# Nature Risks Equal Financial Risks: A Systematic Literature Review[1]

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## Abstract

In this study, we systematically review academic literature to examine whether nature risks translate to financial risks. We identify 154 peer-reviewed articles published in 84 journals that cover 28 countries worldwide. These studies are based on nine nature risks (disease, drought, erosion, flooding, invasive species, oil spill, pollution, solid waste, and bushfire) as well as four sectors of the financial industry (banking, insurance, real estate, and the stock market). The results generally indicate that nature risks have adverse effects on the stock market, banking, and real estate and therefore pose financial risks in the form of bank defaults, drop in stock prices (market capitalization), and house (property) prices. The results further indicate that for the insurance sector, increasing nature risks causes policyholders to increase their coverage. Surprisingly, biodiversity loss as one of the key nature risk has not been empirically investigated so far with regards to financial risk.

Keywords: Nature risks, financial risks, natural capital assets, systematic review

[1]This study was funded by WWF Switzerland.

## 1. Introduction

Calls for environmental protection and issues of sustainability are at their all-time peak (see, e.g., Addoum, Ng, & Ortiz-Bobea, 2019; Dempsey, 2013; Matsumura, Prakash, & Vera-Muñoz, 2014, to name a few). These calls are largely driven by the increasing and persistent risks faced by the environment and nature in general (WWF France, 2019). Environmental risk is believed to account for three of the top five risks in the world in terms of likelihood and four of the top five risks in the world in terms of impact (WEF, 2019). Considering the increasing pace of environmental degradation, much attention is being given to the risks posed by nature to business (Caldecott & McDaniels, 2014; WWF, France, 2019). A number of international organizations and NGOs such as the United Nations Environment Programme, the WWF, and the Natural Capital Finance Alliance are at the forefront of trying to understand how risks posed to nature can lead to financial risks for the financial industry.

This study is motivated by this growing interest in the interaction between nature risks and financial risks for the financial industry. Though there are a number of studies on the impact of nature risks on the economy as a whole, there has been little in the way of empirical research concerning the financial industry in particular. As a result, consensus on the impact of nature risks on the financial industry is far from established. We systematically review existing studies to examine whether past research has found a relationship between nature risks and financial risks for the financial industry.

The benefits of nature are plentiful, and so its destruction influences the global economy. For example, in 2011 the economic value of biodiversity and ecosystem was estimated at about USD 125 trillion (Costanza et al., 2014). This was one and a half times more than the global GDP in that same year. Biodiversity loss and ecosystem destruction are estimated to have cost the global economy (of which the financial industry is a part) between USD 4.3 and USD 20.2 trillion per year for the period 1997 to 2011 (Costanza et al., 2014). For the same period, the cost of land degradation was estimated at between USD 6.3 and USD 10.6 trillion per year globally (ELD Initiative, 2015). Given the current trends, the estimated cost of nature destruction is growing exponentially (OECD, 2019).

Certain financial industry returns are associated with nature through the economic activities they finance. Entities that directly or indirectly rely on nature for production inputs (raw materials, water, energy, pollination, to name a few) rely on the services provided by the financial industry, such as investment, financing, advisory, insurance, banking, etc. (Natural Capital Finance Alliance [NCFA], 2019). When these entities are affected by nature risks, this has a knock-on effect on the financial industry, too. In addition, entities that depend on nature can also pose danger to nature with their activities.[2] The occurrence of nature risks imposes cost on these entities, and because they depend on services from the financial industry, this can affect the financial industry (NCFA, 2019).

Despite the growing concern about nature risks and their potential effect on financial risks for the financial industry, not much is known at least from an empirical perspective. There is empirical evidence that the rise in nature risks is directly influencing sectors such as agriculture. However, this evidence does not exist so far for most of the financial industry.

[2] Maxwell et al. (2016) highlight that human activities such as overexploitation of ecosystems, cultivation of agricultural land, urban development, invasive species, pollution, and system perturbations (dams, fires, etc.) are putting excessive pressure on nature in general and biodiversity in particular.

Even if it seems obvious that nature risks have a direct or indirect influence on the financial industry, there is no general consensus.

This study seeks to answer four questions. First, what is the current state of academic literature on the link between nature risks and financial risks? We identify the financial areas that have been considered in the literature, whether the studies have had a geographical focus, the data/databases employed, the main authors of these studies, and the focus and the rankings of the journals publishing the existing studies. Second, what kind of nature risks have been analyzed in relation to financial risks? Third, does the literature find a link between nature risks and financial risks for the financial industry and if so, how strong is it? Here, we also seek to ascertain whether nature risks are reflected in the pricing of financial assets. Fourth, what research gaps describing nature risks and financial risks can be identified, and which research questions need to be analyzed in the future?

To the best of our knowledge, this study is one of the first systematic reviews of this emerging topic. Only one existing study (Greiff, 2019) focuses on the effect of climate change (and climate related risks) on the financial industry. We exclude climate change from our study and focus on nature risks more broadly.

Our key findings are as follows. We found 154 articles published in 84 journals and identified four financial sectors (banking, insurance, real estate, and stock market) as well as nine nature risks (disease, drought, erosion, flooding, invasive species, oil spills, pollution/environmental contamination [air, groundwater, soil/land, surface water], solid waste, and bushfire). The results generally indicate that nature risks have an adverse effect on the stock market, banking, and real estate and hence pose financial risks in the form of bank defaults, drop in stock prices (market capitalization), and drop in house (property) prices. The results further indicate that for the insurance sector, nature risk increases premium and intake of insurances.

The contribution of our study is manifold. It is the first comprehensive appraisal and analysis of existing literature on nature risks and financial risks. We identify the existing loopholes and lay the foundation for further research. This review is also very valuable to governments, government institutions, and the international community as they seek to understand the extent of the effect of nature risks on the economy.

The reminder of the paper is structured as follows. The next section is an overview of nature risks, financial risks, and the connection between the two. Section three presents the methodology of the study. Section four presents and discusses the results of the study. Sections five and six present the conclusion and research gaps in the literature, respectively.

## 2. Nature Risks and Financial Risks

Nature risk is an environmental change resulting from the deterioration or depletion of natural capital. It can create a catastrophic situation that may involve loss of life, injury, health problems, property destruction, loss of livelihoods and services, and social and economic disruption (International Federation of Red Cross [IFRC], 2019; United Nations Office for Disaster Risk Reduction [UNDRR], 2017). Nature risk therefore incorporates the destruction or threatening of natural capital. In this study, we consider some of the phenomena that threaten natural capital and which are induced naturally or by humans.[3]

[3] We are interested in analyzing the effect of factors such as wildfire, environmental contamination (soil, air, water), deforestation, desertification, sewage discharge, diseases, drought, ecological decline, ecological overshoot,

