Sleeping Financial Giants

Opportunities in financial leadership for climate stability

A REPORT FROM THE EARTH SYSTEM FINANCE PROJECT

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ABOUT THE REPORT

'Once climate change becomes a clear and present danger to financial stability it may already be too late to stabilize the atmosphere at two degrees.'

Mark Carney, *6 April 2018.*

Mark Carney, chair of the G20 Financial Stability Board and governor of the Bank of England, argues that climate change risks may destabilize international capital markets. The destabilization may arise from political turbulence, forced migration, extreme events such as hurricanes and droughts, or stranded assets as economies transition to a zero-carbon future. But capital markets can, and do, also have a direct impact on how the climate change challenge evolves, most directly through investment in fossil fuel infrastructure and companies with high-carbon footprints. However, there are other more hidden impacts, and this is the focus of this report. Emerging insights from Earth System science show that there are key regions in the Earth System that have the potential to rapidly change state if they are pushed too far, with the potential of destabilizing Earth's climate and exacerbating global warming. These are generally referred to as 'tipping elements'. The implications for the global climate if these regions 'tip' raise new and urgent concerns that are of critical importance for the financial sector and humanity at large. These are the reasons for Mark Carney's growing concern about climate change.

This report has two primary aims. The first is to introduce to the financial sector the notion of tipping elements and to provide a short, state-of-the-art review of the scientific knowledge surrounding this rapidly evolving field of enquiry. Second, it makes explicit the links between the investment sector and such tipping elements, and outlines a preliminary approach for how to examine such links using two cases: the Amazon rainforest and the boreal forests of Russia and Canada.

Our focus on the forested tipping elements (the Amazon rainforest and the vast boreal forests of northern high latitudes) is motivated by the fact that these biomes represent tipping elements that lie at the intersection between high vulnerability to tipping in the next few decades and increasing human pressures, and where the financial sector is playing a crucial role in supporting these pressures. But the financial system can also provide an important lever to help ensure the stability of these tipping elements.

The report concludes that the Amazon rainforest, boreal forests and other identified tipping elements are now systemic risks for the global financial system. If the internal dynamics of these large regions change, leading to the soils and forests emitting large volumes of carbon into the atmosphere, then stabilizing the climate in the future will become significantly more difficult, affecting financial stability. Action now, and in the next decade, can greatly reduce this global systemic risk.

Time is short. Financial actors, and humanity at large, need to wake up and recognize that the emerging insights of tipping dynamics and nonlinear change in the Earth System present additional, novel and urgent challenges.

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The content of the report has been reviewed by experts from various fields, including;

Will Steffen, emeritus professor, Australian National University (ANU). Former director of the ANU Climate Change Institute and a member of the Australian Climate Commission.

Tim Lenton, professor, director of the Global Systems Institute, University of Exeter.

Carlos Nobre, professor of the Institute of Advanced Studies, University of São Paulo (USP), and former director of the Centre for Earth System Science, National Institute for Space Research (INPE), Brazil. Also former national secretary for research and development policy in the Ministry of Science, Technology & Innovation of Brazil.

Bert Scholtens, professor at the Faculty of Economics and Business, University of Groningen, Netherlands, and professor in finance at the School of Management at the University of St Andrews, United Kingdom.

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Anders Nordheim, UNEP Finance Initiative programme leader – Ecosystems and Sustainable land use.

Despite expert review, please note that any opinions, findings and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the funders or the reviewers.

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EXECUTIVE SUMMARY

Perhaps the most profound challenge today is to safeguard a prosperous future for people on Earth, through ensuring a relatively stable climate, now and for generations to come.

The last 10,000 years have been marked by a period of unparalleled climate stability. It is during this geological epoch – the Holocene – that human civilizations have evolved and thrived. As the global population heads towards 10 billion people in 2050, we rely on this stable state of the Earth System – composed of the atmosphere, oceans, ice sheets, forests and tundra – to ensure essential supplies of food, water and energy. But its stability and resilience are now at risk.

The rate of change of the Earth System is currently entirely driven by human action, and it is accelerating. In 2000, Earth System scientists compiled data showing Earth's processes had gone beyond Holocene boundaries and they proposed Earth had entered a new geological epoch: the Anthropocene.

Earth System science is a rapidly growing research domain which has begun to uncover so called 'tipping elements' in the Earth System. Tipping elements refer to large-scale components of the Earth System that may pass a tipping point, or critical threshold, where they change into a very different state; for example, the Arctic changing state from having ice in summer to having none, or large parts of the Amazon forest turning into savanna. Some of these tipping elements have also been referred to as 'sleeping giants', because once awakened they can have large-scale impacts on the global climate by becoming large-scale emitters of carbon dioxide, as opposed to storing carbon in soil and vegetation. As an active area of research, uncertainties remain regarding the quantification of the thresholds and impacts of tipping elements. But there is a broad consensus that the further and faster the Earth System is pushed into a warmer state, the greater the risk of surprises.

Two tipping elements of particular relevance for the global carbon cycle, and therefore the climate, are the Amazon rainforest and boreal forests. These biomes are highly vulnerable to tipping in the next few decades, and their state also depends on increasing human and economic pressures.

The Amazon rainforest could cross a tipping point where parts become much dryer savanna, if temperatures rise 3-4°C, or if deforestation reaches approximately 25%. However, with the combined stress of rising temperature, deforestation and increased forest fires, the tipping point may be reached significantly earlier. To date, almost 18% of the Amazonian basin has been deforested.

The world's boreal forests are one of the fastest warming regions on Earth and may face temperatures 6°C higher than pre-industrial temperatures in the near future. This will cause drying, thawing and increased risk of vast fires, emitting millions of tonnes of carbon into the atmosphere. A tipping point is currently estimated to lie somewhere around a 3-5°C rise in global average temperature. Forest management can help reduce this risk.

There are more risks of crossing tipping points: notably, the risk of creating a domino effect where crossing one pushes the world closer to another. Should we overshoot the 2°C target, the risk rapidly grows of catalysing a 'tipping cascade' that could drive climate change irreversibly towards a +4°C (or higher) rise in temperature, leading to much higher sea levels.

The finance sector is implicated in contributing to climate change by enabling economic activities that create greenhouse gas emissions but also through various forms of land-use change. This is an important reason why many investors should, and increasingly do, take responsibility. But while engagement of the financial sector with the climate challenge is at an all-time high, awareness and understanding of tipping points in the Earth System – and how investors may be affecting them – remain low.

This reports shows that financial markets are threatening to push some sleeping giants towards their tipping points. Investors provide capital to and own shares in companies producing soy, beef, timber and other commodities that constitute incremental drivers behind the deforestation and forest degradation that undermine the stability and resilience of these forests. We find that a handful of stockholders own substantial shares across the

largest companies in the most implicated sectors. The total holdings of these investors reach above the 10% threshold in three out of eight companies in the Amazon, four out of nineteen in Canadian boreal forests, and three out of five in Russian boreal forests. We refer to these institutional investors with a global reach as 'financial giants' – as they have a great but unrealized power to influence the resilience of several Earth System sleeping giants. They could influence stronger corporate governance of the companies in their portfolio, for example promoting effective zero deforestation in supply chains, rehabilitation of degraded forests, reforestation, afforestation and forest management practices protecting biodiversity.

The Amazon rainforest, boreal forests and other tipping elements can now be considered systemic risks for the global financial system. Financial assets are at risk not only from the possibility of changing climate policy (e.g., stranded assets and future price of carbon), but also from the impacts of climate change themselves – which may be large-scale and abrupt, especially in the case of tipping points. **Therefore, efforts to avoid dangerous climate change have to include both reductions of greenhouse gas emissions while simultaneously bolstering the resilience and stability of these key tipping elements.** While the financial sector has mobilized to address greenhouse gas reduction, there has been very limited recognition of nonlinear Earth System dynamics in the strategies and risk scenarios developed to guide sustainable investment.

Finance cannot be made single-handedly responsible for a transition to climate sustainability, but it can and must play a critically important role. By taking responsibility and using power and leadership for the good of the planet and their portfolio, financial actors could contribute meaningfully to an emerging and necessary pathway towards biosphere stewardship and climate stability. Yet time is short – financial actors, and humanity at large, need to wake up and recognize the new and urgent challenges posed by nonlinear dynamics in the Earth System.

