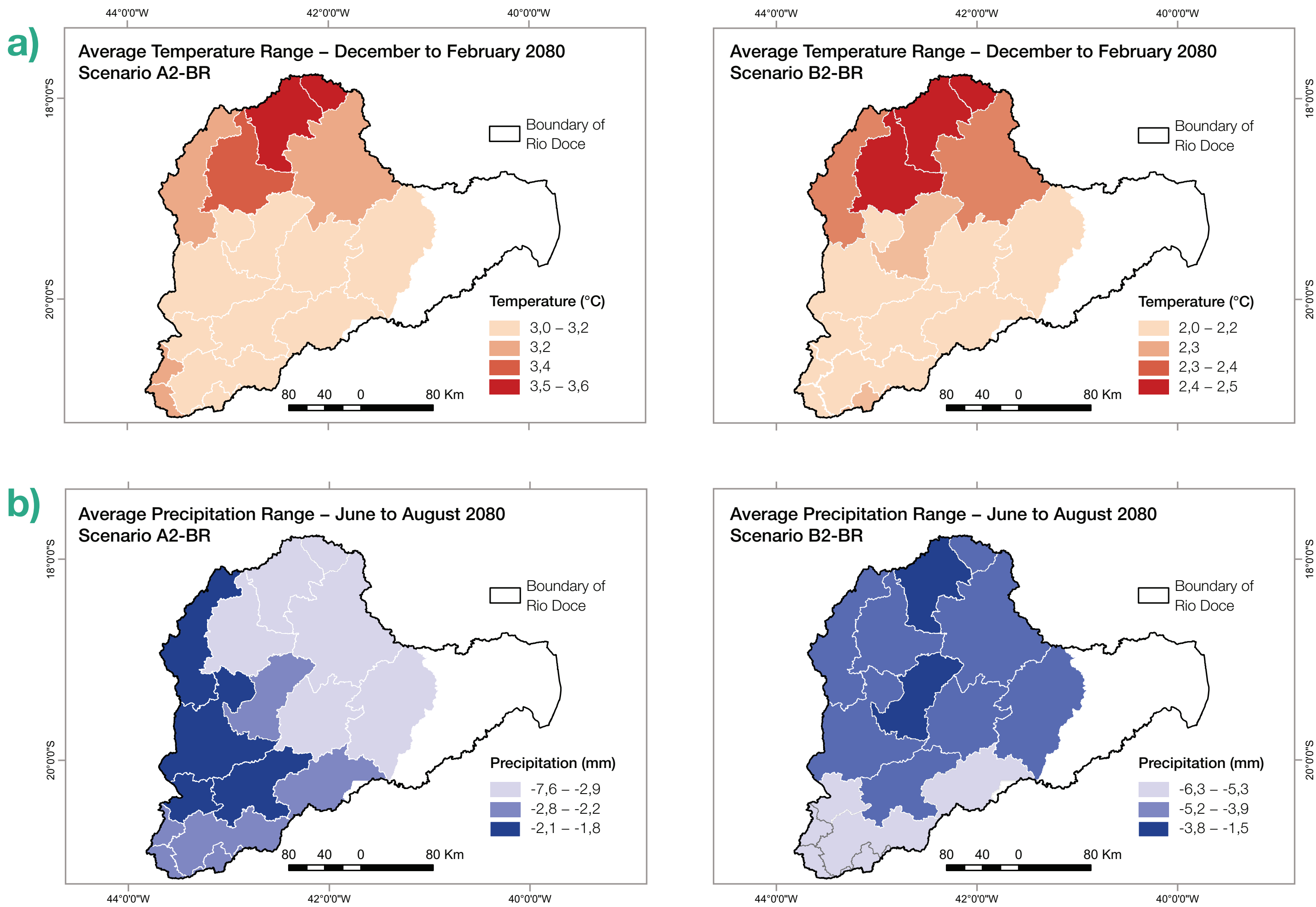
Photo: NITRO

As shown in Figure 3a, temperature projections from the FEAM sub-regional model point to a warmer future for the Rio Doce watershed. The projected temperature rise is higher in the business-as-usual scenario (3°C – 3.6°C) than in the more optimistic emission mitigation scenario B2-BR (2°C – 2.5°C). Higher levels of temperature variation are projected in the northern and western parts of the basin with smaller increments toward the coast. Similarly, the

7 For further information, see: https://www.cptec.inpe.br/
8 For further information, see: https://beta.metoffice.gov.uk/research/applied/international/precis
9 The BR scenario is specific to Brazil, adapted from global climate change projections. For further reading, please see: https://unfccc.int/files/adaptation/application/pdf/brazil_climateeconomy_executive_summary.pdf .
10 Espírito Santo passed a legislation in 2010 (Law nº 9.531 16/09/2010) providing for the preparation of a state climate change plan and providing incentives for climate action including the state's program to restore degraded lands with conditional payments. A state programme for climate adaptation and disaster preparedness, including early warning facilities for hydrometeorological monitoring, was launched in 2013.

Figure 3

Variations in temperature ***(a)*** and precipitation ***(b)*** projected for 2080 in the Minas Gerais segment of Rio Doce watershed under two scenarios (A2-BR and B2-BR)



Source: Adapted from FEAM (2011).

Note: The white part of the map refers to the portions of the Rio Doce Basin within Espírito Santo, whose territory was not included in the original study which was restricted to Minas Gerais. Internal delineations are related to Minas Gerais economic sub-regions. Forecasts were originally provided for the entire state of Minas Gerais.

business-as-usual scenario (A2-BR) provides wider precipitation variations (-1.8 – -7.6, June–August) when compared to the B2-BR scenario (-1,5 – -6,3 mm, June–August). Figure 3b shows a decline in rainfall is anticipated under both scenarios in the whole basin during the dry season (winter). The study also shows that the models project an increase in precipitation in most of Minas Gerais state during the rainy season (summer).

2.3 Potential impact of climate change on people and environment of the Rio Doce Basin

On the basis of the preceding forecasts and instruments, the state government of Minas Gerais predicted the vulnerability of its sub-state regions to climate change (FEAM, 2014). The analysis examined each sub-region's relative sensitivity and exposure to climate change impacts, as well as their adaptive capacity. The results pointed to a 'very strong' sensitivity to climate change in the Rio Doce region. FEAM (2014, p. 87) found that this can be attributed to a number of reasons, such as:

- significant land area dedicated to silviculture;
- high regional dependency on tourism;
- precarious road conditions;
- high rate of out-migration;
- precarious sewer treatment and overall environmental quality;
- historically intense rainfall events; and
- extremely high risk of flooding.

Table 1 presents a matrix of the impacts of exposure to climate change in the Rio Doce region based on the analysis of the part of the watershed that is located in Minas Gerais state. In this analysis, exposure stems from the relative dependence of a particular region on activities that depend on a stable rainfall and temperature regime, together with the intensity of potential impacts from climate change on the environment and human health.

Clearly, the analysis shows that the Rio Doce watershed lies in a region which is considered particularly exposed to climate change risks. The major impacts arise from a potential decline in silviculture viability and reduced cropland, both associated with precipitation reduction, as well as loss of biodiversity. Other climate change impacts include a decrease in hydroelectric generating capacity[11] and risks to human health.

Although no similarly detailed studies were found for the state of Espírito Santo, one forecast points to the same regional trend of a reduction in monthly

Table 1
Exposure to climate change impacts in the Rio Doce region of Minas Gerais

CLIMATE CHANGE IMPACTS		Level of exposure
General impacts	Temperature increase	1
	Precipitation reduction	3
	Precipitation increase	2
Economic impacts	GDP reduction	1
	Depletion in crop area	4
	Decrease in silviculture	4
	Decrease in hydroelectricity generation	3
Social impacts	Migratory pressure	2
	Human health	3
Environmental impacts	Biodiversity	4
	Desertification processes	2

Source: FEAM (2014, p. 121)

1 – Low
2 – Medium
3 – Strong
4 – Very strong

11 The Rio Doce Basin provides hydroelectric generating capacity to four major power plants in Minas Gerais and Espírito Santo totalling over 810 mW at its peak, including the Risoleta Neves (Candonga) plant, currently inoperative due to the Fundão Dam break.