The Natural Capital Coalition (NCC) defines natural capital as “another term for the stock of renewable and non-renewable resources […] that combine to yield a flow of benefits to people” (NCC, 2018). The contributions of natural capital usually remain within the economy; they are not present in the balance sheets of financial institutions or included in indices quantifying economic growth. The positive externalities some organizations enjoy from the contributions of natural capital, and the negative externalities organizations have on this natural capital are not reflected in market prices (Schoenmaker & Schramade, 2018). As a result, Schoenmaker & Schramade (2018) argue, natural capital is under-priced as only the direct cost of extraction is included. The relationship between business activities and natural capital depicts the dependence of businesses on nature. Organizations use natural capital such as atmosphere, water, land, minerals, soil, and others for their production (see Figure 1). In this sense, nature presents itself as an input that makes production possible and enables a profitable business venture. This relationship between business activities and nature can also be considered as meaning that business activities can “impact” nature (McCraine et al., 2019). This impact could either cause a net increase in natural capital, hence generating value, or a net decrease, hence diminish value. In turn, the outcomes have an effect on the quality of the natural capital that is used by the organization in its next production cycle (denoted by the arrowed line from the outcomes to natural capital on the left-hand side of Figure 1). The net decrease of the natural capitals represents nature risks such as bushfire, drought, erosion, invasive species and pollution (as shown in the right-hand side of Figure 1).

ecological uncertainty, ecosystem loss, erosion, exotic species, flooding, forest conversion, grazing, habitat conversion, habitat destruction, habitat fragmentation, habitat shifting, human modification of genetic material, human movement/migration, intensive agriculture, intensive aquaculture, interbreeding/hybridization, invasive species, land conversion, land use change, landslides, littering, monoculture, ocean acidification, oil spills, overconsumption, overexploitation of ecosystems, overexploitation of fish stocks, overharvesting, overhunting, parasites, pests, protected areas, salinization, seepage from mining, solid waste, species collapse, stratospheric ozone depletion, subsidence, water abstraction, and wildlife extinction, among others. We exclude strictly climate related risks. As mentioned above, climate risks and financial risks have already been studied and so we focus on other nature risks.

**Figure 1: The Value Creation Process[4]**

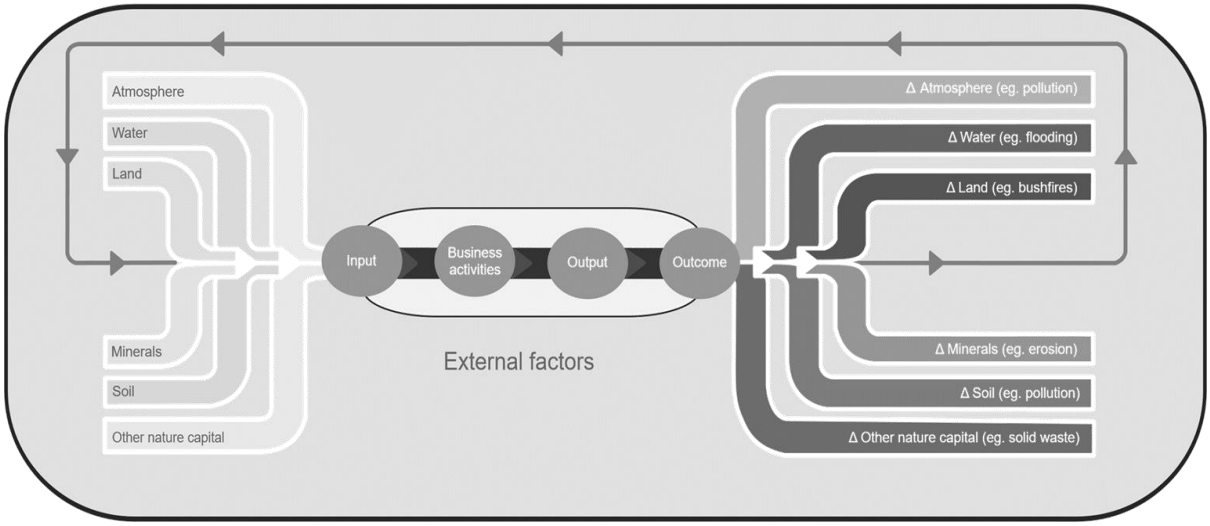



Figure 1 presents the value creation process adopted under the framework of the International Integrated Reporting Council (IIRC) and transferred to the sole use of natural capital such as atmosphere, water, land, minerals, soil, and others. The changes that occur after the use of natural capital by the companies are described as the resulting natural risks (e.g. pollution, flooding).

Nature risks become financial material when businesses are exposed to these risks (Horcher, 2005). As exposure is reflected in the extent to which businesses depend on natural capital for production, the vulnerability of businesses is measured in their ability or inability to overcome nature risks (McCraine et al., 2019). An inability to overcome nature risks is a financial risk for them.

Financial risk is the risk of financial loss that results from uncertainties when it comes to increases in asset prices, future asset returns, and a decline in desirability of assets (Han, 2010; Moles, 2013). It generally arises due to instability and losses in the financial market caused by factors both internal (controlled factors) and external to the organization. Financial risk also arises from an organization's exposure to financial markets, its transactions with other organizations, and its reliance on processes, systems, and people (Horcher, 2005). Financial risk comes in various forms, and the commonly identified ones are market, credit, interest rate, operational and liquidity risks (Deloitte, 2018; Horcher, 2005).[5] Financial risk leads to reduction in revenues and increase in costs and hence negatively affects the profitability of organizations. Horcher (2005), Moles (2013), and Williams (2012b) emphasize that financial risk can also be caused by factors beyond their control. Among the factors that organizations cannot control but that could pose a financial risk for them is nature risk or, more generally, environmental risk. The Organization for Economic Co-operation and Development (OECD) asserts that organizations whose activities destroy nature may be exposed directly to a number of risks including reputational risk (denigration of reputation), liability risk (litigation), regulatory risk (restrictions on access to land and resources, clean-up and compensation costs), and market risk (OECD, 2019). Similarly, the NCC postulates that nature-related risks can pose operational, legal and regulatory, markets, reputational, and societal risks to organizations (NCC, 2018).

[4] Adopted from the value creation process according to the framework of the International Integrated Reporting Council (IIRC).

Financial industry players may not be seen as directly interacting with nature. However, they do so at least indirectly through their investments, credits, advisory, and insurance. Firms that suffer the devastating effects of nature risks rely on financial services that are provided by the financial industry. The incidence of nature risks and the associated losses to borrowers can increase bank risk and default in the short run (Klomp, 2014; Schüwer et al., 2019). The value of real estate in areas subject to nature risk begins to decline (Cao, Xu, & Guo, 2015; WWF France, 2019). For example, flooding can adversely affect the value of real estate. Nature risks are assumed to have two contrasting consequences on insurance firms. On the one hand, they could boost the insurance sector since nature risks can cause insurance premiums to increase (Angbazo & Narayanan, 1996; Ewing, Hein, & Kruse, 2006; Koerniadi, Krishnamurti, & Tourani-Rad, 2016; Yang, Wang, & Chen, 2008). Premiums may also increase because previously uninsured firms may seek coverage in the wake of nature risks (Angbazo & Narayanan, 1996; Yamori & Kobayashi, 2002). On the other hand, nature risks could push up payouts to policyholders (Koerniadi, Krishnamurti, & Tourani-Rad, 2016; Yang, Wang, & Chen, 2008). The expectation of negative effects (losses) of nature risks on insurance firms could also cause insurance stocks to fall when disaster strikes (Angbazo & Narayanan, 1996; Yang et al., 2008). It is argued that firms in the construction and materials industry may benefit as demand for their goods and services rises after a natural disaster (Koerniadi et al., 2016). Generally, one firm's loss is an opportunity for another firm to profit. In view of this, nature risks do not always pose a danger to life or to the economy; they could also create opportunities for firms that specialize in lessening exposure to said risks (Dempsey, 2013).