INTRODUCTION

'The straw that broke the camel's back.'

The notion of tipping points has existed for a long time, as evident from idioms and sayings in many cultures. The proverbial 'straw that broke the camel's back' is possibly the most well-known. The Oxford English Dictionary defines a tipping point as, 'The point at which a series of small changes or incidents becomes significant enough to cause a larger, more important change.' The Cambridge Dictionary provides additional nuance by stating; 'the time at which a change or an effect cannot be stopped'. Scientifically, a tipping point can be defined as a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system[1]. In other words, small change can make a big difference.

Meet the sleeping giants

Scientists studying the deep past have uncovered evidence of large-scale and rapid shifts in climate. As knowledge of climate tipping points grows, this has become an important part of climate change research[2]. The particular components of the Earth System* and associated processes identified as likely tipping elements include melting sea ice and Greenland and Antarctic ice sheets, changes in ocean and atmospheric circulation, and loss or alteration of critical biomes (large ecological regions). Many of these regions and processes are changing rapidly due to human pressures[3,4]. Researchers have demonstrated, either through past evidence, current observations and climate models, or all of them, that they can flip to new states abruptly and with little immediate warning. As such, they can cross tipping points, rapidly changing their internal dynamics and driving feedbacks that subsequently affect the climate. For this reason, tipping elements, including those that relate to the carbon cycle and have the potential to accelerate the rate of warming beyond that attributed to human emission of greenhouse gases, have also been referred to as sleeping giants[5].

* This report uses the term Earth System, originally adopted by the International Geosphere–Biosphere Programme[7], to emphasize that the various subsystems, including the hydrological system and atmospheric circulation, are nonetheless all part of one single system – the Earth System.

Box 1. **Tipping points and scientific uncertainty**

Research on tipping points has expanded rapidly in the last 25 years. As an active area of research uncertainties remain. Current computer climate models used by researchers do not include, or fully represent, all known processes that may affect the climate, nor all the interactions that contribute to a self-stabilizing Earth System. In addition, we know climate models do not, of course, include unknown processes that may be relevant for climate stabilization. For these reasons there is a broad consensus in the research community that the further and faster the Earth System is pushed into a warmer state, the greater the risk of surprises[3].

A recent assessment of climate outlined five uncertainties relating to tipping points[3]:

1. whether proposed tipping elements , for example Arctic sea ice or coral reefs, actually tip and pass a threshold where they undergo a transition to a different state;
2. the magnitude and timing of forcing that will be required to initiate such transitions in tipping elements;
3. the speed of the transition once it has been triggered;
4. the characteristics of the new state resulting from such transition; and
5. the potential for new tipping elements to exist that are yet unknown.

In addition, recent research also highlights the risks of cascading tipping points – that is, once one tipping element transitions into a new state, it may lead to the tipping of others, like a domino effect[6].

Some of the feedbacks associated with individual tipping elements and their interrelations can be quantified with high confidence, while others are known but cannot be quantified, and still others may exist that are yet currently unknown[3].

Sleeping giants of particular concern are the vast tracts of Amazonian and boreal forests, which are sensitive to rising temperatures and changes in rainfall. But in addition, these regions are under intense pressure from human economic activities, such as logging, mining and conversion to agriculture production.

Knowledge about the state of these sleeping giants is important for defining thresholds for dangerous climate change, not least because if one giant wakes, it may wake others, making our ability to control the climate within manageable boundaries more difficult[6]. The scientific consensus is therefore that sleeping giants should remain asleep.

Current financial markets are threatening to wake at least some of these sleeping giants. Investors provide capital to companies producing soy, beef, timber and other commodities that constitute incremental drivers behind the deforestation that undermines the stability of sleeping giants, such as the Amazon rainforest and the boreal forests. But the notion of sleeping giants, and the role of the financial sector in pushing them towards tipping points that could jeopardize climate stability, has not been widely discussed.

This report examines the latest evidence for tipping points in the Earth System. We highlight the risks of crossing them and, more notably, of creating a domino effect where crossing one pushes the world closer to another. Homing in on two sleeping giants, the Amazon rainforest and boreal forests of Russia and Canada, we also outline how the financial system can be linked to these through investments in corporate activities that are currently threatening to push these giants over the edge.

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THE STATE OF THE EARTH SYSTEM

'One of the most profound and rapid transformations in the history of the planet has occurred since 1950.'

Steffen and **colleagues,** in 'The trajectory of the Anthropocene: The Great Acceleration' (2015)

Stability and human prosperity

Around 10,000 years ago our ancestors began a remarkable societal transformation from hunting and gathering to becoming sedentary farmers. Villages sprouted up along with engineered irrigation systems. Societal hierarchies grew and the first cities emerged.

It is no coincidence that human development occurred as Earth's climate became markedly less variable. In the last 10,000 years, global average temperatures have fluctuated only plus or minus 1°C[1]. But this is unusual. Over the last 2.6 million years the climate has been remarkably unstable, oscillating between deep, long ice ages and short periods of relative warmth[2]. Before this unstable period, Earth's climate settled into very stable states that were either significantly warmer than today (+4°C), with little or no ice at the poles and sea levels up to 70 m higher, or deep freezes further back in geological time.

Geologists call the most recent period of climatic stability the Holocene. It has served humanity very well by allowing the development of modern agriculture and advanced civilizations[3, 4], thus greatly improving overall human well-being. As the global population heads towards 10 billion people in 2050 and beyond, we rely on this stable state of the Earth System – composed of the atmosphere, oceans, ice sheets, forests and tundra – to ensure essential supplies of food, water and energy. But the stability and resilience of the Earth System is now at risk.

The Great Acceleration

By 1800, the global population reached 1 billion people and the Industrial Revolution took firm hold in the UK, then in Europe. Population growth accelerated, economic development geared up, driven by cheap abundant fossil fuels, and people began swarming to cities. This fuelled creativity and innovation in commerce and the sciences, and enormous growth[4].

New artificial fertilizers, coupled with new machinery, led to agricultural intensification and the world now had the resources to feed vastly more people. But it was not until after the Second World War that the industrial revolution went into overdrive. This has been referred to as the Great Acceleration because of the exponential growth and intensification in many social and biophysical processes (Figure 1). During the past two centuries, the global population increased more than seven-fold to approximately 7.6 billion today, with over half of us living in cities. Yearly economic output grew some 100-fold to over $60 trillion[5].

From international tourism and foreign direct investment to population and GDP, the pace and scale of change moved from incremental to exponential (Figure 1). Despite growing inequalities, the Great Acceleration has delivered huge improvements in human well-being for many parts of the world population, but this has come at a cost: the resilience of our planet. In other words, the Earth's ability to absorb shocks and remain in its current state is reducing rapidly[6, 7].

Entering a new epoch – the Anthropocene

The world has experienced five mass extinction events in the past and current extinction rates indicate we may be moving towards the sixth[8]. Ocean acidification is occurring at rates unprecedented in the past 300 million years, and there is no evidence that the climate change of the last 50 years has been caused by anything other than human emissions [3, 9, 10, 11].