The Rio Doce floods 14 neighborhoods of Governador Valadares (February 2020)

Photo: ©Antônio Cândido, Prefeitura Municipal de Governador Valadares

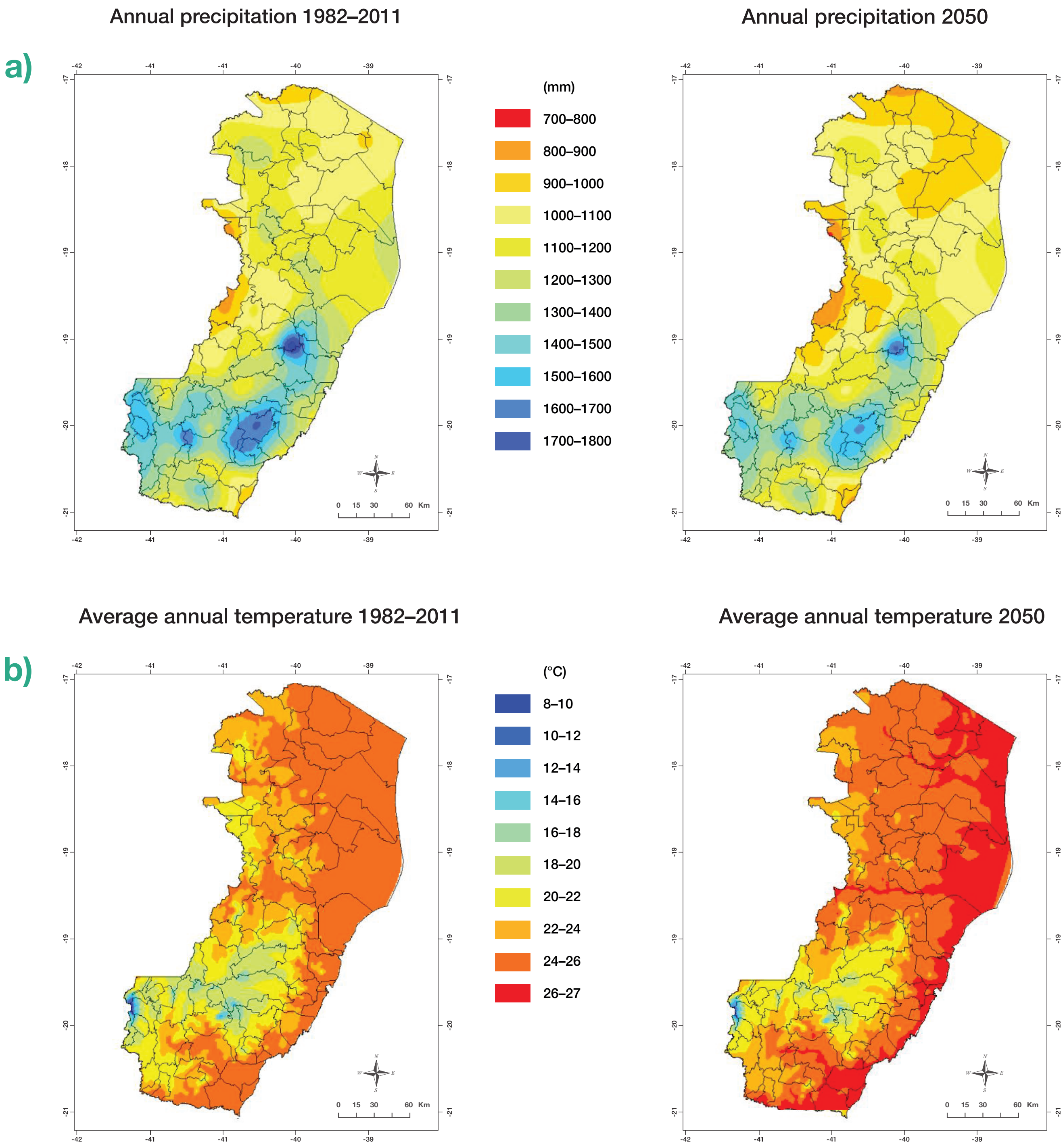
average precipitation and an increase in mean air temperature of up to 2.1°C by 2050 (Pirovani, 2014, Figure 4). The same research found that annual water deficit would tend to increase in most regions of the state, which can further affect that portion of the Rio Doce watershed. The climate regime and other environmental configurations in the basin suggest a similar scenario to that described for Minas Gerais by FEAM (2011), with the most notable difference being the impacts of the rise of sea level which is expected to affect the river mouth and its adjacent coastal areas, with an imminent risk of floods in urban areas.

The complexity of the region's vulnerability has been revealed in previous studies, which have shown that wave-induced longshore sediment drift played an important role in the formation and erosion of the Rio Doce coastal plain (Dominguez et al., 1987). According to Albino et al. (2001), a recent increment in the frequency of polar cold fronts, which blow winds from the southeast and increase rainfall intensity, may block longshore sediment flow, triggering coastal erosive processes, bringing greater vulnerability to those areas of the littoral of Espírito Santo which have become urbanized. In a review of Brazilian coastal vulnerability to climate change, it was similarly found that due to the low occupation of large sectors of the coastline, the risks are concentrated in the urbanized areas (Muehe, 2010), with particular reference to the flooding of the town of São Mateus in the coastal zone adjacent to the Rio Doce (Tessler, 2008).

With regard to the impact of climate change on coastal areas affected by the Fundão Dam's collapse, recent research suggests that sediments deposited along the river can be dislocated by extreme rainfall events, thus leading to its release into estuarine areas and further deposition by tides and currents to mangroves and beaches (Queiroz et al., 2018). Climate change is also a cause of ocean acidification, which can increase bioavailability of suspended or deposited contaminants. Mangroves, wetlands and seagrasses are among irreplaceable ecosystems whose importance is key to the protection of coastal communities and assets from sea level rise and extreme climate events (Goldstein et al., 2020).

Figure 4

Climate change scenarios for Espírito Santo for the period 1982–2011 and 2050: Average annual precipitation ***(a)*** and average annual temperature ***(b)***



Source: Pirovani (2014, p. 77 (a), p. 82 (b)).

3 | Risks and opportunities: Steps toward climate action

3.1 Exploring courses of action

In this section, the Panel provides information to support Renova's decision-making for actions to address both climate change adaptation and mitigation. Addressing climate change adaptation and mitigation in the Rio Doce watershed could represent a significant opportunity to revisit the established restoration programmes and achieve greater synergies. Climate change action can also be an important tool for programme integration, since the subject requires a cross-disciplinary perspective. Such an opportunity would clearly place the Rio Doce restoration effort at the vanguard of national and international action to prepare for climate change.

As Renova continues to implement the 42 TTAC programmes, it is a pivotal moment to engage the Rio Doce restoration effort in building a pathway towards climate action. Recognising that risk leads to opportunity, the restoration undertaking opens up opportunities to Renova and Rio Doce municipalities, which can be fruitfully synchronised with a coordinated strategy for climate action planning in the watershed.[12] Renova has a diverse range of strategic options to contribute to such an outcome, taking an approach the business sector has widely adopted through 'carbon management practices' (Lee & Lee, 2018).

In this report, the Panel underlines the importance of a thorough understanding of climate change and its repercussions, from the moment Renova's activities are planned and beyond their implementation. Given that it is a cross-cutting issue, there is a wide range of actions and specific proposals that can be undertaken which will not be possible to describe fully in this report, but that could be developed through a coordinated management endeavour. However, three major themes stand out and are described in further detail in this section:

i) adaptation to climate change;
ii) carbon sequestration opportunities in natural systems; and
iii) energy efficiency, use and generation strategies.