Overall, little is known about the relationship between nature risk and financial risk from an empirical perspective. This section has highlighted that organizations depend on nature, and that their activities can pose danger to the natural capital that is essential for value creation, hence leading to nature risks. In the next sections, we contribute to the literature by examining the current state of research on the relationship between nature risks and financial risks for the financial industry.

## 3. Methodology

This study involves a systematic review of existing studies on the relationship between nature risks and financial risks for the financial industry (Petticrew & Roberts, 2006). This review is based on an interdisciplinary approach, meaning we do not limit ourselves to one particular discipline, say, economics or finance.

In line with Fink (2010) and Tranfield et al. (2003), we followed four steps in conducting the systematic review. Step one involved the identification and selection of research questions, keywords, and databases. Having established the research questions, we identified and built the keywords and search terms of the topic, arriving at a total of about 120 keywords to search.[6] We searched five major scientific academic databases: ABI/INFORM (ProQuest),

[6]Acidification, "air quality", biodiversity, "biodiversity crisis", "biodiversity decline", "biodiversity degradation", "biodiversity loss", "biodiversity-related risks", "biomass destruction", bushfire*, "change in land use", contamination, conversion, deforestation, degradation, "degradation of biodiversity", "degradation of ecosystems", "degradation of nature", desertification, "discharge of untreated effluents", "untreated effluents", "sewage discharge", "disease*", "domestic construction", drought*, "ecological collapse", "ecological crisis", "ecological decline", "ecological overshoot", "ecological uncertainty", ecosystem, "ecosystem collapse", "ecosystem degradation", "ecosystem destruction", "ecosystem loss", "ecosystem degradation", "environment* degradation", "environment* pressure", erosion*, "exotic species", "exploitation of natural capital", extinction, "extinction crisis", fire*, flood*, "forest conversion", "forest loss", grazing, "habitat alteration", "habitat conversion", "habitat

EBSCO, JSTOR, Scopus, and the Web of Science.[7] These databases contain thousands of academic journals published across all the major publishing outlets. For every database, we limited the search to publications in the broad fields of accounting, business and management, economics, finance and investment, and in some instances environmental and development studies, where possible. For every database we restricted our search to article titles. In step two, we applied inclusion and exclusion criteria, restricting our search to publications in peer-reviewed journals. As a result, we excluded book reviews, unpublished materials, editorial notes, comments, policy documents, news articles, and the like. We required the papers to be English-language journal publications. To enhance reliability, we imposed no geographical or time restrictions. In step three we applied methodological screening criteria. We screened each paper by reading the keywords, abstracts, conclusions and in some cases, the content of the papers to establish whether any were fundamentally relevant for our objectives. In our search for relevant literature, we considered all major areas of the financial industry including banking, credit markets, investment, insurance, real estate markets, bond markets, stock markets, and the like.[8]

Considering the broad nature of the databases we used and the large number of keywords employed, the majority of the papers identified were not deemed fit for purpose. We arrived at 154 papers that we considered relevant to the topic. In step four we proceeded to the actual review of the papers and the evaluation of the findings.

degradation", "habitat destruction", "habitat fragmentation", "habitat loss", "habitat modification", "habitat shift*", "human modification", "modification of genetic material", "human movement", "industrial construction", "intensive agriculture", "intensive aquaculture", interbreeding, hybridization, "invasive alien species", "alien species", "invasive species", "land conversion", "land degradation", "land use", "land use change", landslide*, litter*, "loss of ecosystem*", "ecosystem* loss", "mass extinction", migration, monoculture, "natural capital", "natural capital degradation", "natural capital depletion", "natural capital destruction", "natur* degradation", "nature destruction", "natural capital exploitation", "nature pressure", "nature risk", "nature related risk", "ocean acidification", "oil spill*", overconsumption, overexploitation, "ecosystem* overexploitation", "overexploitation of ecosystem*", "overexploitation of fish stock", "fish* overexploitation", "overexploitation of fish*", overfishing, overharvesting, overhunting, parasite*, pest*, pollutant*, pollution, "population change*", "protected area*", salinization, "seepage from mining", "mining seepage", "sixth great extinction", "soil contamination", "soil degradation", "solid waste*", "species collapse", "species decline", "species destruction", "species extinction", "stratospheric ozone depletion", "ozone depletion", subsidence, "waste water" "waste water run-off", "water abstraction", wildfire*, "wildlife depletion", "wildlife extinction", "wildlife destruction"

[7] The Web of Science database covers the following indices: Science Citation Index, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index, Book Citation Index and Emerging Sources Citation Index.

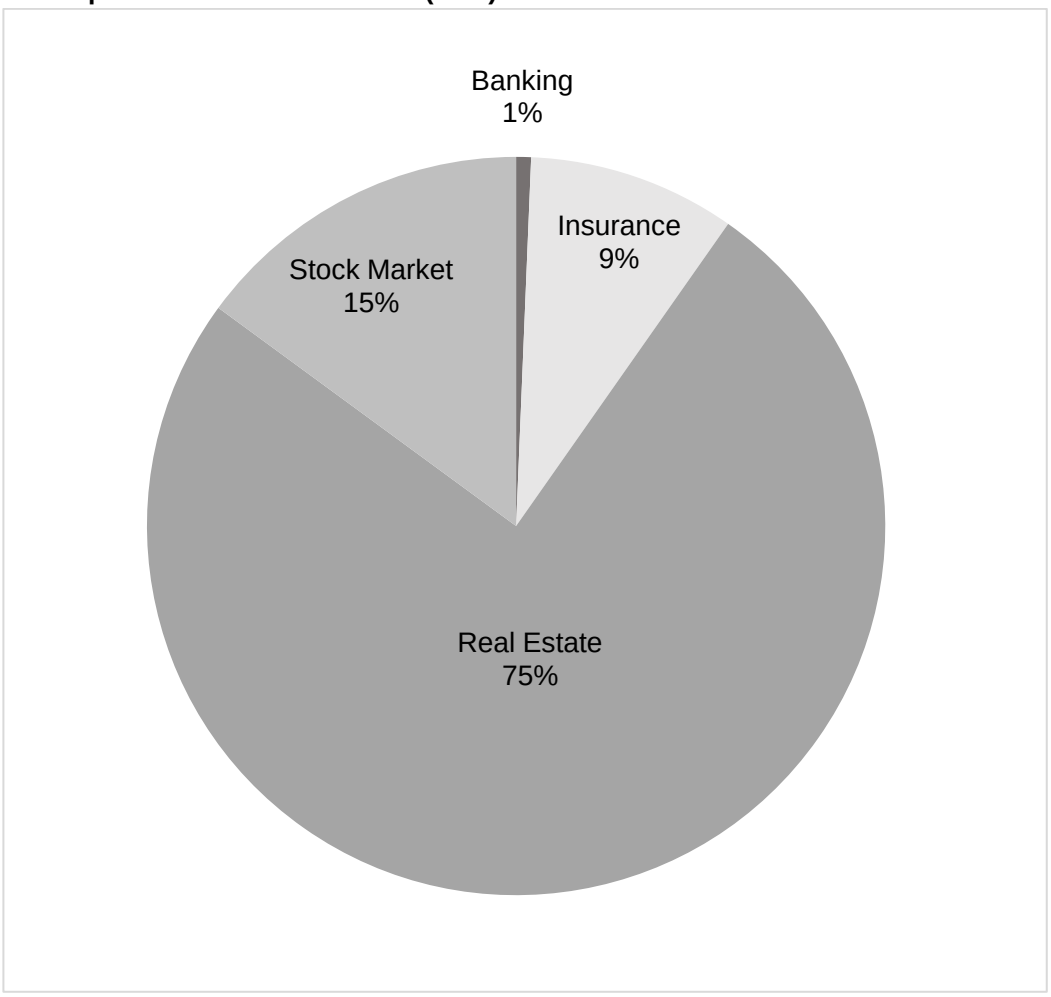
[8] For the stock market, the interest was on how nature risks affected listed companies listed on an stock exchange.