In 2000, Earth System scientists compiled data showing Earth's processes had gone beyond Holocene boundaries[12, 13]. They proposed Earth had entered a new geological epoch, the Anthropocene. This concept was further reinforced in 2004 with the publication of a major academic synthesis, Global Change and the Earth System by the International Geosphere-Biosphere Programme[14]. Now, evidence

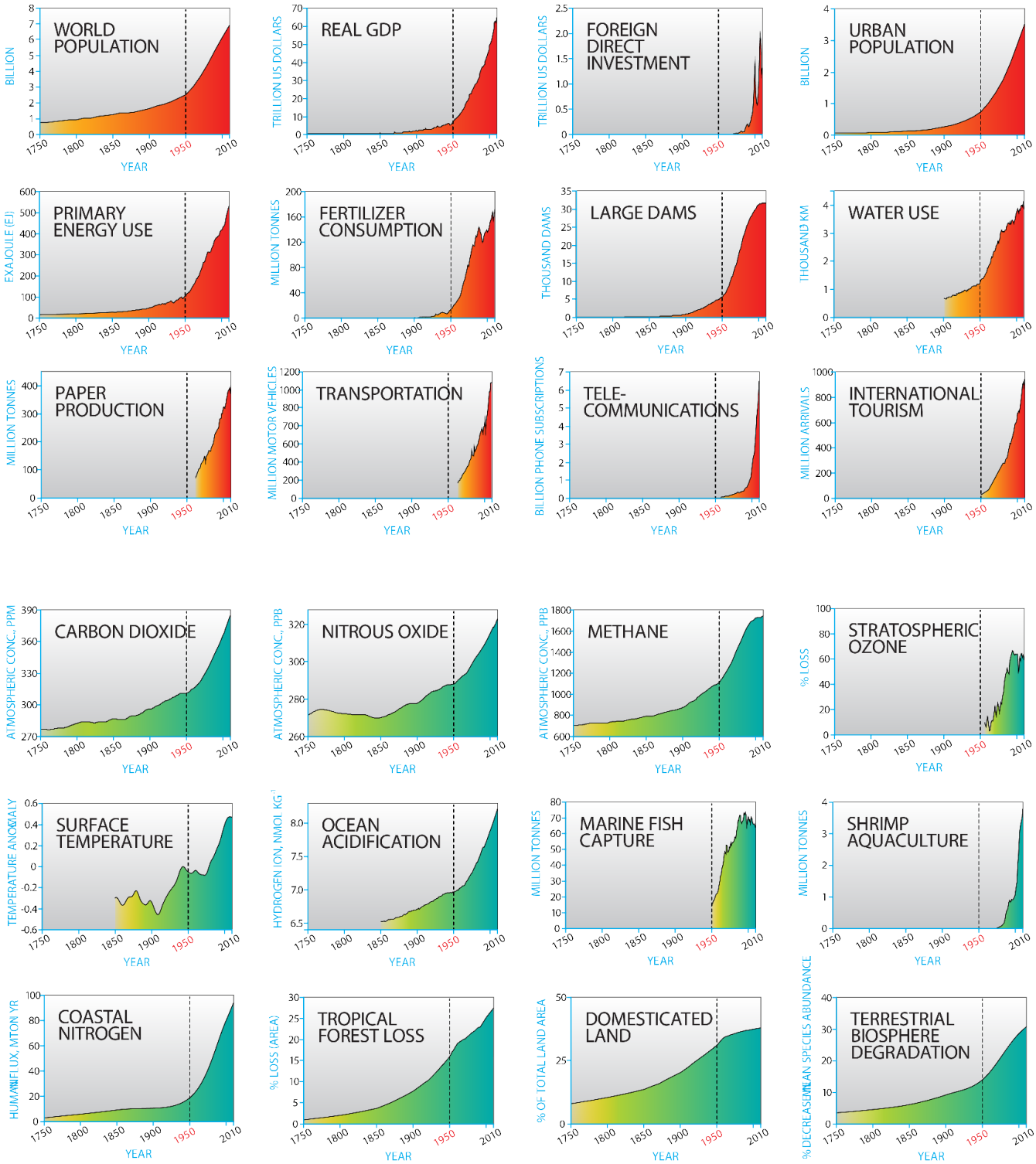

Figure 1: **The Great Acceleration**, as shown through multiple different social, economic and biogeophysical variables, which all show a similar pattern of exponential increase (Source: IGBP, adapted from Steffen et al. 2015)

has shown that the rate of change of the Earth System is currently primarily driven by human factors – deforestation, greenhouse gas emissions, fertilizer use, air pollution and so on[11].

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TIPPING POINTS AND TIPPING ELEMENTS

'It is unwise to discover the precise location of a tipping point by crossing it.'

Carlos Nobre, professor and former national secretary for research and development policy in the Ministry of Science, Technology & Innovation of Brazil

The concept of tipping points has been around for over a century in chemistry and mathematics[1, 2]. Social scientists first used the idea in 1957 to refer to racial segregation in the United States[3]. In 2000, the writer Malcolm Gladwell popularized the term with his book *The Tipping Point*[4].

While climate scientists have used words like 'thresholds' and 'nonlinearities' for decades, the term 'tipping point' began appearing in climate research papers around 2005[5], the same year that the British Embassy in Berlin also hosted a scientific meeting entitled 'Tipping Points in the Earth System'. Three years later, some of the scientists attending this meeting published a landmark scientific study on tipping points led by Timothy Lenton, now at Exeter University, UK[6].

Lenton and colleagues define the term 'tipping point' as 'a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system.' The system they explored is the Earth System – the complex interactions between the atmosphere, ice sheets, oceans, land, water and carbon cycles, and rich diversity of life. They also introduced the term 'tipping element' to describe 'large-scale components of the Earth System that may pass a tipping point', for example Arctic sea ice, the Amazon forest or monsoon systems. Subsequently, the tipping elements in the carbon cycle, of particular relevance for the climate, have also been referred to as sleeping giants, because once awakened (i.e., the threshold crossed) they can have large-scale impacts on the entire Earth System[7] (see also introduction).

More recently, in 2017 the U.S. Global Change Research program identified 12 tipping elements (see Table 1). This list is based on previous research using climate data from the deep past, Earth System models and expert elicitation[8]. But scientific knowledge in this field is advancing rapidly and debates remain as to the number and nature of tipping elements, their internal mechanisms, and the magnitude of their impacts. For example, the West Antarctic ice sheet and the marine-based East Antarctic ice sheet are often considered separately[9], because they behave largely independently and they differ in their internal dynamics and in their vulnerability to warming. Another example of a tipping element mentioned in some studies is the Indian summer monsoon, which could be destabilized by climate forcing by aerosols and land use change, resulting in a significant decrease in rainfall over South Asia, and associated problems for food production[6]. It is also important to keep in mind that the release of carbon from regions that experience a tipping point will vary a lot from one region to the next, and large uncertainties prevail (see Box 1 in introduction).

Tipping forests – an urgent concern for climate risk mitigation

As outlined in the previous section there is a range of different tipping elements. From here on we will focus on the two forested biomes: the Amazon rainforest and the boreal forests of Russia and Canada. These are sensitive to both warming and changes in the moisture regime, and are also under intense pressure from human economic activities – and can therefore be directly linked to the investment community.

The Amazon

Twice the size of India, the Amazon rainforest is a major engine in the Earth's biosphere. It pulls carbon out of the atmosphere and into its soils, trunks and roots. Between 135 and 180 billion tonnes of carbon are stored there. This can be compared to the approximately 10 billion tonnes of carbon humans emit every year.

The Amazon is changing rapidly. Since the 1960s, almost 20% of the forest has disappeared. This is already having major impacts on societies through reduced rainfall and increasing fires. The forest influences rainfall by evapotranspiration and through this process contributes to about half of its own rainfall. Without the forest, rainfall in the region can shift dramatically, and in the recent past the region has been hit by record-breaking droughts (2005, 2010, 2015-2016) and floods (2009, 2012, 2014; the latter over the south-western Amazon).

Table 1. **Potential tipping elements in the Earth System** (adapted from USGCRP Chapter 15, 2017)

Tipping element	What happens if tipping point is crossed?	Climate and environmental impacts	Economic impacts
	ATMOSPHERE–OCEAN CIRCULATIONS		
Atlantic Meridional Overturning Circulation (AMOC)	Major reduction in strength	This has the potential to influence regional temperatures and rain and snow, in the North Atlantic region. Also, potential impact on global average temperature and sea level	Requires major adaptations for populations
El Niño (El Niño–Southern Oscillation or ENSO)	Increase in amplitude	El Niño and its counterpart La Niña affect extreme weather patterns globally, including rainfall and drought	Increasingly difficult to predict regional-scale extreme weather, monsoon onset, droughts
Equatorial atmospheric superrotation	Initiation	Reduction in cloud cover, increase in climate sensitivity	
Regional North Atlantic Ocean convection	Major reduction in strength	Regional temperature and precipitation	
	CRYOSPHERE		
Antarctic Ice Sheet	Major decrease in ice volume	Rise in sea level; albedo (heat reflected or absorbed by surfaces); ocean circulation	Increases coastal flooding
Arctic sea ice	Large-scale decrease in summertime and/or perennial sea ice area	Regional temperature and precipitation increase; decrease in albedo	Potential change in duration and amplification of extreme weather (drought, rainfall) in northern hemisphere with impacts globally.
Greenland Ice Sheet	Major decrease in ice volume	Sea level; albedo; freshwater forcing on ocean circulation	Accelerates sea level rise
	CARBON CYCLE		
Methane hydrates	Massive release of carbon	Increased greenhouse gas emissions	Accelerates global temperature rise, leading to more severe impacts
Permafrost carbon	Massive release of carbon	Increased greenhouse gas emissions	Accelerates global temperature rise, leading to more severe impacts