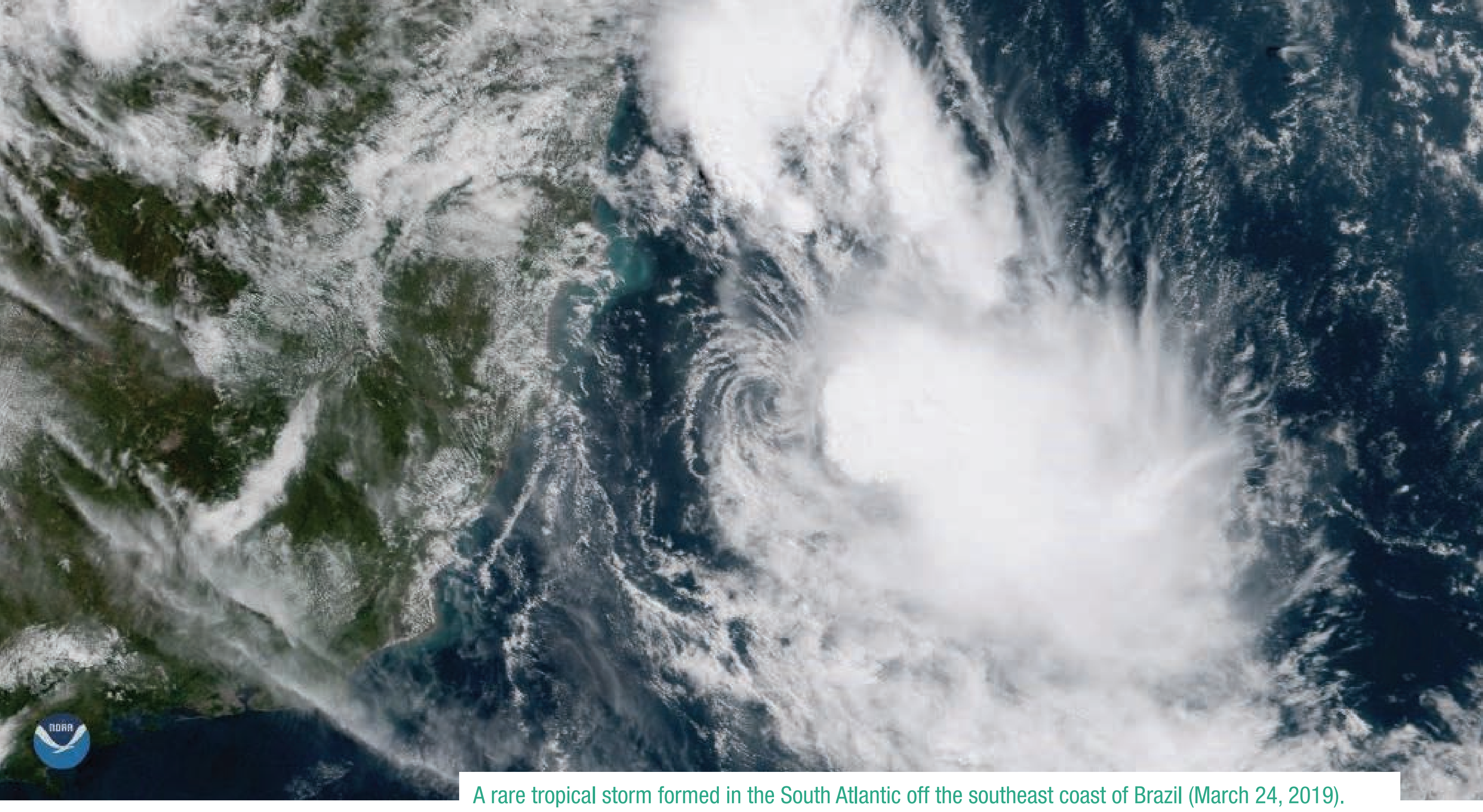
3.2 Climate change adaptation in TTAC programmes

Strengthening adaptive capacity implies attention to institutional and social capital variables, such as coordination, social networks, information flows and participatory decision-making. These factors are taken into account in this section insofar as they interact with the efforts toward ecosystems restoration and compensation of damages associated with TTAC programmes under execution by Renova and the need for complementary long-term efforts by Renova's partners at the state and local levels. Such an approach warrants a transition strategy to support institutional learning (Rotmans & Loorbach, 2009).

Ideally, climate change effects should be taken into consideration during the planning, monitoring and evaluation phases. Although the design of the 42 TTAC programmes[13] did not explicitly take climate change into account, climatic predictions and

12 The AdaptaCLIMA platform offers suggestions on how to develop adaptation plans that reflect Brazilian reality. Available in Portuguese at: http://adaptaclima.mma.gov.br/elabore-sua-estrategia-de-adaptacao

13 A description of all 42 programmes is available at Renova Foundation's website: https://www.fundacaorenova.org/en/discover-the-programs/



A rare tropical storm formed in the South Atlantic off the southeast coast of Brazil (March 24, 2019). Tropical Storm Iba is the first named tropical storm in the South Atlantic in nearly 10 years.

Photo: Environmental Visualization Laboratory, National Oceanic and Atmospheric Administration (NOAA).

anticipated impacts in parts of the Rio Doce Basin were available to decision makers who participated in the definition of TTAC programmes due to prior efforts by the Minas Gerais state government to prepare for climate adaptation (FEAM, 2011; 2014). Moreover, one of these studies had assessed the vulnerability of the communities in Minas Gerais to climate change impacts and their capacity to adapt to them as a basis for a state climate change adaptation plan (FEAM, 2015). In its first thematic report, the Rio Doce Panel addressed these questions and recommended that Renova "review regional climate change models and propose improvements in mitigation programmes to address risks to the achievement of outcomes", as well as to identify "threats to sustainability and resilience of mitigation outcomes" that could prevent those programmes in meeting their objectives (Sánchez et al., 2018, p. 28). The present report sets out a number of preliminary initiatives to address this recommendation.

Using a preliminary qualitative approach, the Panel undertook a review of TTAC's 42 programmes to identify potential climate change-related setbacks or obstacles to achieving their outcomes (see Table 2). The methodology involved reviewing the implementation strategies and approaches adopted for each programme, as per the principal sources of climate change impacts anticipated to occur in the watershed, and aimed at identifying potential threats.

Six expected socio-economic and environmental impacts of climate change in the Rio Doce watershed were identified, as reflected in FEAM (2011; 2014) and other studies regarding coastal zone impacts in Espírito Santo (Pirovani, 2014):

i) change in temperature;
ii) decrease in rainfall in the dry season;
iii) long-term droughts;
iv) intense rainfall events leading to flooding or landslides;
v) coastal erosion; and
vi) flooding due to sea level rise in the estuary and surrounding coastal zone.

Table 2
TTAC programmes vulnerable to climate change impacts

PROGRAMME NO. AND TITLE	TEMPERATURE CHANGE	PRECIPITATION REDUCTION	SEVERE DROUGHTS	INTENSE RAINFALLS	COASTAL EROSION	SEA-LEVEL RISE
3 – Protection and restoration of quality of life of indigenous peoples	Not threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Directly threatened
4 – Re-establishment of the quality of life of other peoples and traditional communities	Not threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Directly threatened
8 – Reconstruction of villages	Not threatened	Not threatened	Not threatened	Directly threatened	Not threatened	Not threatened
9 – Recuperation of the reservoir of the Risoleta Neves hydroelectric plant	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
10 – Recuperation of all other impacted communities and infrastructure between Fundão and Candonga	Indirectly threatened	Indirectly threatened	Indirectly threatened	Directly threatened	Not threatened	Not threatened
11 – Recovery of schools and reintegration of school community	Not threatened	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Directly threatened
13 – Tourism, culture, sport and leisure	Indirectly threatened	Indirectly threatened	Indirectly threatened	Indirectly threatened	Indirectly threatened	Indirectly threatened
14 – Physical and mental health of impacted population	Indirectly threatened	Indirectly threatened	Indirectly threatened	Indirectly threatened	Indirectly threatened	Indirectly threatened
16 – Resumption of aquaculture and fishing activities	Directly threatened	Not threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
17 – Resumption of agricultural and livestock activities	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
23 – Tailings management	Not threatened	Not threatened	Not threatened	Directly threatened	Not threatened	Not threatened
24 – Implementation of tailings retention and treatment systems in impacted rivers	Not threatened	Not threatened	Not threatened	Directly threatened	Not threatened	Not threatened
25 – Revegetation, riprap and other methods for river restoration	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
26 – Recuperation of permanent preservation areas (PPAs) and water recharge	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
27 – Springs recovery	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
28 – Biodiversity conservation	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened	Not threatened
29 – Recovery of wild fauna	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
30 – Terrestrial fauna and flora	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
31 – Collection and sewage treatment and destination of solid waste	Not threatened	Not threatened	Not threatened	Directly threatened	Not threatened	Not threatened
32 – Improvement of water supply systems	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
38 – Monitoring of the Rio Doce Basin	Directly threatened	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened
39 – Conservation units	Directly threatened	Directly threatened	Directly threatened	Not threatened	Not threatened	Not threatened

Source: Rio Doce Panel.