## 4. Results and Discussion

### *4.1 Description of the Sample*

Using the criteria as detailed in the methodology section, we identified about 501,000 titles (articles). Upon scrutiny of the titles, we obtained a first sample of 1,323 related articles. Having reviewed their content, we settled on 154 which correspond directly to our objectives.[9] We identified four areas in the financial industry (banking, insurance, real estate, and stock market) and nine nature risks (disease, drought, erosion, flooding, invasive species, oil spills, pollution/environmental contamination [air, groundwater, soil/land, surface water], solid waste, and bushfires.

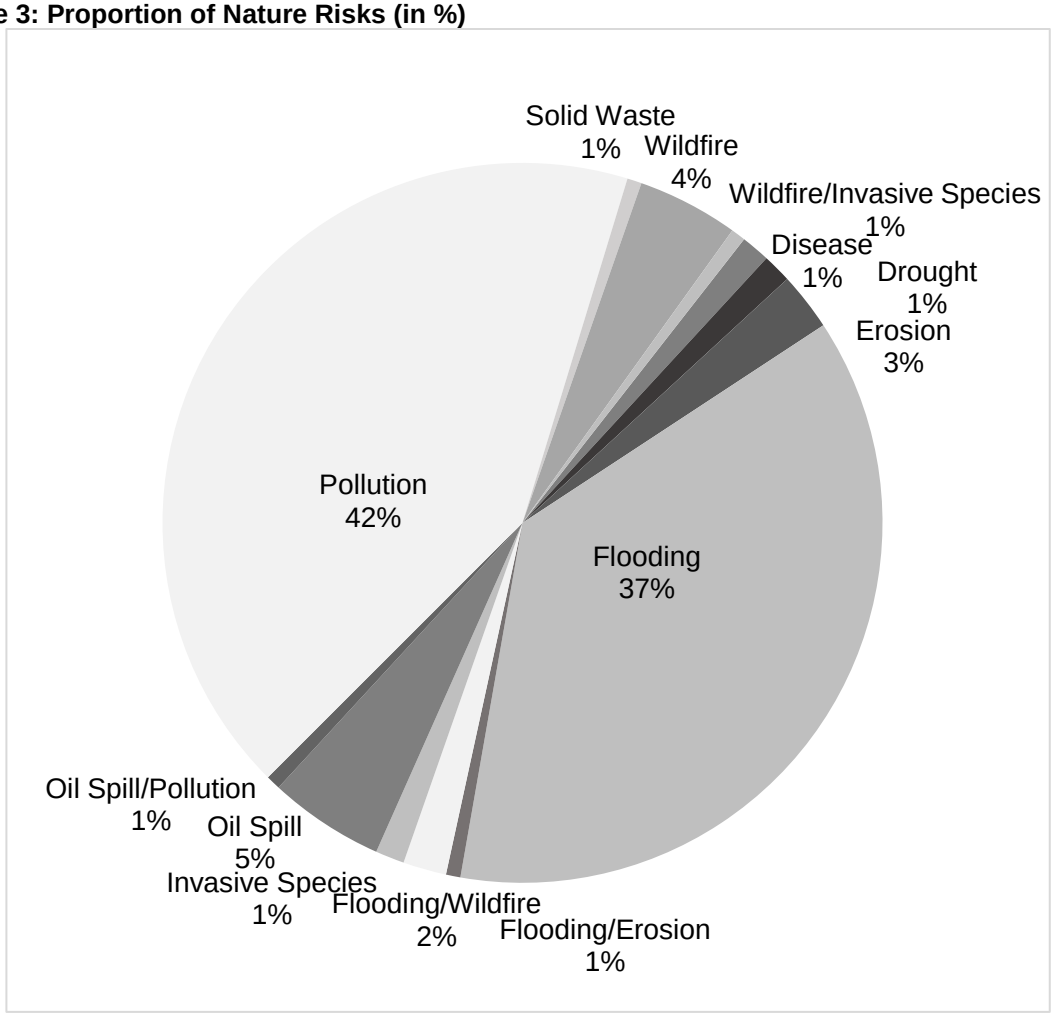
**Figure 2: Proportion of Financial Areas (in %)**




The diagram presents the allocation in percent of the 154 identified studies to the four financial areas examined.

[9] Search completed on 15 July 2019.

**Figure 3: Proportion of Nature Risks (in %)**




The diagram shows the distribution of nature risks examined in the 154 considered studies in percent.

75 percent of the identified studies examine the effects of nature risks on real estate, 15 percent focus on the stock market (see Figure 2). The most affected financial area we identify is real estate. Around 85 percent of the papers on real estate in the sample indicate a negative impact of nature risks on the sector. Flooding is found to be the nature risk with the worst effect on real estate. Pollution is found to have the strongest impact on all areas. Most of the studies we identified are pollution-related (42 percent) (Figure 3).

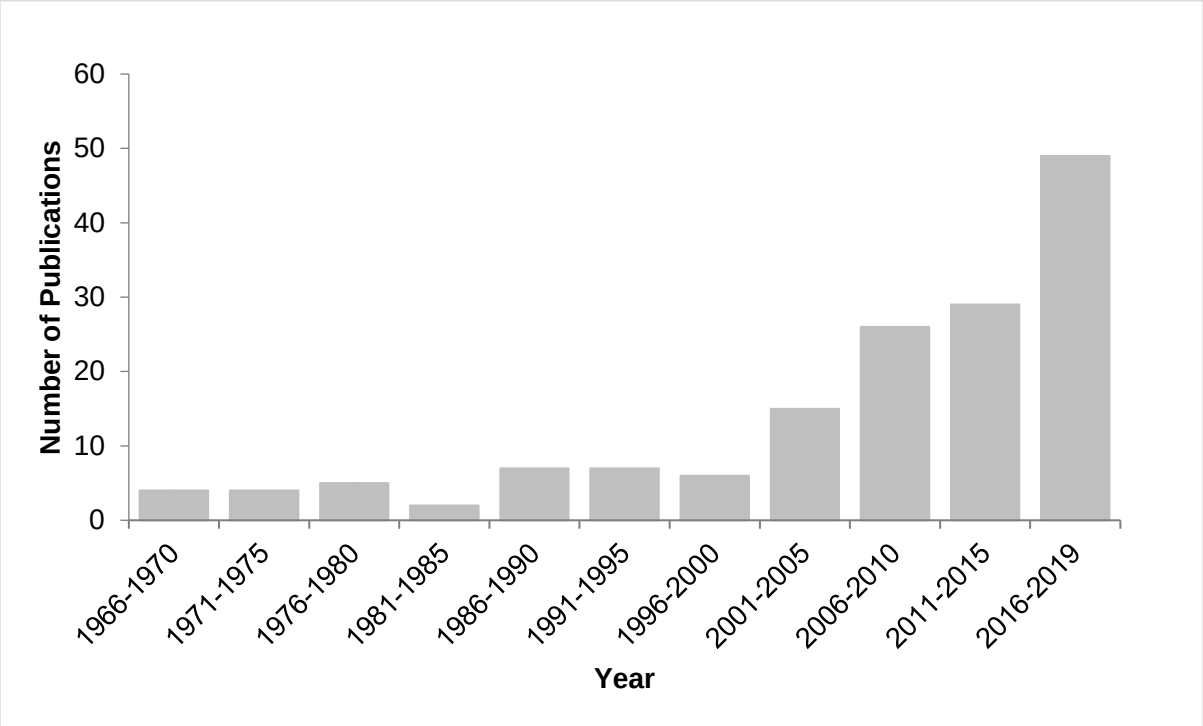
The studies draw on various data sources. Since most focus on real estate, most of the data is sourced from realtors' associations, land registries, city/county assessors, and the United States Census of Housing. Other financial industry data was sourced from Bloomberg, COMPUSTAT, the Center for Research in Security Prices (CRSP), the WIND Database, Tax Offices, China Premium Database (CEIC), and Surveys. Nature risk data generally came from national environmental protection agencies, environmental ministries, pollution monitoring centres, media reports, and emergency and disaster/hazard centers.