Tipping element	What happens if tipping point is crossed?	Climate and environmental impacts	Economic impacts
		BIOME	
Amazon rainforest	Forest die-off (death of large areas of forest), transition to grasslands	Greenhouse gas emissions, loss of biodiversity	Accelerates global temperature rise, leading to more severe impacts; loss of regional ecosystem goods and services, e.g. major economic impact on agricultural production
Boreal forests	Forest die-off (death of large areas of forest), transition to grasslands	Greenhouse gas emissions, change in albedo, loss of biodiversity	Accelerates global temperature rise, leading to more severe impacts; loss of regional ecosystem goods and services
Coral reefs	Coral die-off, transition to different ecosystem	Loss of marine biodiversity	Major economic impact on tourism, fishing and related industries

It has been estimated that the Amazon rainforest could cross a tipping point where major parts of the forest die off, potentially emitting vast amounts of carbon, while huge tracts of land switch to savanna-like states. The tipping point has most commonly been estimated to occur if global temperatures rise to 3-5°C or if deforestation reaches 40% of original tree cover [10, 11]. These potential tipping points could be reached in the second half of the 21st century.

These estimates, however, are based on each of the two processes acting on their own. **The most recent research, based on a more systems-level approach, now indicates that deforestation, combined with already warmer temperatures and increasing forest fires, may bring the tipping point much closer**. Indeed, in 2018 experts on the Amazon system speculated that the tipping point could be crossed as early as at 20-25% deforestation of pristine levels – only slightly more than the current levels[12]. They also point out that while there is still great uncertainty around exactly when the Amazon may start to tip, it is unwise to discover the precise location of the tipping point of this globally important biome by crossing it.

These findings make it clear that forest stewardship will play a critical role in the stability and resilience of the Amazon, and hence the global climate. Currently the main drivers of Amazon deforestation are beef, soy, timber production, and mining, as well as the infrastructure associated with these. In the next chapter we examine these sectors and their link to the financial industry in more detail.

Boreal forests

Boreal forests sprawl across Canada, Russia, Alaska, and Scandinavia and comprise about 30% of total forest area on the planet[13]. They are the largest biome on land; play a critical role in the climate system; store vast amounts of carbon (about 340 billion tonnes); and affect surface albedo, potentially amplifying Arctic warming if they spread further north (dark forests absorb heat, white snow reflects heat)[14].

Like the Amazon, these forests are changing rapidly. Insect attacks have increased as temperatures have risen and wildfires are becoming bigger and more intense[15, 16]. Record-breaking fires have been recorded in Canada, Russia and Alaska in recent years. This is likely to worsen in the decades to come. Increased water and heat stress could lead to a decrease in boreal forest cover but significant uncertainties remain about the stability and resilience of the boreal forests[17, 18].

In recent years, the Arctic and boreal regions have been warming at rates as high as 0.5°C per decade, making them the fastest warming regions on Earth. In the 21st century, boreal forests are expected to experience the largest increase in temperatures of

all forest biomes[13]. Projections indicate potential future warming of 4 to 11°C by 2100 in these regions, according to the Intergovernmental Panel on Climate Change's scenario assuming no action to mitigate climate[13].

Such extreme temperature increase, coupled with resource extraction, will have a profound impact on the stability of this critical biome. Permafrost melt and wildfires emit large amounts of greenhouse gases to the atmosphere, increasing the rate of temperature rise and thus leading to a vicious cycle (also known as a positive feedback loop) of warming begetting more warming. Permafrost is more likely to melt in boreal regions than in the Arctic because temperatures in the boreal zone are closer to the thawing point, so less additional warming is needed to melt them. Furthermore, research indicates that as much as 40 billion tonnes of carbon could be emitted by boreal forests to the atmosphere by 2100 with a 2°C temperature rise, and even more if a tipping point is crossed. This tipping point is currently estimated to lie somewhere around a 3-5°C rise in global average temperature[9]. Should this happen, even if we manage to reduce human emissions drastically, the emission of carbon from these boreal biomes would continue, making it more difficult to constrain future temperature rise.

Forest management will increasingly play a critical role in the stability and resilience of the boreal region. Currently, about two-thirds of boreal forests are under some form of management, mostly for wood production. In Russia, up to 20% of current logging is carried out illegally, with overharvesting inevitable[13], while forests elsewhere – in Scandinavia, Canada and Alaska, are relatively well managed, and deforestation levels are low. Even with good management under present conditions, new approaches to forest management will be required to build the resilience of this biome to cope with even warmer temperatures in the future. These new approaches include protecting forest biodiversity by allowing the presence of decaying wood and shifting towards more heterogeneous, mixed-species forests[19].

A domino effect

As noted earlier, crossing one tipping point can often increase the risk of crossing others. The worst case scenario for climate policy – and humanity – is the domino effect where crossing critical tipping points can lead to a cascade of feedbacks in the Earth System, so that other tipping points are subsequently crossed (see Figure 2)[9]. For example, as Arctic sea ice decreases, the open sea water absorbs more solar

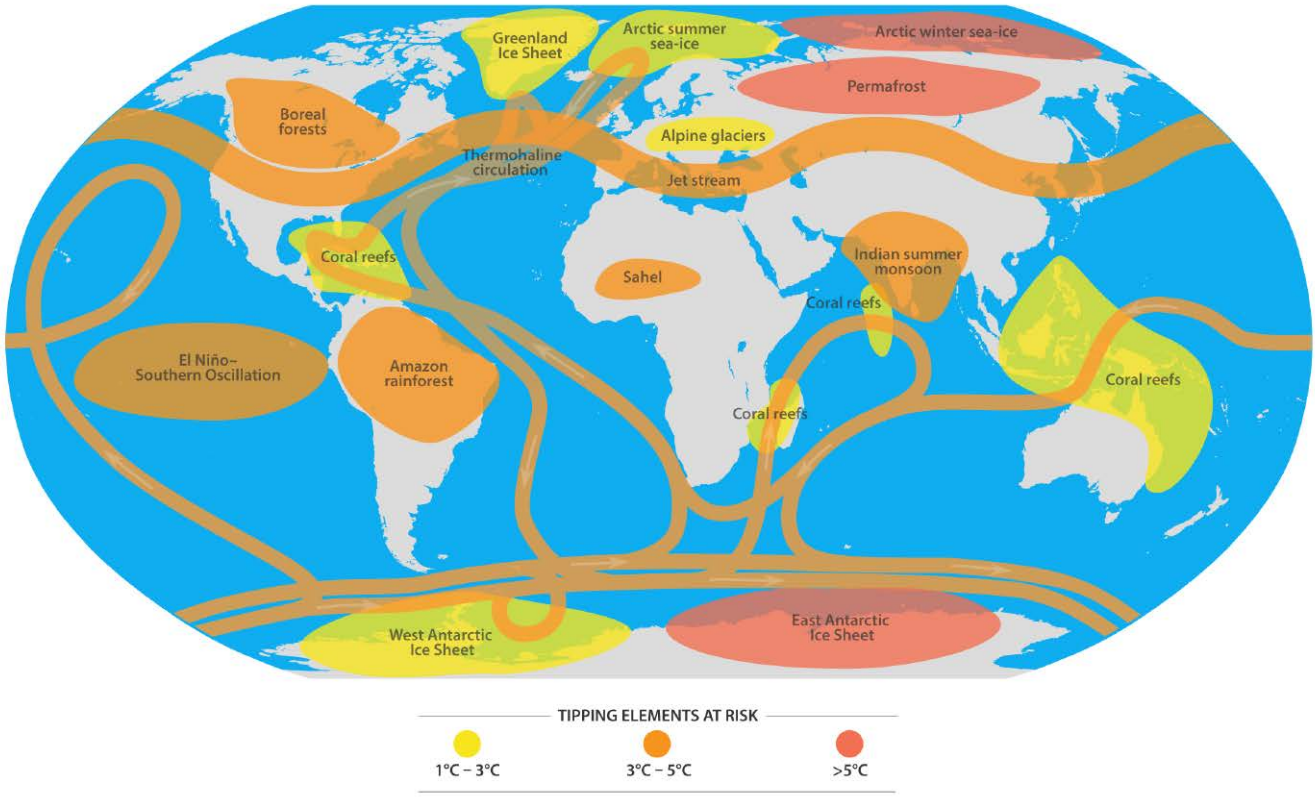

Figure 2. **Tipping elements of the Earth System**. Key parts of the Earth System (regions, biomes and ocean circulations) interact to keep Earth's climate relatively stable over long periods. But as the global average temperature rises, these parts of the system could change state rapidly, potentially further raising global temperature to levels that will affect other tipping elements, creating a domino effect that may drive temperature even higher. Illustration by J. Lokrantz/Azote (adapted from Steffen et al. 2018).