Directly threatened | Indirectly threatened | Not threatened

Table 2 lists each of the programmes included in the TTAC for restoration, under Renova's responsibilities, which on assessment by the Panel, show evidence of vulnerability to impacts of climate change. Each of these programmes involves specific actions whose effective outcomes may be threatened by one or more of the six principal impacts expected to occur in the Rio Doce Basin.

The analysis is considered to represent the first tier of a multilevel assessment to distinguish which specific programmes and outcomes could be more susceptible to climate change effects from those that are less so. After review by Renova's internal working groups in consultation with stakeholders and collaborating government entities, the programmes identified as particularly susceptible could then be reinforced and/or redirected as necessary to ensure greater regional resilience to the impacts of climate change. Such reinforcement should give due attention to adaptive capacity. For this reason, other TTAC programmes (notably *6–Social dialogue; 33–Environmental education;* and *34–Preparing for environmental emergencies)* that provide an indirect but transversal role across the remaining programmes were identified, as these could address the need to strengthen adaptive capacities.

As shown in Table 2, not all programmes and outcomes are categorized as being vulnerable to climatic impacts. However, several programme groupings should be given attention to ensure their effectiveness. Of the 42 TTAC programmes, 20 may be directly threatened and three indirectly threatened by some aspect of climate change effects. This section describes some of the potential impacts anticipated by climate change in the basin and how they may affect the results of the TTAC restoration programmes underway.

Environmental programmes, such as those concerned with re-naturalisation of waterways and the isolation and protection of permanent preservations areas (PPAs) and springs, such as:

- *Revegetation, riprap and other methods (25);*
- *Recuperation of permanent preservation areas (PPAs) (26); and*
- *Springs restoration (27)*

provide *ecosystem services* that favour resilience to climate extremes in rural production systems.

While outcomes may be vulnerable, these programmes have the potential to increase resilience and to avert vulnerability if they successfully adapt to climate threats. For instance, the occurrence of severe drought or reduced rainfall can heavily affect the survival of seedlings used in revegetation programmes, resulting in increased costs due to the need to repeat plantings. At the same time, long-term droughts could impair the survival of tree stands and make them more vulnerable to fires. Species selection for drought tolerance and irrigation during the establishment period for such plantings can be included as adaptive measures.

In the case of the *revegetation programme (25)*, floods can damage channel containment structures as well as impede soil conservation on riverbanks and related sediment deposition. Conversely, insufficient rainfall can impede the productivity of agroforestry and rotational pasture systems, while intense rainfall events can wash away topsoil and intensify pasture degradation *(17)*. These adverse effects need to be counterbalanced with efforts to build local capacity to respond to climate extremes with the support of local extension services, where structural interventions may require design adaptation to adjust for extreme rainfall events. Such approaches are in line with successful international experience in integrated landscape conservation and management, which seek to ensure resilience of local agroecosystems to climate change (Scherr et al., 2012).

Renova's Sustainable Land Use component, responsible for coordination of rural interventions in the Rio Doce Basin, has been proactive in ensuring that the measures needed to adapt to potential climate impacts have been taken into account in planning restoration activities. These have involved detailed assessment with georeferencing of ecological, abiotic and socio-economic factors which may affect successful restoration activities, as well as recourse to natural regeneration rather than rely on relatively more risky planting of seedlings. Renova has also paid particular attention to fire hazards in its restoration activities, equipping and training local fire brigades to respond in the event of forest fires.

Other programmes associated with nature conservation, such as

- *Biodiversity conservation (28);*
- *Recovery of wild fauna (29);*
- *Terrestrial fauna and flora (30); and*
- *Conservation units (39)*

can be affected by the rise in temperatures and reduction in precipitation which together combine to raise the risk of fires and other adverse impacts on biodiversity. These changes can also alter species richness and variety and the environmental services they provide, as well as impact extractive economic activities. In the coastal zone and estuarine areas of the watershed, biodiversity conservation objectives can be adversely hampered by sea-level rise, resulting in unwanted effects on nesting sites and migration along shoreline and coastal areas, as well as changes in the marine water biota.

Successfully meeting global objectives for nature conservation and ensure adequate response to predicted climate change implies the need for the creation of additional protected areas in terrestrial and aquatic biomes. An international review of the measures needed to ensure successful species and ecosystem adaptation to climate change shows that more effective approaches imply going beyond the current status of species in a given landscape (Watson et al., 2012). In fact, it is necessary to integrate planning for protected areas to reflect potential adaptation response of species to shifts in climate, and to carefully monitor such responses to adapt these plans over time. In the Rio Doce context, this suggests the need to not only extend the protected area network, but also to plan and prepare adaptive measures as climate change occurs at basin scale. Water supply and stability of water flows are key environmental services promoted by both integrated landscape management and protected areas expansion.

With specific reference to the quality of life of indigenous peoples and other traditional communities addressed by programmes *3* and *4*, they may be affected by reduced water availability due to extended dry spells. This suggests the need to adapt plans for augmented water supply facilities to provide for scarcities.

Furthermore, *reconstruction* of villages *(8)* requires adaptive measures to ensure slope stability under extreme intensive rainfall events that are expected to arise with climate change. Since such impacts would be felt long after the reconstruction programmed under the TTAC has been completed, retrofitting would invariably cause further costs and delays in the delivery of housing. It is encouraging to note that special efforts to protect homes against slope instability have been made by Renova.

Threats to the provision of adequate public health services to support the *physical and mental health of the impacted population (14)* could arise from an increase in temperature, as well as from factors associated with water, whose availability and treatment are essential to public health. Such beneficial services are intertwined with the

Monitoring Rio Doce (October 2019)

Photo: NITRO

programmes on *sewerage and water supply* improvements *(32)*, and *monitoring of the Rio Doce Basin (38),* which can be imperilled by the predicted greater occurrence of extreme events (floods, for instance).

In this context, RDP Issue Paper No. 5 on interconnections between human and ecosystems health recommends that Renova build capacities for monitoring impacts on health and the environment, by enhancing the engagement of community members (Alonso et al., 2020). This capacity building should also involve awareness of the impacts of climate change on health and the environment. The adoption of an integrated human and ecosystem health approach considering climate change, which can be included in Renova's proposed project for Integrated Environmental Management for Health and Environment (*Gestão Ambiental Integrada para Saúde e Meio Ambiente*, or GAISMA) can facilitate the response to this area of climate vulnerability.

Among the cross-cutting programmes, as long as climate change effects are considered effectively integrated into Renova's actions, the outcomes of the programme to *prepare for environmental emergencies (34)* would not be able to counteract all possible scenarios – especially considering that forest fires, droughts and extreme rainfall events are expected to be more recurrent and intense with climate change. In this regard, Renova's support toward preparation of local fire brigades contributed to climate change adaptation.

Consultations with local stakeholders regarding infrastructure or communications networks can be developed through the *social dialogue* programme *(6)* to channel resources where they are most needed. Overall, *environmental education (33)* and social communication are understood to enhance the capacity of a population to adapt and respond to climate change. The paramount importance of social capital, institutional capacities, local leadership and participation of affected people in this sense should be emphasised.

3.3 Carbon sequestration opportunities in natural systems

Globally, deforestation and forest degradation release an estimated 4.4 GgO_2eq per year into the atmosphere (Matthews and van Noordwijk, 2014), or around 12% of anthropogenic CO_2eq emissions (IPCC, 2014a). When agriculture, forestry and other land uses are considered, the contributions account for about 24% of annual global anthropogenic emissions. Avoidance of these emissions, through better conservation and land management actions, is a powerful intervention that can make a significant contribution towards global mitigation efforts (Cohen-Shacham et al., 2016).