The identified papers are published in 84 journals with around 80 percent being SSCI/SCI or Scopus indexed journals. These cut across the fields of accounting, ecology, economics, environment studies, and finance. The authors with two or more published papers on the topic are Allan Beltrán, Burrell Montz, Chris Eves, Douglas S. Bible, Jessica Lamond, Lei Zhang, Nur Hafizah Ismail, Okmyung Bin, Thomas Jackson, and Wasantha Athukorala. At the time of

the completion of the search, the papers had 12,496 citations in total. The years of publication range between 1967 and 2019. Figure 4 below shows the number of publications per five-year period from 1966 to 2020, demonstrating that interest in the effect of nature risks on the financial industry increased strongly over the last decade.

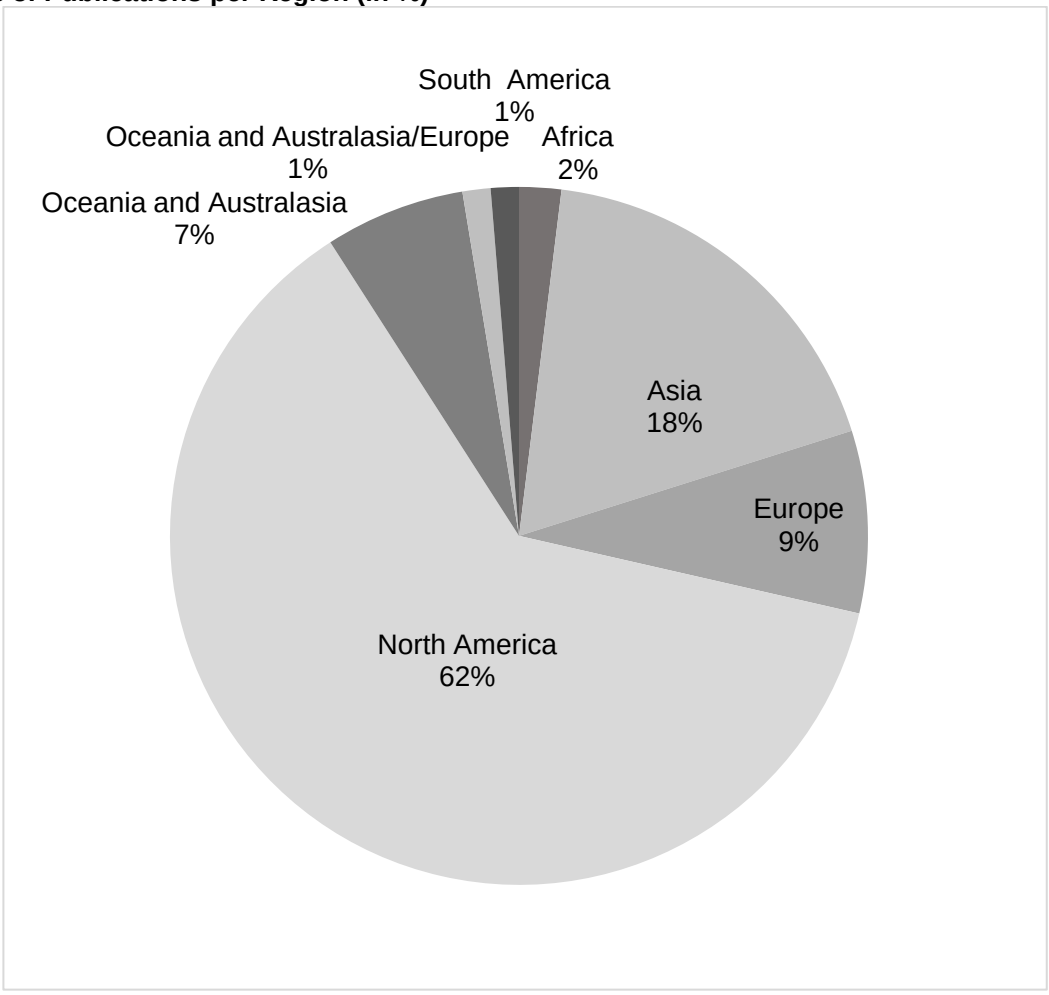
The studies are focused geographically on 28 countries and six continents/regions (Africa, Asia, Australasia & Oceania, Europe, North America, and South America). The proportion of studies on each region is shown in Figure 5. 62 percent focus on North America, mainly the United States (60 percent of all studies). United States is also the country with the most authors.

**Figure 4: Number of Publications per Five-year Interval**




The diagram shows the respective number of publications per five-year interval. Note that the last interval ends 2019, thus covering only four years, as 2019 is the last considered year.

**Figure 5: Publications per Region (in %)**




The diagram shows the geographical distribution of the 154 identified and observed studies.

**Table 1: Nature Risks per Regions (Captured as Number of Studies)**

| Nature Risks/Regions | Africa | Asia | Europe | N. America | Aust. & Ocean. | S. America | Aust. & Ocean. /Eur. | **Total** |
|---|---|---|---|---|---|---|---|---|
| Disease | – | 2 | – | – | – | – | – | 2 |
| Drought | 2 | – | – | – | – | – | – | 2 |
| Erosion | – | – | – | 4 | – | – | – | 4 |
| Flooding | 1 | 8 | 7 | 32 | 6 | 1 | 2 | 57 |
| Invasive Species | – | – | – | 2 | – | – | – | 2 |
| Oil Spills | – | – | – | 8 | – | – | – | 8 |
| Pollution | – | 17 | 6 | 40 | 1 | 1 | – | 65 |
| Solid Waste | – | – | – | 1 | – | – | – | 1 |
| Wildfire | – | – | – | 6 | 1 | – | – | 7 |
| Flooding, Erosion | – | – | – | 1 | – | – | – | 1 |
| Oil Spills/Pollution | – | 1 | – | – | – | – | – | 1 |
| Wildfire/Flooding | – | – | – | 1 | 2 | – | – | 3 |
| Wildfire/Inv. Species | – | – | – | 1 | – | – | – | 1 |
| **Total** | 3 | 28 | 13 | 96 | 10 | 2 | 2 | **154** |

The table displays the number of natural risks examined in each geographical region. Environmental contamination is classified as pollution. North America, Australasia & Oceania, South America, and Europe are abbreviated as N. America, Aust. & Ocean., S. America and Eur., respectively.