radiation, accelerating regional warming and further destabilizing northern hemisphere atmospheric circulation patterns such as the polar vortex and the jet stream. Observations show that these atmospheric circulation patterns are behaving more erratically, influencing weather around the northern hemisphere. The unprecedented heat waves that several regions in the northern hemisphere experienced in 2018 may be linked to this change, and scientists have established connections between the extreme California drought and changes in the Arctic[20, 21].

Nations have agreed to keep the global temperature rise to well below 2°C to minimize the risk of dangerous climate change – prompted in part by scientific concerns relating to tipping points[21]. However, some tipping points may already have been crossed. Should we overshoot the 2°C target, however, the risk rapidly grows of catalysing a domino effect that could drive climate change irreversibly towards a +4°C (or higher) rise in temperature, leading to much higher sea levels[9]. Forested biomes play a particularly important role in this dynamic for reasons stated earlier, not least their diminishing capacity to store carbon. A +4°C planet is believed to have catastrophic consequences for all societies[23, 24].

Peaking global emissions by 2020 and thereafter halving them every decade to become carbon neutral by about 2050 is consistent with the Paris Agreement on climate change. Such a scenario would provide a 66% or greater chance of staying below the 2°C target[25]. But ensuring that we maintain climate stability also means building resilience of the key biomes that make up some of the important tipping elements outlined here, and thus preventing them from tipping. This includes controlling pollution, deforestation and habitat destruction and other human pressures in these critical regions.

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BIOSPHERE FINANCE – NEW OPPORTUNITIES IN FINANCIAL LEADERSHIP FOR CLIMATE STABILITY

'The combination of the weight of scientific evidence and the dynamics of the financial system suggest that, in the fullness of time, climate change will threaten financial resilience and longer-term prosperity. While there is still time to act, the window of opportunity is finite and shrinking.'

Mark Carney, governor of the Bank of England, chair of the Financial Stability Board, in his speech 'Breaking the Tragedy of the Horizon – climate change and financial stability', 29 Sept, 2015

The last decade has seen an increased awareness of the role and importance of the financial sector for social and environmental outcomes. Financial supervisors have begun to broaden their perspectives (Carney 2015), and a host of organizations and institutions (such as the Equator Principles, the UN-supported Principles for Responsible Investment, UNEP Finance Initiative, Climate Futures, etc.) have taken on leadership roles in driving the move to a greener financial system.

As finance has sought to become a more positive force for change to address the big climate and environmental challenges we face, various strategies have emerged, ranging from the development of 'green' financial instruments and impact investments, to divestment, and the development of sustainability policies to guide loans and investments.

While these are all welcome changes for promoting ways in which the financial sector can help combat climate change, two related issues need to be addressed for the financial sector to fully realize its potential of playing a leading role in society's race to mitigate ongoing climate change.

First, there has been very limited recognition of nonlinear Earth and climate system dynamics in the strategies and risk scenarios developed to guide sustainable investment. In other words, Earth's sleeping giants, elaborated above, have not featured in most discussions on how the finance sector can address climate change. The dynamics noted in the work on climate tipping points show that neglecting to account for the risk of sudden shifts and self-reinforcing feedbacks that can rapidly accelerate temperature increase can have disastrous outcomes. The financial industry is putting financial assets at risk not only of the possibility of changing climate policy (e.g., stranded assets and future price of carbon), but also of the impacts of climate change themselves, which may be large-scale and abrupt, especially in the case of tipping points, and may be deemed a new type of systemic risk (Aglietta & Espagne 2016).

Second, most 'green' financial initiatives currently designed to address climate issues focus primarily on reduction of greenhouse gas emissions through e.g. renewable energy, energy efficiency and low-carbon transport. Together these represent 79% of the green bond market (OECD 2017). The finance sector is evidently implicated in contributing to climate change by enabling economic activities that create greenhouse gas emissions and land-use change in general and this is an important reason why many investors should and increasingly do take responsibility.

Emissions reduction is of utmost importance when discussing climate change mitigation. But the increasing risk of waking Earth's sleeping giants makes efforts to increase the resilience of these giants an urgent measure to manage risk and help maintain climate stability in a high-CO2 world. This is an area where the financial sector could play a potentially transformative role. Through their influence over economic activities that modify the planetary regions referred to as sleeping giants, financial actors play a critical role in affecting climate stability, in both positive and negative ways. Investment strategies that in multiple ways help bolster the resilience of these planetary regions and biomes (and rapidly halt their current degradation) are paramount. The financial industry is powerful

and has the means and capacity to require change from business and to direct capital flows to economic activities that bolster, rather than undermine, climate resilience. This is its responsibility as well as in its long-term interest. Associated with this is the deep challenge we face to change the incentive structure within the investment sector, so that it can focus on long-term risks and opportunities rather than quarterly performance targets.

As nicely summarized by Mark Carney, in his speech at Lloyd's of London, on 29 September 2015: 'The more we invest with foresight; the less we will regret in hindsight.'

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INVESTORS AND EARTH SYSTEM TIPPING POINTS

How can investments align with climate stability? There is a growing awareness among investors that climate change poses a significant global systemic risk. The natural capital (also commonly referred to as ecosystem services) that underpins a large portion of economic activity is increasingly being affected by climate change, and the risk of damage to natural and financial capital by adverse weather events and long-term climate change is projected to rise, with large economic consequences notably for the insurance sector[1]. Recent research has established a novel method to support investment decisions to build resilience of certain tipping elements of particular relevance for climate stability, thus reducing the risk of crossing irreversible tipping points. As noted above, these include the forested biomes of the Amazon and boreal regions, which have also been likened to sleeping giants. In the following sections, we outline the key steps by which the methodology identifies financial investors linked to these giants. The methodology can be adapted to investors' own portfolios and decision-making processes. Specific influence strategies to be pursued by investors are not elaborated here. Rather, the approach is designed to provide a first step towards assessing investor links to key biophysical processes that govern climate stability, and to support investors in making decisions about how to allocate efforts at influencing companies in their portfolios.

Step 1. Identifying key tipping elements and drivers of change

The first step identifies the tipping elements (or sleeping giants) of critical relevance for the climate and which are directly impacted by extractive economic activities: the Amazon rainforest and the boreal forests of Canada and Russia (Figure 3). These were chosen because, in addition to rising temperatures and changing rainfall patterns associated with climate change, humans have a direct and local impact on them via erosion of their resilience, in contrast to some other tipping elements where human pressures are almost entirely felt via distal forcing via climate change. Climate mitigation should thus not only aim to reduce emissions, but also reduce the direct human pressures on these critical biomes that regulate the Earth System through carbon sinks and moisture feedbacks[2]. The Amazon and boreal biomes thus provide the most direct and easily traced link between climate stability and investors. Currently, the resilience of these biomes is predominantly shaped by greenhouse gas emissions, deforestation and forest degradation. About 64% of the Amazonian forest area is within Brazil[3], around 70% of the boreal forests are within Russia and 23% lie within Canada[4], hence this pilot analysis focuses on these three countries.