In the Rio Doce watershed, where agriculture and land use change have historically been poorly managed, the regeneration of native vegetation is one way to compensate for GHG emissions by absorbing carbon in forests through natural processes. A strategy of landscape restoration would also permit the recuperation of ecosystem functions and processes, renewing water availability for human and animal requirements, as well as rebuilding food webs and microbial action in soils, and diminishing soil erosion. Industrial reforestation is another means to increase forest carbon stocks, but may not result in the same level of restoration of ecosystem functions.

At least 47,850 hectares will be restored under the TTAC agreement, one of the largest landscape restoration efforts in Brazil

The average carbon stock stored in secondary native forests in the Atlantic Forest biome has been found to be 47 tonnes C/ha based on measurements in the Paraiba do Sul River Basin (Ronquim et al., 2014). Lacking more specific monitoring of carbon stocks, this value can be taken to represent the mean above ground carbon sequestration potential of native secondary forests in the Rio Doce watershed. Above ground carbon storage potential is complemented by carbon sequestration in soils under secondary forest regeneration.

Native vegetation restoration technology currently in use in the Rio Doce Basin by Renova emphasises streambank and spring revegetation. Efforts have also been made to enhance hillside vegetation cover through enrichment with native fruit species and other woody plants. The strategic definition of those areas holding greatest physical and socio-economic priority for reforestation and agroforestry included the potential for income generation as well as protection of natural resources and ecosystems (Renova Foundation et al., 2018).

If we consider that at least 42,500[14] hectares are due to be restored under TTAC, this could result in a total additional carbon storage potential of approximately 2 million tC in above-ground biomass

14 Equivalent to the sum of 40,000 ha of permanent preservation areas and water recharge, in accordance with the National Forest Code (pursuant to Clause 161 of TTAC), and revegetation surrounding 5,000 springs (pursuant to Clause 163 of TTAC), each with an average of 0.5 ha.

alone. Although representing a small portion of Brazil's forest-related Nationally Determined Contributions (NDC) commitments under the Paris Agreement of 12 million hectares of net degraded land restoration by 2030 (Brazilian Federative Republic, 2015), this would be one of the largest landscape restoration efforts in Brazil. It represents an aim for which Renova and partner agencies may rightfully claim credit as a climate mitigation contribution. Such opportunities may well attract investment from industries procuring carbon offsets, including those in the mining sector (see section 4.1).

3.4 Energy efficiency, use and generation strategies

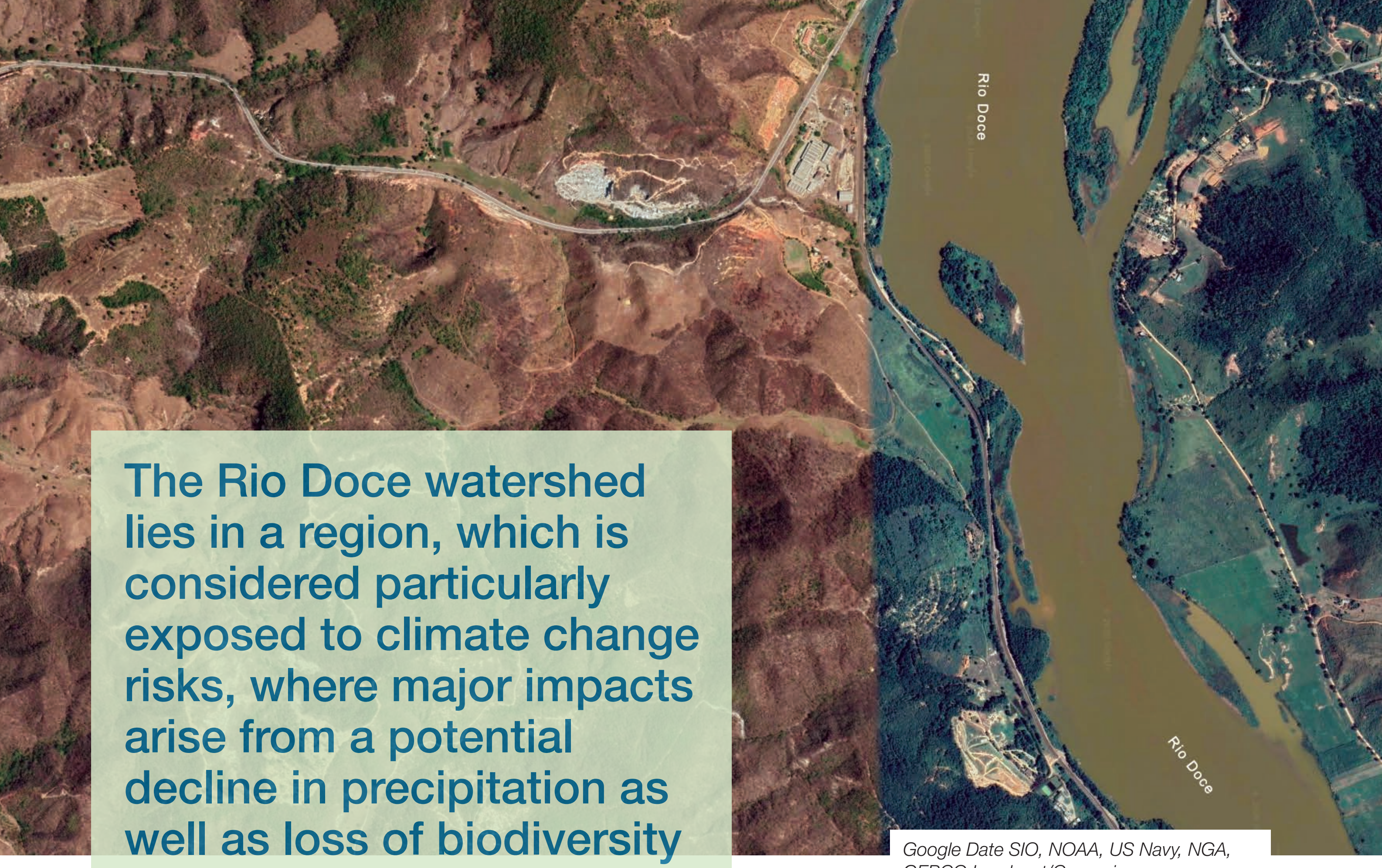
The energy sector is the largest contributor to global GHG emissions, with energy production and use including transport accounting for around two-thirds of global emissions (Crippa et al., 2019). In Brazil, data from the SIRENE national emissions registry system (*Sistema de R*egistro Nacional de Emissões, in Portuguese) reflect that annual emissions from the energy sector, amounting to 422,498 $GgCO_2eq$, had surpassed other individual sectoral sources of emissions, such as land use change and forests, in 2016 when it was last inventoried.[15] This trend is also observable in Minas Gerais, where energy emissions were projected to surpass agricultural sources by 2020 (FEAM, 2015). Similarly, industrial processes and energy emissions had exceeded agricultural, forestry and land use related emissions in Espírito Santo by 2006 (Lorena et al., 2013). Energy-related emissions had thus grown in relative importance for climate change mitigation actions in Brazil.[16]

To measure their contribution to GHG emissions, organizations and enterprises have typically addressed energy consumption by undertaking a GHG emissions inventory and mainstreaming them according to processes, type and quantity of fuels, and their respective emissions levels under current technology. Such emissions are often classified according to their respective scope of measurement: Scope 1 refers to those emissions directly due to an organization's actions and under its direct control; Scope 2 refers to indirect emissions from the acquisition of electric and thermal energy which is consumed by the company; and Scope 3 refers to other indirect emissions, such as extraction and production of raw materials (WBCSD & WRI, 2004). Energy use and generation offer considerable potential for investment in low carbon technologies and initiatives that could stabilize and perhaps even reduce overall GHG emissions, including actions associated with sustainable land use.

There are two pathways among many which can be pursued by Renova: energy efficiency and renewable energy.