Table 1 shows the number of studies per region that focus on a nature risk or a combination thereof. We can infer that for almost all nature risks, North America leads in terms of the number of studies.

### *4.2 Effect of Nature Risks on Financial Areas*

#### *4.2.1 The Effect of Nature Risks on Banking*

Only one paper in the sample examines the impact of nature risk on banking (e.g. lending and savings). Specifically, it explores the effect of drought shock on the credit and liquidity risks of microfinance institutions (MFIs) in rural Africa. The study indicates that drought shocks can negatively affect the ability of MFIs to provide financial services on a sustainable basis (Castellani & Cincinelli, 2015). Given rural Africa's strong dependence on rain-fed agricultural activities, drought shocks and drought exposure can adversely affect the income of the rural population, reducing borrowers' ability to pay back loans and eventually leading to default, resulting in turn in credit risk (Castellani & Cincinelli, 2015). Credit losses from drought affects the capital reserves of the MFIs, which in response limit access and decrease supply (Castellani & Cincinelli, 2015).

#### *4.2.2 The Effect of Nature Risks on Insurance*

Figure 6 indicates that 93 percent of the studies on insurance do not find a negative impact of nature risks. Insurance premiums rise as hazards in a neighbourhood rise (Belanger & Bourdeau-Brien, 2018; Bin, Kruse, & Landry, 2008; Skantz & Strickland, 1987). In most cases, businesses that are prone to nature risks have mandatory insurance, such as flood insurance. Considering the cost of repairing damage indused by a nature risk, individuals tend to buy insurance so they are assisted in mitigating the losses and costs (Hung, 2009). This increases insurers' customer base. The rise in insurance subscriptions following an increase in nature risks is largely consistent for drought (Takeshi & Thomas, 1997), erosion (Landry & Jahan-Parvar, 2011), flooding (Atreya, Ferreira, & Kriesel, 2013; Atreya, Ferreira, & Michel-Kerjan, 2015; Baumann & Sims, 1978; Brouwer, Tinh, Tuan, Magnussen, & Navrud, 2014; Browne & Hoyt, 2000; Gallagher, 2014; Hung, 2009; Kousky, 2017; Kriesel & Landry, 2004; Landry & Jahan-Parvar, 2011; Petrolia, Landry, & Coble, 2013; Ren & Wang, 2016), and air pollution (Chang, Huang, & Wang, 2018). All these studies have shown that individuals' uptake of insurance rises with an increase in flooding, air pollution, erosion, and drought. These results are largely consistent across Africa, Asia, Europe, and North America. There has been strong demand for insurance owing to the recent increase in and frequency of nature risks (mainly flooding) and individuals' past experience of nature risks (Atreya et al., 2015; Baumann & Sims, 1978; Petrolia et al., 2013; Ren & Wang, 2016). Landry & Jahan-Parvar (2011) note that in areas that are particularly vulnerable to erosion and flooding, insurance coverage of assets has increased from USD 0.26 to USD 0.70 per USD 1 of asset value.

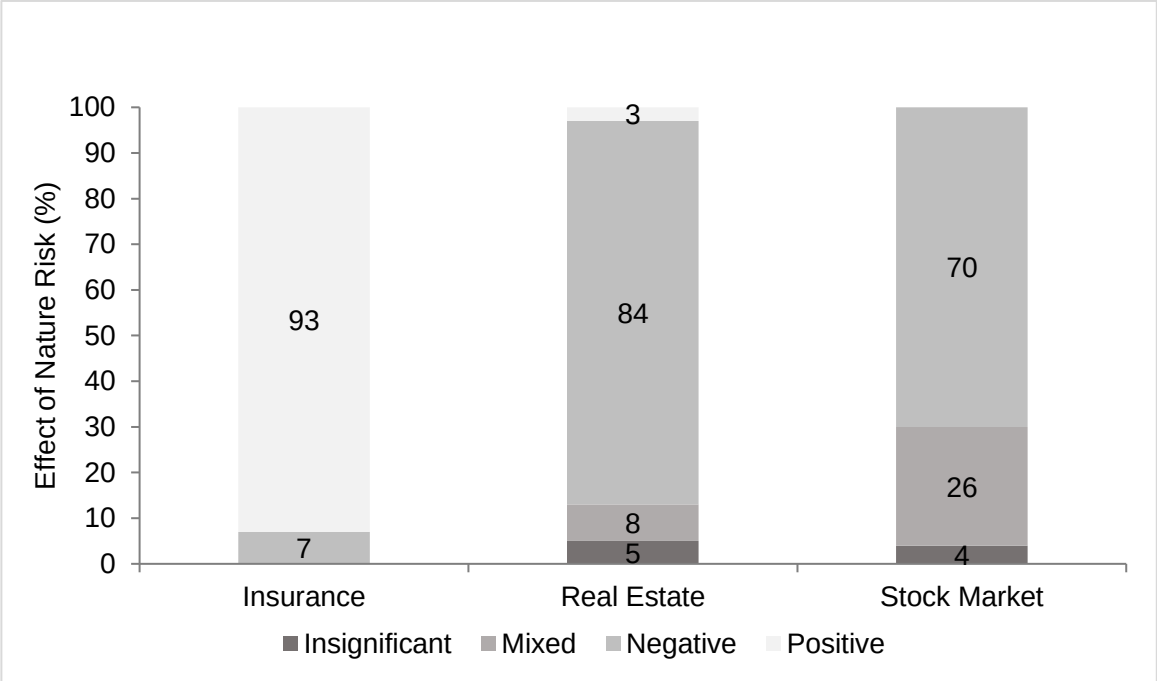
Only one study finds that an increase in nature risk (in this case flooding) has no positive impact on insurance subscriptions (Browne, Knoller, & Richter, 2015). The authors find that policyholders tend more towards insuring against low-consequence risks than high-consequence risks. They also find that individuals do not hold on to a policy forever, as they cancel (some) insurance when nature risks lessen (Atreya et al., 2015; Gallagher, 2014; Kousky, 2017; Ren & Wang, 2016). In the case of flooding, studies have found that insurance uptake is greater in areas along a shoreline or near the coast (Atreya et al., 2015; Kousky, 2017; Kriesel & Landry, 2004). Previous experience of flooding or other disaster lead some individuals to obtain insurance cover, too. Baumann & Sims (1978) note that 75 percent of

homeowners who had experienced previous flooding had flood insurance, and out these, 90 percent indicated this was because they had experienced a flood. Petrolia et al. (2013) note that households in particularly flooding-prone areas are 73.7 percent more likely to have flood insurance than those elsewhere. Gallagher (2014) finds that in a year with flooding, there is an 8 percent increase in the uptake of flood insurance relative to the base year. Regarding air pollution, Chang et al. (2015) note that a one standard deviation increase in daily air pollution leads to a 7.2 percent increase in the number of insurance contracts sold that day.

Although the uptake of insurance in response to nature risks is largely due to flooding, for most of the 20th century flood insurance for households did not exist. This is argued to be due to the lack of accurate flood risk information (Gallagher, 2014).