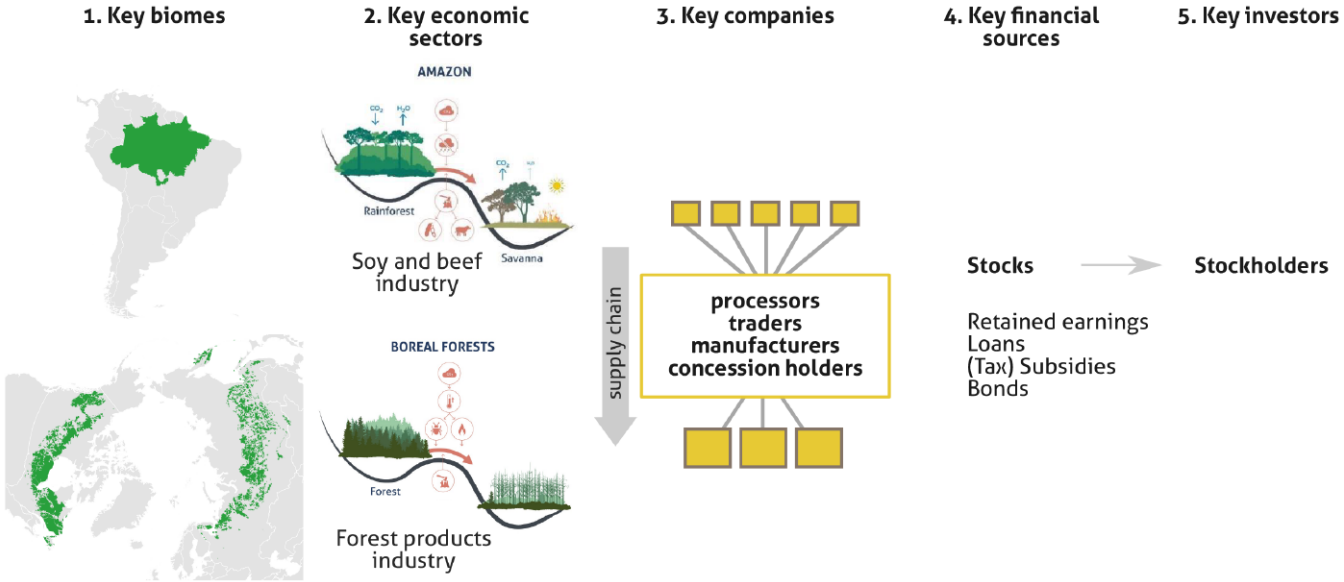

Figure 3. **Pilot methodology linking two tipping elements to the financial sector**. Adapted from Galaz et al. (in press).

Step 2. Identifying economic sectors directly impacting the stability of tipping elements

Step two identifies economic sectors associated with large-scale change in the relevant biomes. Specific agricultural commodities can be identified using tools such as the Global Map of Environmental & Social Risk in Agro-commodity Production (GMAP), published by the International Finance Corporation (https://gmaptool.org/). This tool provides up-to-date data enabling users to conduct rapid environmental and social due diligence and risk assessments. Academic and 'grey' literature also provide evidence for identifying sectors with a historical exposure to deforestation risk. Using scientific publications, we identified the most significant industries in the regions in relation to forest resilience: beef and soy in Brazil and timber, pulp and paper in Russia and Canada. The cattle sector has been identified as the predominant proximate cause of deforestation in the Brazilian Amazon, while soybean cultivation is probably a major underlying cause of deforestation, through the displacement of pastures[5]. Russian logging is estimated to account for 23% of current reductions of intact forest landscapes in Russia[6], second only to human-made fires (60%). Tree-harvesting in Canada is the third largest driver of forest disturbance (around 700,000 hectares per year in 2010), after fires and insect outbreaks[7].

Step 3. Identifying leading companies

Once key economic sectors are pinpointed, we identify the most influential companies in each sector. We rank the companies by their market share, and select the largest companies until we reach a cumulative representation of a minimum of 50% of the sector. The number of companies selected will therefore depend on market concentration. Although somewhat arbitrary, this threshold of 50% allows a reasonable and consistent share of each sector to be captured, whatever the consolidation level in the sector considered. The exact indicator used to assess market share varies from sector to sector, and depends on the characteristics of the sector and on data availability. In the case of the soy and beef sectors in Brazil, the companies with most influence over the supply chain are companies controlling the middle part of the chain: processing plants, logistical facilities (including warehouses and transportation) and trading activities (including exports). Within these parts of the supply chain, existing research indicates that the market is quite concentrated, with five companies controlling 52% of the export value of soy products from Brazil, and three companies representing almost 70% of the export value of beef products from Brazil[8]. In the timber, pulp and paper sectors in Canada, we selected companies based on the size of their industrial concessions (forest tenures), where 15 companies represent 50.2% of total forest tenure[9]. In Russia, concession data was unavailable, and we selected companies based on their revenue as a rough proxy for size of operations. Four companies represented 50.5% of the total revenue of the top 50 companies in the timber, pulp and paper sector[10]. Note that, even though the data on the top 50 companies indicate a relatively high degree of market concentration, no data were available for the rest of the timber, pulp and paper sector in Russia, which may lead us to slightly overestimate the market share of the top four companies.

As noted in this example, data resolution and availability will differ depending on which sector and which tipping element is in focus. Metrics can, and should, therefore be adapted to the relevant context. Market research, as well as reference to industry reports and industry news, are currently the most important information sources for characteristics of leading companies and sectors.

The result of this exercise is a manageable list of companies, which are deemed to be leverage points for enhancing – or undermining – climate stability, and therefore priority for assessment and engagement by investors. In the soy and beef sectors we cannot attribute deforestation or forest degradation directly to these companies, as much of the production is done through contract farming. However, they are the biggest traders in the supply chains that drive the deforestation and as such tangible, rapid, positive impacts could arguably be achieved by focusing on these leading companies, in these particular sectors.

Step 4. Analysing sources of finance

Sources of finance available to businesses for their economic activities include bank loans, different types of debt finance such as bonds and commercial papers, equity (stocks), and of course retained earnings, which are in part dependent upon taxes and subsidies in a particular jurisdiction. In this pilot study, we limit ourselves to the study of equity in publicly listed firms. The first reason for this is that current lack of publicly available data makes it very difficult to reliably estimate and verify information about the other financing sources of companies. The second reason is that equity investors not only have a strict financing role, but also have a say in the strategic choices of the firm. In other words, stocks are associated with both dividend and voting rights. However, a similar exercise can of course be conducted to assess whether fixed-income investments (loans) and insurance cover are also aligned with promotion of climate stability through their effect on key tipping elements.

We analysed the ownership of the companies identified in the previous step. Two were joint ventures, and one a dual-listed company, giving a total of 29 parent companies, out of which 19 are listed on a stock exchange. We extracted the list of their shareholders (owning at least 0.01% of shares) as of fiscal year end 2016 or latest available date, using the Orbis database[11].

Step 5. Financial giants are present in all tipping elements and sectors

Our goal was to identify investors who hold stocks across all sectors and countries studied, i.e. investors with ownership in at least one leading soy company and one leading beef company in Brazil; one leading forest products company in Canada and one in Russia. The reason for this is that such (primarily institutional) investors have the potential to influence drivers of environmental change in multiple regions at the same time. Through their investments policies or engagement strategies they could therefore in principle affect multiple known tipping elements simultaneously. However, the methodology can easily be used by any investor to assess their exposure to tipping elements.

We identified 16 institutional investors that have a significant ownership interest in all sectors connected to the stability of the two sleeping giants under investigation. We called these the 'financial giants'. The list includes a variety of investors: investment managers, banks, pension funds, an insurance company, but 87.5% are investment management firms or have investment management branches. Table 2 provides some descriptive statistics about these investment managers. The asset managers are rarely the underlying owners; instead holdings are distributed across thousands of clients. However, one can argue that the asset managers have a duty of care to the beneficiaries to invest in a responsible way (both in terms of economics and sustainability). Large asset managers are therefore a group of investors with large potential leverage to promote sustainability and climate stability. All investors listed have shares in at least five of the leading companies, and three have shares in almost all (18 out of the 19 publicly listed companies in our sample). Six investors have blockholding power (defined as a share of 5% or more) in at least one company. Two thirds of investors are based in the United States. The financial company with the largest 'size of ownership' (more than USD 8 billion) also has the highest number of blockholdings (7).