- **Energy efficiency (EE)**
  Energy efficiency implies using less energy to achieve the same results. Besides reducing GHG emissions, EE also reduces demand for energy imports, lowering operational costs. Improving energy efficiency is the cheapest, and often the most immediate, way to reduce the use of fossil fuels. There are different opportunities for efficiency improvements in numerous processes conducted by Renova, including, for example, transportation, construction, machinery use in streambank restoration and tailings removal.

15 SIRENE – Sistema de Registro Nacional de Emissões. For further information, please see: https://www.mctic.gov.br/mctic/opencms/indicadores/detalhe/dados_setor_comunicacoes/SIRENE.html
16 It is important to note that this shift in relative importance of sectoral emissions was due to Brazil's success over the period 2005 to 2015 in reducing the rate of deforestation. This success was, however, has reversed since 2015 (SEEG, n.d.).



Google Date SIO, NOAA, US Navy, NGA, GEBCO Landsant/Copernicus

The Rio Doce watershed lies in a region, which is considered particularly exposed to climate change risks, where major impacts arise from a potential decline in precipitation as well as loss of biodiversity

- **Renewable energy (RE)**
  As well as having a large potential to mitigate climate change, RE can provide wider benefits. If implemented properly, RE may contribute to social and economic development, energy access, a secure energy supply and reduction of negative impacts on environment and health (IPCC, 2014). The potential for mainstreaming RE in TTAC programmes must be ascertained and assessed. Some of the alternatives in this area are fuel switching (to renewable or less carbon intensive fossil fuels), solar power generation and wind power generation.

With respect to Renova's processes, energy efficiency and renewable energy should be assessed in light of the 42 TTAC programmes. Although the Panel understands that Renova is already implementing energy efficiency and renewable energy initiatives in several programmes, a coordinated review with a carbon-management perspective would be important.

Experience shows that some initiatives can be easily implemented without significant changes in the programmes' budgets and timetables. On the contrary, some GHG emissions reduction mitigation efforts related to energy can reduce investment costs significantly when correctly planned and implemented. As with carbon sequestration initiatives, interesting funding and image opportunities may arise from energy related mitigation project implementation.

Table 3 addresses each programme that may have direct opportunities for GHG emissions reductions related to energy efficiency and renewable energy, and presents possible actions that can be implemented.

Table 3
Opportunities for promoting/increasing energy efficiency and renewable energy use across selected TTAC programmes

PROGRAMME NO. AND TITLE	ENERGY EFFICIENCY (EE)	RENEWABLE ENERGY (RE)
8 – Reconstruction of villages	• Use less energy in construction through energy efficient processes and machinery • Consider adapting EE in the projects of the houses to be built	• Consider: – installing solar energy in the buildings – installing RE plants for community energy generation such as: wind power, solar power, waste-to-energy plants
9 – Recovery of the reservoir of the Risoleta Neves (Candonga) hydroelectric plant	• Use less energy in the construction through energy-efficient processes and machinery	• Consider: – installing solar energy in the Risoleta Neves (Candonga) site – switching fuel in internal and external transportation (e.g. biodiesel or ethanol)
10 – Recovery of all other impacted communities and infrastructure between Fundão and Candonga	• Use less energy in the constructions through energy efficient processes and machinery • Consider adapting EE in the projects of the houses to be built	• Consider: – installing solar energy in the buildings – installing RE plants for community energy generation, such as: wind power, solar power, waste-to-energy plants
11 – Recovery of schools and reintegration of school community	• Use less energy in the constructions through energy efficient processes and machinery • Consider adapting EE in the projects of the houses to be built	• Consider using solar energy in the schools to be recovered
16 – Resumption of aquaculture and fishing activities	• Consider adapting EE in the projects	• Consider using solar energy in the sites
17 – Resumption of agricultural and livestock activities	• Consider EE in the projects	• Consider using solar energy and waste-to-energy biodigesters in the sites
18 – Development and economic diversification	• Consider adapting EE in the projects	• Fuel switch in transportation
19 – Recuperation of micro and small business	• Consider adapting EE in the projects	• Consider solar energy in the sites
23 – Tailings management	• Consider adapting EE in the projects	• Consider solar energy in the sites
24 – Implementation of tailings retention and treatment systems in impacted rivers	• Use less energy in construction through energy efficient processes and machinery	• Fuel switch in transportation
26 – Recovery of permanent preservation areas (PPAs) and water recharge	• Use less energy in construction through energy efficient processes and machinery	• Fuel switch in transportation
27 – Springs recovery	• Consider using more energy efficient innovative treatment systems	• Fuel switch in transportation
31 – Collection and sewage treatment and destination of solid waste	• Consider using more energy efficient innovative treatment systems	• Consider solar power generation and waste-to-energy
32 – Improvement of water supply system	• Consider using more energy efficient innovative treatment systems	• Consider solar power generation
33 – Environmental education to revitalize Rio Doce Basin	• Include EE in the curricula	• Include RE in the curricula

Source: Rio Doce Panel.

4 | Exploring alternative paths

4.1 Financing arrangements for climate action

In 2018 and 2019, the number of carbon pricing[17] initiatives around the world increased and existing systems were strengthened. Governments raised approximately US$ 44 billion in carbon pricing revenues in 2018 (World Bank, 2019). A national carbon pricing scheme for Brazil to stimulate such investment has recently been proposed by industrial coalitions (CEBDS & CPL, 2018). These governmental initiatives, among other GHG emissions reduction opportunities, ranging from carbon taxation to emission trading systems, generate several distinct modalities for carbon finance, including offset of emissions in other industries through carbon sequestration, renewable energy or energy efficiency projects.

One such example is the mining industry, which generates significant emissions which can be subject to governmental carbon pricing mechanisms. These industries could in part offset their emissions through forestation programmes and clean energy related initiatives, investing in projects in Brazil or elsewhere in the world. If developed with local partners, project revenues from such investment could then be re-invested in local communities for capacity building and preventive actions for climate change adaptation, as well as further mitigation efforts. At the global level, the Green Climate Fund (2019) has been established by the UNFCCC as a source of financing for climate adaptation by the public and private sector in developing countries (Green Climate Fund, n.d.). Green investment funds have also been created (Sullivan, 2020).

Carbon finance continues to play a role in forest restoration efforts which, after a decline in the scale and pricing of carbon markets, is regaining force with the recent implementation of carbon pricing mechanisms by several countries. One of the initiatives that can benefit from the carbon markets is the creation of Payments for Environmental Services (PES) schemes, a mechanism which has also been adopted by Renova in its restoration activities with private landowners to compensate their efforts to conserve and restore streambank forests. In Brazil, offsetting GHG emissions by financing natural forest restoration efforts is also enabled through existing legislation,[18] which brings opportunities to restore degraded areas.

Success in restoring and regenerating native vegetation will rely on landowners' willingness to dedicate part of their land to this purpose, and thus contribute actively towards its successful restoration. In order to boost such actions, the CIF Technical Chamber for Forest Restoration and Water Production (*Câmara Técnica de Restauração Florestal e Produção de Água*, or CT-Flor) and Renova Foundation have designed a PES initiative aimed to support and stimulate rural property owners' adhesion, through which producers are given an incentive of up to BRL 252[19] per hectare per year.[20]

17 According to the United Nation Framework Convention on Climate Change (UNFCCC), carbon pricing curbs greenhouse gas emissions by placing a fee on emitting and/or offering an incentive for emitting less. The price signal created shifts consumption and investment patterns, making economic development compatible with climate protection. For further information, please see: https://unfccc.int/about-us/regional-collaboration-centres/the-ci-aca-initiative/about-carbon-pricing#eq-1.

18 The national Forest Code (Law 12.651/2012) provides for trading of areas protected as Legal Reserves between landowners, and carbon trading is also permitted within the framework of the national plan for climate change.

19 At an exchange rate of BRL 4.5 = US$ 1, this amount is equivalent to about US$ 56 per hectare.

20 For further information, please see: https://www.fundacaorenova.org/en/news/payment-for-environmental-services-psa-will-compensate-rural-landowners-who-promote-environmental-recovery-actions/

It must be highlighted, however, that an important part of the success of PES approaches is the continuity of payments to ensure the protection and monitoring of onsite carbon stocks and/or water or other ecosystem services, as well as to target payments to prioritise where they will deliver greatest social and environmental benefit (Pagiola et al., 2012).[21] In this regard, Renova could identify other industries' offset opportunities and create funding mechanisms that can guarantee long-term funds for PES.