The impact of nature risks on the insurance sector mainly manifests in an increase in the number of subscriptions due to pending or actual occurrence of nature risks. The data we work with, however, do not tell us how much the rise in nature risks costs the insurance area and how much insurers benefit from the increased subscriptions. We can therefore not factually assess the net gain of the insurance sector. Our findings on insurance should hence be interpreted with caution.

**Figure 6: Effect of Nature Risks on the Financial Areas (in %)**




The diagram shows the (positive, negative, mixed and insignificant) effect of nature risk on financial risk found in the respective studies in regard to the insurance, real estate and stock market fields in percent. Banking is not displayed because only one study focuses on this sector.

### *4.2.3 The Effect of Nature Risks on Real Estate*

The results indicate that the real estate sector is most strongly affected by nature risk. The studies on real estate account for 75 percent of the entire sampled papers; of these, 84 percent indicate that nature risks have negative impact on property value. The impact manifests as a drop in property prices and difficulty in selling the properties, hence posing market and liquidity risks to the area (see Figures 2 and 5). The nature risks affecting real estate most prominently are flooding and pollution.

Instances of flooding have been more prominent in recent periods owing to increasing urbanization and development, subsequent rises in water runoff, and changes in weather patterns (Belanger & Bourdeau-Brien, 2018; Eves, 2004; Rajapaksa, Wilson, Managi, Hoang, & Lee, 2016). Flooding generally causes damages to structures (including residential buildings and other supporting amenities). Apart from the physical destruction of properties, another cause of property value decline is the perceived risk or stigma associated with a hazard (Bible, Hsieh, Joiner, & Volentine, 2002; Mueller, Loomis, & González-Cabán, 2009). As a result, the occurrence of flooding or the threat of future flooding reduces the utility attached to the land and properties on said land, which lowers property values (Bin, Kruse, et al., 2008; Tobin & Montz, 1988). Consequently, property values in flood-prone areas are expected to be lower than those of properties in safe areas. For areas not prone to flooding, property values could fall slightly following a rare flooding but then revert to prior levels or levels close to these (Tobin & Montz, 1988). Remarkably, almost all studies indicate that flooding has detrimental effect on property values (Atreya et al., 2013; Eves & Wilkinson, 2014; Harrison, Smersh, & Schwartz, 2001; Holway & Burby, 1990; Ismail, Abd Karim, & Hasan-Basri, 2019; Komarek & Filer, 2019; MacDonald, White, Taube, & Huth, 1990; Samarasinghe & Sharp, 2010; Speyrer & Ragas, 1991; Turnbull, Zahirovic-Herbert, & Mothorpe, 2013; Turner, Said, & Afzal, 2014). Bin, Crawford, Kruse, & Landry (2008) estimate that the premium that buyers are willing to pay in return for avoiding a flood-prone location is about USD 36,082. Montz & Tobin (1988) note that floodplain property values declined on average from around USD 50,000 to around USD 31,000 after a flood. Speyrer & Ragas (1991) note a value decline of up to USD 13,700 for properties in flood-prone areas. Harrison et al. (2001) note that given comparable characteristics, homes located within a flood zone sell on average for less (USD 1,000 – USD 2,000) than homes located outside. Eves & Wilkinson (2014) find that property values in flood-affected areas fall up to 35 percent in the twelve months after a flood. In very flood-prone areas, Rabassa & Zoloa (2016) find that house prices fall up to 15.4 percent.

Though flooding has a generally negative impact on property values, the timing of the effect differs. For example, while some home prices fall immediately after a flood (Montz & Tobin, 1988; Tobin & Montz, 1988), some do not (Skantz & Strickland, 1987). Also, after some time has passed, prices may rise (Tobin & Montz, 1988) or not (Skantz & Strickland, 1987). Tobin & Montz (1988) find that housing prices dropped as much as 50 percent immediately after a flood, then returned relatively quickly to a level significantly lower than before the incident. It is also argued that the discount on the price of a property in a flood-prone zone is significantly higher after a flood than before (Bin & Polasky, 2004). Shr & Zipp (2019) find that housing values decrease more than 11 percent when a property is assigned as being in a flood-prone zone. Property values do not rebound immediately when flood zone status is removed. In some instances, floods have been found to affect property prices for between six and seven years after a flood (Beltrán, Maddison, & Elliott, 2019).

Flooding-related erosion has also been found to have a negative impact on property values (Below, Beracha, & Skiba, 2015; Hertzler, Ibanez-Meier, & Jolly, 1985; Palmquist & Danielson, 1989). Hertzler et al. (1985) note that the productive value of land is reduced by USD 170 per acre due to soil erosion. Turner et al. (2014) note a similar reduction in land prices. Palmquist & Danielson (1989) note a reduction in land prices equivalent to USD 3.06 per unit increase in the erosion potential of the land on an average tract.

Pollution (air, water, land) or environmental contamination more generally is found to have detrimental effect on property values and the surroundings of said properties. Pollution can affect health (sufferers of asthma and other respiratory diseases can be at high risk), affect breathing, cause damage to structural materials, destroy plants, cause eye, nose, and throat irritation, hasten the corrosion of metals, and discolor buildings (Chen & Chen, 2017; Jaksch, 1970; Ridker & Henning, 1967). These factors cause a neighbourhood to look shabby (Ridker & Henning, 1967), hence affecting the values of local properties. The majority of existing empirical studies have found pollution to reduce the value of residential buildings, land, and other properties in general (Carriazo & Gomez-Mahecha, 2018; Chen & Chen, 2017; Chen, Hao, & Yoon, 2018; Liou, Randall, Wu, & Chen, 2019; Peeters, Schreurs, & Van Passel, 2017; Tang, Heintzelman, & Holsen, 2018). Shaaf & Erfani (1996) note that a five percent increase in mean concentration levels of total suspended particulate and in mean concentration levels of $SO_2$ resulted, respectively, in a decrease in housing prices of 1.15 percent (inelastic) and 5.8 percent (slightly elastic). Berezansky et al. (2010) find that an increase in perceived air pollution is associated with an apartment price decrease by up to 20 percent. Regarding water contamination, Guignet (2012) notes that groundwater contamination leads to a USD 90,850 decrease in property values, and that a 1 ppb increase in benzene (in groundwater) leads to an additional price drop of USD 5,767. Solid waste and oil spills, too, are found to have a detrimental effect on real estate (Cano-Urbina, Clapp, & Willardsen, 2019; Epley, 2012; Havlicek, Richardson, & Davies, 1971; Winkler & Gordon, 2013).

Improvements in air quality and the environment, however, increase the value of residential properties (Chay & Greenstone, 2005; Nelson, 1978; Kim, Phipps, & Anselin, 2003). Kim et al. (2003) estimate that the marginal willingness to pay for a four percent improvement in mean $SO_2$ concentrations is about USD 2,333 or 1.4 percent of mean housing prices. As a result, the rich tend to live in cleaner (less polluted) environments than the poor (Hanna, 2007).

Another destructive nature risk that can affect real estate is bushfires. The sampled studies generally find that bushfires negatively affect property values (Athukorala, Martin, Neelawala, Rajapaksa, & Wilson, 2016; Hansen & Naughton, 2013; Kalhor, Horn, Valentin, & Berrens, 2005; Kiel & Matheson, 2018; McCoy & Walsh, 2018; Mueller et al., 2009; Stetler, Venn, & Calkin, 2010). Bushfires cause billions of dollars of damage in the United States each year (Mueller et al., 2009). Stetler et al. (2010) note that homes within a 5 km radius around bushfire sites have decreased in value as much as USD 33,232.