Note that the current list of financial giants contains 16 institutions, but this is only indicative and by no means exhaustive, as this number depends on our selection criteria for the tipping elements, sectors and leading companies chosen in this pilot study. Furthermore, the date at which we analysed stock ownership also affect the results.

Table 2. **Ownership statistics** for investment management firms with ownership across all studied sectors and countries ('financial giants')

	Min	Median	Max
Ownership breadth[a]	5	10	18
Number of holdings ≥5%[b]	0	0	7
Size of ownership (million USD)[c]	93	1,137	8,027

[a] *Ownership breadth*: Number of companies in which a stockholder is invested (out of 19 publicly listed companies).

[b] *Number of holdings ≥5%*: Shareholding of minimum 5% is generally referred to as block-holding, and assumed to entail considerable influence over corporate governance.

[c] *Size of ownership*: Product between the market capitalization of the listed company and the percentage of shares directly or indirectly owned by the stockholder.

Reducing global systemic risk related to the sleeping giants

The approximate USD 45 billion invested by the 16 investors identified here amounts to only a small fraction of their total assets under management. However, this report aims to highlight that while the short-term financial incentive for engaging with the knowledge of nonlinear climate dynamics and tipping elements may seem small, there are long-term financial and sustainability rewards to be reaped in doing so.

The economic consequences of passing a tipping point in one, or several, of the tipping elements discussed throughout this report cannot be estimated with precision but are certain to significantly affect institutional investors due to their systemic ownership in the economy globally, not only in the specific holdings associated with individual tipping elements. These 'universal owners' have less ability to avoid large-scale planetary changes that affect economies and sectors[12]. Therefore, developing strategies that can make investments into these sectors promote the resilience of the underlying biomes is important and makes sense for both sustainability and business in the long term. These could include, but are not limited to: engagement with companies to achieve effective zero deforestation in supply chains, rehabilitation of degraded forests, reforestation, afforestation,

forest management practices protecting biodiversity (such as allowing the presence of decaying wood and shifting to more heterogeneous, mixed-species plantations).

Investor influence in the landscape

A critical first step for an investor to understand their actual impact is to visualize where in the landscape investments are having an influence. As an example, Figure 4 (a and b) identifies the extent, on the ground, of the (publicly listed) leading companies in the soy and beef sectors respectively.

Next, we assess the strength of influence investors can have. We have created a simple scoring system that takes account of stock ownership and block-holding power, to devise maps that illustrate investors' agency at the landscape level. Figure 4c shows an aggregate account of the areas where

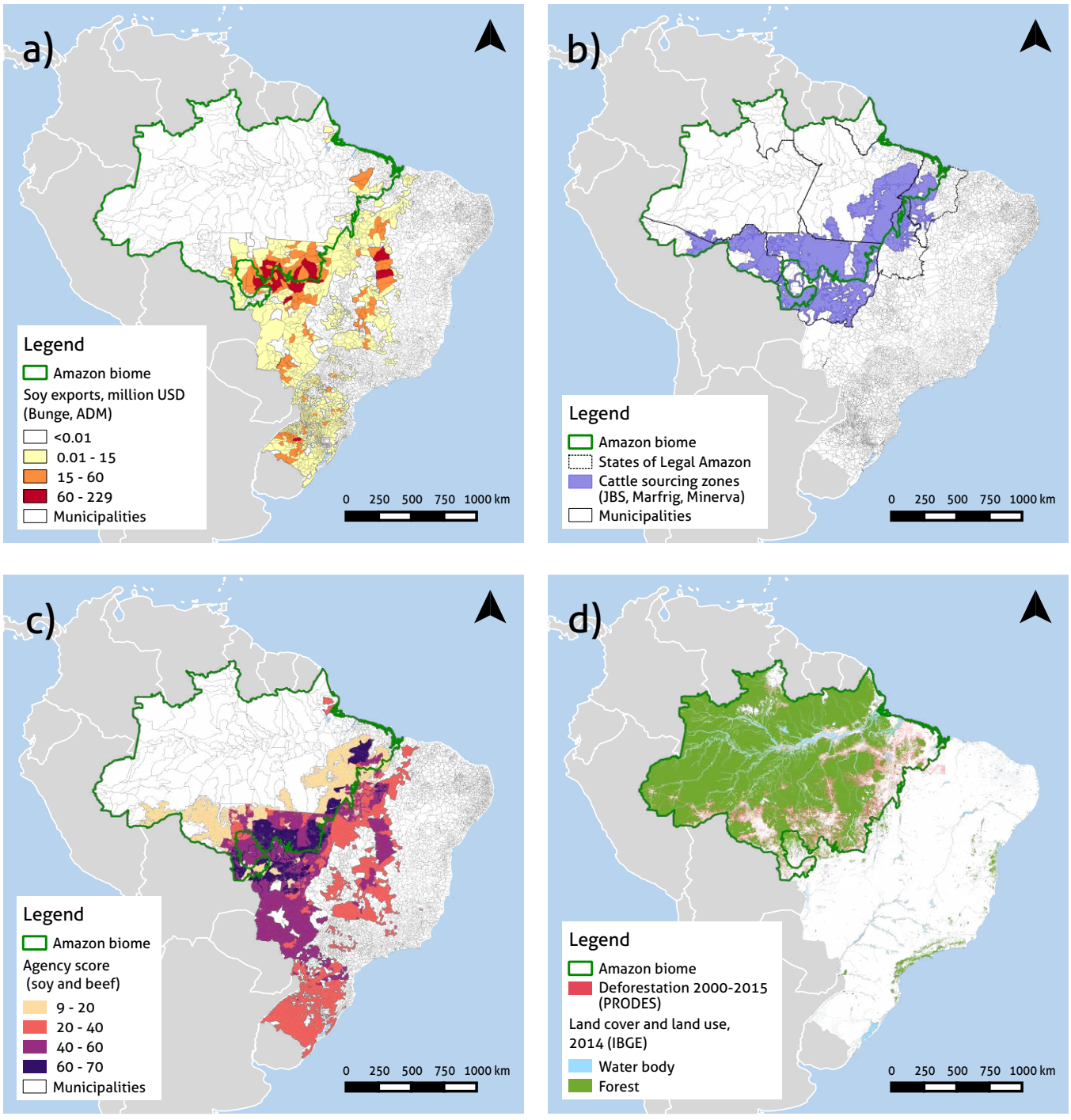

Figure 4. **Influence and agency maps of the 16 financial giants in the Brazilian Amazon**. Panel a is based on total exports per municipality in 2015[8], and panel b on zones from which slaughterhouses source the cattle[14].

the 16 financial giants would have the most agency, through their ownership in the companies identified here. Darker hues indicate a higher 'agency' score. Agency is calculated as follows:

- 1 point for being a stockholder, whatever the percentage owned.
- 2 extra points for being a blockholder, i.e. owning more than 5%.
- 2 extra points for being among the top 5 stockholders of the company (this is to account for the different ownership structures).

Each municipality or locality then gets a score equal to the sum of the points held by each stockholder that is present there via the company (or companies) in which it is invested.

Similar maps can be created to show the agency of any single investor in the landscape. For comparative purposes, panel d) shows the extent of deforestation in the Brazilian Amazon over the period 2000-2015, and thus where attention to halt deforestation and reforestation should be most focused.

Exerting agency

Most institutional investors are well aware of their influence on the global climate, and many are already taking action through their voting at annual general meetings of companies in their portfolios. Several major investors consistently voted in favour of climate change resolutions in 2017, and a growing number of major asset management firms started expressing demands for more disclosures on climate-related risks[13]. Could financial giants – like the set of investors identified in this pilot – mobilize to influence stronger corporate governance of the companies in their portfolio? To assess this we examined the aggregate voting power of the 16 investors with ownership in all sectors and tipping elements in our sample.