4.2 Nature-based Solutions for climate adaptation

IUCN defines NbS as: "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016). This indicates that NbS implies going beyond the mere enjoyment of ecosystem services to proactively enhancing the capability of ecosystems to provide those services essential to human well-being. NbS are framed to deal with specific applications of the ecosystem approach, when the management or restoration of ecosystem functions can play a key role in helping address societal challenges such as adaptation to climate change.

During the last century, humankind has undertaken to replace natural infrastructure like forests that are effective in providing clean water, with man-made infrastructure like dams that store water and sediments and levees against flooding. More often than not, such man-made structures were not designed to bear the effects of climate change or calamitous storm events. Hence, the maintenance of such structures and facilities has been increasingly risky to human societies. NbS seek to address these risks, in some cases by re-naturalizing watercourses and removing man-made obstacles to the flow of water and other critical ecosystem services.

The role of NbS as a support to climate change adaptation should therefore heed the potential to deliver a 'bundle' of ecosystem services, including for example accumulation of carbon stocks, biodiversity conservation and water provision. Similar measures adopted in other countries which could potentially serve as models for Renova's actions are described in case studies appraised using the IUCN NbS Framework (Andrade Pérez et al., 2010; Cohen-Schacham et al., 2019).

Some of the TTAC's environmental programmes' approaches and outcomes could be associated with objectives and goals related to NbS, such as the *restoration of springs* (26) and *permanent preservation areas* (27), as well as the consolidation of *conservation units* (39). Indeed, the TTAC-inspired goal of restoring 47,850 hectares of native forest may be insufficient to satisfy the many demands for ecosystem services throughout the Rio Doce watershed, but its effectiveness can be reinforced by strategic intervention in the landscape, as well as with the adoption of complementary NbS practices and approaches.

Another example of an NbS approach that Renova is already conducting within the *tailings management* (23) programme is that of the re-naturalisation of watercourses in portions of the Gualaxo do Norte watershed.[22]

21 For further information, please see May et al. (2019) for a description of PES programmes in Minas Gerais and Espírito Santo that have contributed to the design of TTAC's PES programmes.
22 See: https://www.fundacaorenova.org/dadosdareparacao/terra-e-agua/

Preparing seedlings for replanting native vegetation at Instituto Terra, in partnership with Renova Foundation to replant trees and recover springs along the Rio Doce.

Photo: NITRO

5 | Conclusions and recommendations

Based on the data and information presented in this report, the Panel has arrived at the following conclusions:

- Available climate models point to a rising average surface temperature and alterations in rainfall regimes over the entire Rio Doce Basin in the long term. On the coast, floods due to sea-level rise and coastal erosion are expected, although no detailed predictions of climate change are yet available for Espírito Santo.
- The impacts derived from the Fundão Dam failure contribute to the increase of the territory's vulnerability by exacerbating exposure and sensitivity to risk factors associated with climate change adaptation, particularly in relation to livelihoods and human and ecosystem health.
- Over half of the 42 TTAC programmes present objectives or outcomes which are potentially threatened by or compromised by the predicted effects of climate change, in particular those associated with water resource scarcity or extreme rainfall events. Although Renova has taken appropriate steps to avoid climate vulnerability in several of these programmes, some would be imperilled by predicted climate change.
- Several TTAC programmes and their long-term maintenance can contribute to GHG emissions mitigation through adoption of appropriate technologies for energy use and generation.
- Proliferation of global carbon pricing mechanisms offers several opportunities for financing arrangements for climate action.
- Renova is already implementing NbS that can contribute to climate adaptation, forest restoration and emission reduction that can benefit from carbon finance and can be enhanced to guarantee long-term implementation and investments in capacity building and preventive actions for climate change adaptation as well as further mitigation efforts.

In light of these findings and drawing on the recommendations of its first thematic report, the Panel recommends that Renova Foundation addresses potential long-term threats posed by climate change to the effectiveness and sustainability of its programmes' numerous outcomes, and thereby contribute to transition toward a low carbon economy at the watershed level as part of its legacy.

To achieve these objectives, the Panel urges Renova to extend full cooperation with its stakeholders and partner institutions, including public prosecutors and the judiciary, to integrate climate change considerations into its programmes and to strengthen local and state capacities for climate adaptation.

The sustainability of the TTAC programmes ultimately depends on an appropriate response to impending climate change. Subsequently, the Panel proposes the following recommendations:

Recommendation 1

Initiate a dialogue towards the development of a Rio Doce Watershed Climate Action Plan

Recognising that Renova cannot be held responsible for factors associated with mitigation and adaptation to climate change in the Rio Doce Basin, the Panel recommends that Renova convenes an **inter-institutional working group.** Together with representation from the two state governments, sectoral representatives, public prosecutors and the judiciary, as appropriate, they would consider first and foremost the potential threats posed by climate change to successful outcomes of TTAC programmes and subsequently develop a climate action plan for the watershed. The working group would focus initially on adaptation measures, definition of emission reductions projects, as well as identification of financial opportunities related to climate action for the watershed.

Convening of such a working group could be coordinated by the Rio Doce Watershed Committee. Recognising the need to take into account the Rio Doce Basin as a whole, within a source-to-sea system, the Panel recommends that efforts the adoption of a unified catchment area strategy for assessment and adaptation to climate change effects.

Recommendation 2

Propose that CIF and other entities mainstream climate change within a timely review of relevant TTAC programmes

Involving CIF members and participating entities in carefully revisiting the TTAC programmes and the interactions among them with a climate change perspective is expected to lead to an improvement in the synergies between the programmes. This will help ensure long-term results to society and nature in the Rio Doce Basin from the implementation of TTAC programmes, by promoting:

- greater resilience to extreme climate events in the long term for the restoration actions;
- identification of emission reduction projects that could be implemented, beyond those already in place;
- adoption of strategic objectives for climate action based on discussion of possibilities, prioritisation of options and setting goals to achieve programmes' implementation;
- development of inventories of carbon withdrawals and additions resulting from restoration actions, which will show the proactive role of the overall restoration effort to support adaptive readiness to expected climate change and extreme events;
- assessment of the carbon footprint of operations conducted by Renova, including net carbon additions/withdrawals to regional ecosystems and technological low carbon options. As part of the assessment of climate change threats and opportunities associated with restoration actions, the realisation of carbon accounting would permit a strategic identification of those actions whose climate mitigation effects are most significant; and
- identification of possible financial opportunities for already on-going programmes, such as PES and other services.

Recommendation 3

Adopt Nature-based Solutions when considering technological alternatives for remediation, restoration and compensation

An NbS approach should be adopted to guide principles of restoration of ecosystem functions and services, including carbon sequestration. This was the case of the re-naturalisation of water courses conducted by Renova in portions of the Gualaxo do Norte watershed. Such an approach could be extended to the pursuit of NbS rather than infrastructure approaches that are intensive in earth moving and construction, implying heavy use of fossil fuels, for example in tailings removal.

The utilisation of natural processes as a basis to prioritise restoration interventions represents a means not only to ensure greater resilience to climate extremes (owing to greater diversity of natural ecosystems), but can also be significantly less costly than those grounded in material capital investment. Adopting an NbS approach implies the need to compare such options for restoration with those based on conventional techniques to ascertain their relative costs and benefits, as well as their expected effectiveness in responding to extreme climate events.

Recommendation 4

Invite state and local governments to build capacity and undertake actions to prepare for adaptation to climate change

The key to a successful preparation for extreme climate events is the development of capacity at the state and local levels. Currently, climate vulnerability, impacts assessment and planning processes have been conducted by Minas Gerais at a statewide and microregional level, but a parallel assessment and plan are lacking in Espírito Santo. In both cases, such studies and instruments should be based on a participatory process and be subject to regular review and revision to inform state and local authorities and other relevant stakeholders as well as serve as a basis for climate actions.

Some examples of adaptation measures include restrictive zoning of areas at risk owing to slope instability, emergency warning and escape routes, etc. In some cases, such actions are similar to those which were needed to respond to the Fundão Dam collapse. However, capacity building for climate adaptation will need to consider the worst-case scenarios of climate extremes in the long term, and to provide for such variations.

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Annex Definition of selected terms

Adaptation In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2018a, p. 556).

Anthropogenic Resulting from or produced by human beings (IPCC, 2018a, p. 556).

Anthropogenic forcing All human-related factors that cause climate change (Myrrhe et al., 2013).

Business-as-usual (BAU) or baseline scenario Expectation that state variables, for example in the economy and policy setting, will remain unchanged as they are in the baseline (IPCC, 2018a, pp. 543–544).

Carbon market A trading system through which countries may buy or sell units of greenhouse gas emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or under other agreements, such as that among member states of the European Union. The term comes from the fact that carbon dioxide is the predominant greenhouse gas, and other gases are measured in units called ‘carbon-dioxide equivalents’ (UNFCCC, n.d.).

Carbon sequestration The process of removing carbon from the atmosphere and depositing it in a reservoir (UNFCCC, n.d.).

Climate change Climate change refers to a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Article 1 of the Framework Convention on Climate Change (UNFCCC) defines climate change as ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.’ The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes (IPCC, 2018a, p. 544).

Climate model (modelling) A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties. The climate system can be represented by models of varying complexity; that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrizations are involved. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and inter-annual climate predictions (IPCC, 2018a, p. 545).

Climate system The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land-use change (IPCC, 2018a, pp. 545–546).

CO_2eq equivalent (CO_2-eq) The amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs. There are a number of ways to compute such equivalent emissions and choose appropriate time horizons. Most typically, the CO_2-equivalent emission is obtained by multiplying the emission of a GHG by its global warming potential (GWP) for a 100-year time horizon. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas. CO_2-equivalent emission is a common scale for comparing emissions of different GHGs but does not imply equivalence of the corresponding climate change responses. There is generally no connection between CO_2-equivalent emissions and resulting CO_2-equivalent concentrations (IPCC, 2018a, p. 546).

Ecosystem A dynamic complex of vegetable, animal and microorganism communities and their non-living environment that interact as a functional unit. Ecosystems may be small and simple, like an isolated pond, or large and complex, like a specific tropical rainforest or a coral reef in tropical seas (IUCN, n.d.).

Ecosystem services Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fibre, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation (IPCC, 2018a, p. 548).

Exposure The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2012, p. 559).

Global warming The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or a 30-year period centred on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue (IPCC, 2018a, p. 550).

Global-warming potential (GWP) The relative potency, molecule for molecule, of a greenhouse gas, taking account of how long it remains active in the atmosphere. The global-warming potentials (GWPs) currently used are those calculated over 100 years. Carbon dioxide is taken as the gas of reference and given a 100-year GWP of 1 (Eurostat, n.d.).

Greenhouse effect The process in which the absorption of infrared radiation by the atmosphere warms the Earth. In common parlance, the term 'greenhouse effect' may be used to refer either to the natural greenhouse effect, due to naturally occurring greenhouse gases, or to the enhanced (anthropogenic) greenhouse effect, which results from gases emitted as a result of human activities (IPCC, 2012, p. 560).

Greenhouse gas (GHG) Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2018a, p. 560).

Köppen-Geiger Climate classification The Köppen-Geiger system classifies climate into five main classes and 30 sub-types. The classification is based on threshold values and seasonality of monthly air temperature and precipitation. […] The first version of this classification was developed in the late 19th century. It is still widely used today for many applications and studies conditioned on differences in climatic regimes, such as ecological modelling or climate change impact assessments (Beck et al., 2018).

Mitigation (of climate change) A human intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC, 2018a, p. 554).

Nationally Determined Contribution (NDC) A term used under the United Nations Framework Convention on Climate Change (UNFCCC) whereby a country that has joined the Paris Agreement outlines its plans for reducing its emissions. Some countries' NDCs also address how they will adapt to climate change impacts, and what support they need from, or will provide to, other countries to adopt low-carbon pathways and to build climate resilience. According to Article 4 paragraph 2 of the Paris Agreement, each Party shall prepare, communicate and maintain successive NDCs that it intends to achieve. In the lead up to 21st Conference of the Parties in Paris in 2015, countries submitted Intended Nationally Determined Contributions (INDCs). As countries join the Paris Agreement, unless they decide otherwise, this INDC becomes their first Nationally Determined Contribution (NDC) (IPCC, 2018a, p. 554).

Nature-based Solutions Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (IUCN, 2016).

Paris Agreement The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is 'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels', recognising that this would significantly reduce the risks and impacts of climate change. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts of climate change. The Paris Agreement is intended to become fully effective in 2020 (IPCC, 2018a, p. 555).

Payments for ecosystem services Market-based approaches using payments or rewards to encourage or discourage specific practices in natural resources management (IUCN, n.d., p. 54).

Permanent preservation areas Protected area, covered or not by native vegetation, with the environmental purpose of preserving hydric resources, the landscape, the geological stability and biodiversity, to facilitate the gene flow of fauna and flora, to protect the soil and guarantee human well-being (translated from Brazilian Forest Code, Law 12.651/2012) (Government of Brazil, 2012).

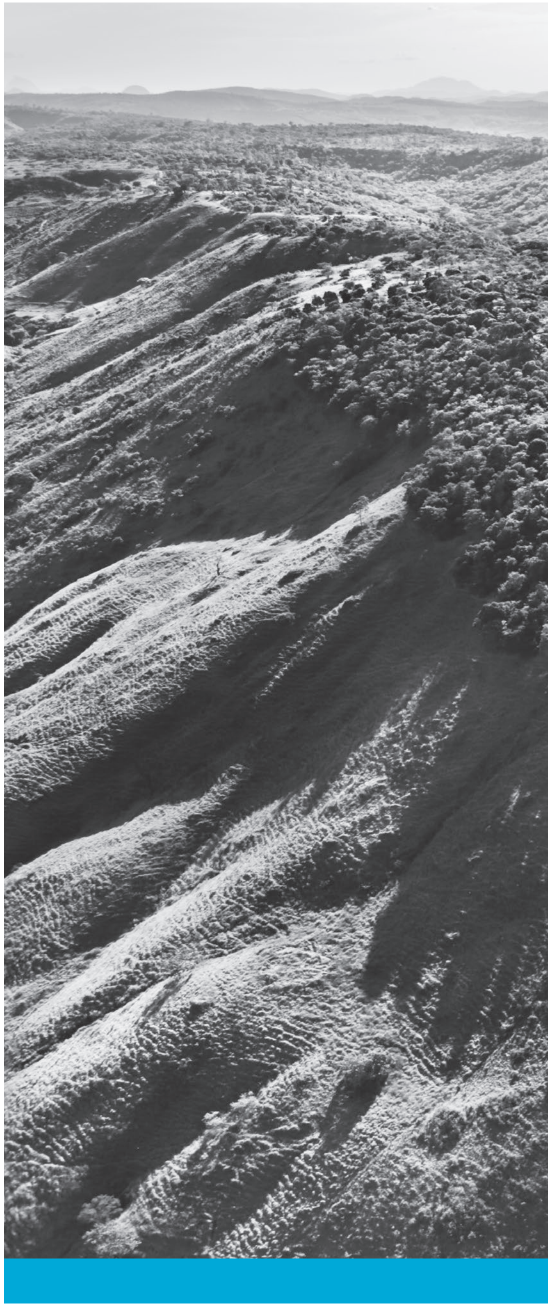
Protected area An area of land and/or sea especially dedicated to the protection of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN, 2011, p. 59).

Restoration (of ecosystems) All of the key ecological processes and functions are re-established and all of the original biodiversity is re-established (IUCN, 2011, p. 64).

Silviculture The art and science of producing and tending forests by manipulating their establishment, species composition, structure and dynamics to fulfil given management objectives (IUCN, 2011, p. 68).

United Nations Framework Convention on Climate Change The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement (IPCC, 2018a, pp. 559–560).

Vulnerability The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2018a, p. 560).



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