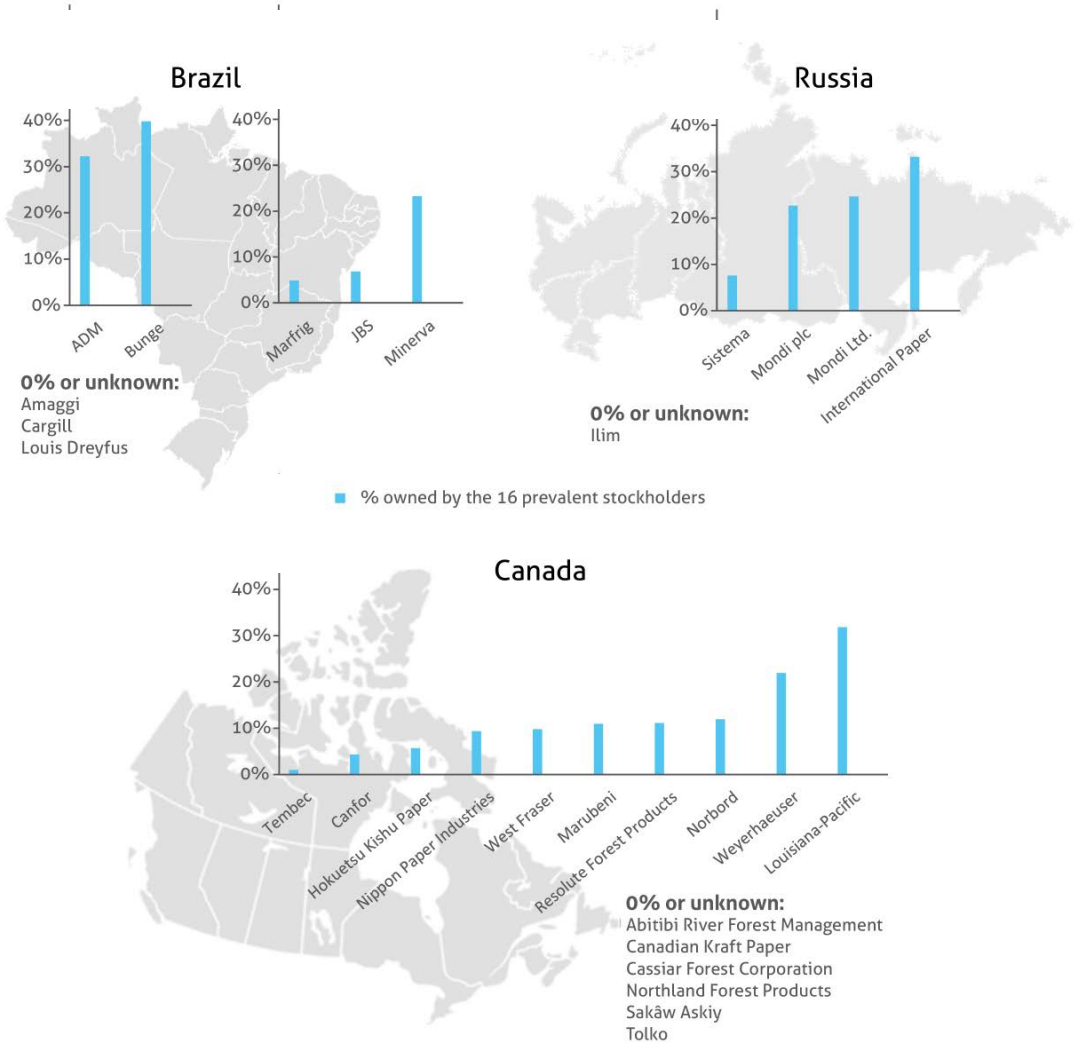

Figure 5. **Aggregated shares owned at year end 2016 by the 16 financial giants in leading companies of sectors associated with environmental changes in two tipping elements: the Amazon forest (Brazil) and boreal forests (Russia and Canada)**. Pie charts show the total market share of the selected leading companies in their respective sector. Adapted from Galaz et al. (in press).

Figure 5 shows that the total holdings of these investors reach above the 10% threshold in three out of eight companies in the Amazon, four out of nineteen in Canadian boreal forests, and three out of five in Russian boreal forests (given that one of them is dual-listed). This demonstrates that financial giants have a great but unrealized power to influence the resilience of several Earth System sleeping giants. We call on these financial giants to wake up and realize this power by integrating Earth System dynamics as a core consideration in their investment policies.

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A WAY FORWARD

Climate action has hitherto focused predominantly on the pressing need to reduce greenhouse gas emissions, and in this regard climate finance has been no different. Of course, greenhouse gas emissions must be reduced, and at a pace and scale that is without precedent – certainly much greater than current trends and pledged reductions. But focusing on the reduction of carbon and other greenhouse gas emissions alone is unfortunately not enough. Because of historical emissions, and continuing high level of emissions, the planet is already committed to a temperature increase that puts us at risk of triggering a dangerous cascade of tipping elements that could accelerate temperature rise and greatly increase impacts on human societies. Some of these tipping elements are large biospheric reservoirs of carbon (such as the boreal and Amazon forests). Eroding the resilience of these reservoirs has become a dangerous game. Therefore, while simultaneously reducing its greenhouse gas emissions, humanity also needs to bolster the resilience of these key tipping elements or sleeping giants. This means identifying human activities with a damaging impact on these critical regions, and transforming these activities so that they reinforce, instead of weaken, the ability of the sleeping giants to withstand temperature increase without tipping.

This is where the financial sector has a role to play. Finance has the means and power to influence businesses to develop strategies for long-term sustainability. In terms of the boreal and Amazon forests, this means reducing deforestation rapidly with the aim of completely eliminating it in the near future, and supporting regenerative rather than exploitative industries. The number of binding and voluntary initiatives for green finance, climate finance, and various impact investments is staggering. However, a substantial part of finance still disregards the risks involved with tipping points in key biomes and their relation to the global climate. This means that the financial industry is not only overlooking systemic risks, but also possibly a new generation of financial innovation that explicitly focuses on contributing to climate stability.

Finance cannot be made single-handedly responsible for a transition to climate sustainability, but it can and must play a critically important role. Through collaboration with governments, including public or partly public financing agencies, as well as with businesses and civil society, investors can trigger a rapid and large-scale change that will prevent an equally rapid and significant acceleration of climate change. Global financial institutions have a role to influence change in a positive direction by working for widespread awareness and acceptance of the importance of achieving climate stability. This includes pressure on national and international bodies to review legislation in light of the latest knowledge about nonlinear dynamics in the climate system. Corporate governance is also paramount, as businesses are the actors directly linked to tipping point risks in certain sectors (notably because of deforestation and forest degradation). The production of agricultural and silvicultural commodities, for example, applies significant pressure to natural ecosystems, and while supply chains are complex, and deforestation often legal, the corporate and financial sectors have both an economic and moral imperative to develop governance strategies that help safeguard key tipping elements and thus work towards climate stability.

CONCLUSION

A common way that the finance sector engages with climate change is to assess and factor in the risks that climate change impacts would pose to their assets. Exposure of financial actors to the material impacts of an increased risk of floods, migrations, conflicts and water shortages, among others, are modelled as well as risks of mitigating policies, like high carbon prices or new regulations leading to stranded assets.

This report has taken a different approach to mapping the links between the financial sector and climate change by examining how financial actors influence global systemic risks related to climate. For institutional investors and universal owners, this should make perfect sense. However, we argue that the financial sector as a whole must not stop at keeping portfolios clean and returns high. There is also a moral imperative for global economic actors to conduct business and investment so as to not undermine the capacity of future generations to inhabit Earth, and the social licence to operate is becoming an ever stronger factor that corporations need to consider. Two recent examples where governments have stepped in to guide this development include the UK's Modern Slavery Act (2015), which requires companies to disclose measures adopted to address slavery and human trafficking; and the French Corporate Duty of Vigilance Law (adopted in 2017), which created a legal requirement for companies to identify and prevent abuses of human rights and the environment related to their activities and those of their subsidiaries, subcontractors and suppliers applied to entire global supply chains[1].

By taking responsibility and using power and leadership for the good of the planet and the portfolio, financial actors could contribute meaningfully to an emerging and necessary pathway towards biosphere stewardship and climate stability. This includes keeping the sleeping giants in a deep and long slumber – the alternative is not something any of us want to see.

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