Another factor that has been found to affect real estate in recent years is invasive species (Hansen & Naughton, 2013; Horsch & Lewis, 2009; Zhang & Boyle, 2010). Zhang & Boyle (2010) note that an invasive species (here, the Eurasian watermilfoil) infestation of a lake decreases property values in the area by between one and 16 percent. Horsch & Lewis (2009) find that land values around lakes infested with milfoil experienced an average decrease of 13 percent.

Nature risks have been found to have either a positive or an insignificant effect on real estate. Similarly, mixed effects have also been found. For example, Fernández-Avilés et al. (2012)

and Wieand (1973) find pollution to have a positive effect on housing prices. However, Fernández-Avilés et al. (2012) ascreibe their results to a potential discrepancy between residents' subjective perception of the environmental and objective measures of pollution. Athukorala, Martin, Wilson & Rajapaksa (2019) find that the threat of bushfires does not deter residents, as they prefer to remain near forested areas because they enjoy the greenery. As a result, house prices in bushfire-prone areas still rose despite the risk. Studies that have also found a mixed effect of nature risks on real estate include Chasco & Gallo, 2013; Jackson, 2001; Mínguez, Montero, & Fernández-Avilés, 2013; Won Kim et al., 2003 (for pollution), Ervin & Mill, 1985 (for erosion), Meldrum, 2016; Sawada et al., 2018 (for flooding), and Donovan, Champ, & Butry, 2007 (for bushfires).

The results generally show that in the case of real estate, nature risks are generally capitalized in property pricing, usually in the form of discounted prices (Beltrán, Maddison, & Elliott, 2018; Bin, Kruse, et al., 2008; Case, Colwell, Leishman, & Watkins, 2006; Page & Rabinowitz, 1993; Rabassa & Zoloa, 2016; Skantz & Strickland, 1987; Tobin & Montz, 1988; Turnbull et al., 2013; Yi & Choi, 2019; Zheng, Kahn, & Liu, 2010). Evidence of the capitalization of risks in pricing is found for erosion, flooding, pollution, and bushfires (Below et al., 2015; Beltrán et al., 2018; Bin, Kruse, et al., 2008; Shaaf & Erfani, 1996; Turnbull et al., 2013). This happens when properties are located in or near places highly prone to nature risks, as well as in areas designated as nature risk-prone (erosion, flooding, pollution) (Below et al., 2015; Bin, Kruse, et al., 2008; Speyrer & Ragas, 1991).

Insurance premiums rise as hazards in a neighbourhood rise, and the rise in insurance premiums is capitalized into property values and hence cause prices to decline (Belanger & Bourdeau-Brien, 2018; Bin, Kruse, et al., 2008; Skantz & Strickland, 1987). In most cases, businesses prone to nature risks have mandatory insurance, such as flood protection. The cost of insurance discounts the values of the properties in question (Belanger & Bourdeau-Brien, 2018; Bin, Kruse, et al., 2008; Speyrer & Ragas, 1991).

#### *4.2.4 The Effect of Nature Risks on the Stock Market*

Concern about the environment has motivated many investors (especially institutional investors) to limit their investments to corporations with lower pollution (Cormier, Magnan, & Morard, 1993). Corporations with unfavorable pollution records will generate lower cashflows as they are compelled to invest in additional anti-pollution equipment (Cormier et al., 1993). These corporations hence face potential liabilities that could adversely affect their stock market valuation (Cormier et al., 1993). In recent years, pollution information disclosure (such as the pollutant release and transfer register) has become mandatory, acting as a source of information of companies' pollution profiles. This can cause polluting firms to be penalized by investors buying fewer shares (Ferraro & Uchida, 2007).

Pollution, particularly air pollution, is perceived to have a negative emotional (mood) effect on humans, hence including on investors (An, Wang, Pan, Guo, & Sun, 2018). Pollution-induced emotional and health effects are believed to have adverse economic implications, thus affecting stock market returns and performance (Lepori, 2016; Levy & Yagil, 2011). Mood affects decision making, and a bad mood can accelerate risk aversion and enhance one's subjective assessment of future risks (Lepori, 2016; Levy & Yagil, 2011; Slovic & Peters, 2006; Wu, Hao, & Lu, 2018; Wu, Chen, Guo, & Gao, 2018). Generally, studies indicate that air pollution has negative effect on market capitalization and stock valuations (An et al., 2018; Chugh, Hanemann, & Mahapatra, 1978; Cormier et al., 1993; Ferraro & Uchida, 2007; Jaggi

& Freedman, 1992; Lepori, 2016; Levy & Yagil, 2011; Varma & Szewczyk, 1990; Wang, Zhang, Lu, Wang, & Song, 2019; Q. Wu et al., 2018; X. Wu et al., 2018), hence posing risks to the stock market. Other studies have found pollution to have a mixed effect on the stock market. Zhang, Jiang, & Guo (2017) indicate that pollution has a negative effect on stock returns and a positive effect on stock volatilities through the channel of investor mood. Li & Peng (2016) stress that the negative effect of pollution on the stock market is weaker for companies that protect air quality. He & Liu (2018) assert that the effect of pollution on the stock market is only significant with public environmental awareness. The majority of these pollution-based studies have been focuses China.

The impact of the April 20, 2010 oil spill involving British Petroleum's (BP) Deepwater Horizon in the United States on the stock market has also been analyzed. The impact has largely been found to be negative (Heflin & Wallace, 2017; Hsu, Liu, Yang, & Chou, 2013; Humphrey, Carter, & Simkins, 2016; Lee & Garza-Gomez, 2012; Sabet, Cam, & Heaney, 2012). By the end of June 2010, the oil and gas industry had lost around USD 463.1 billion in market capitalization (Lee & Garza-Gomez, 2012). Lee & Garza-Gomez (2012) estimate on market-based measures that as of September 19, 2010 up to USD 562 billion loss in market capitalization had been wiped out. This loss was mainly sustained by BP itself, eight partners of BP, and other firms in the oil and gas industry. Between April 20, 2010 and September 19, 2010, BP lost around USD 68.2 billion in market capitalization. Hsu et al. (2013) report that following the BP oil spill, sampled firms in the petroleum industry saw their market value drop by 0.5 percent during a two-day event window. A corporate disaster can adversely affect a firm's market valuation induced by the regulatory, legal, and technological improvements, fines, clean-up and reputation costs that the firm has to manage (Heflin & Wallace, 2017; Lee & Garza-Gomez, 2012; Sabet et al., 2012). The direct cost of the oil spill to BP was around USD 54 billion (Humphrey et al., 2016). Investor awareness of an environmental disaster can also affect a firm due to the fear of recurrence (Giudici, Tona, Reddy, & Dai, 2019; Heflin & Wallace, 2017; Hsu et al., 2013).

Giudici et al. (2019) find no pattern regarding the effect of pollution and oil spills on the stock market in China. They emphasize that the reaction of the most heavily polluting industries is rarely negative. However, environmental disasters generate market uncertainties and usually change investors' risk perceptions in the short and long term.

Some studies examine the impact of disease on the stock market (Pendell & Cho, 2013; Wang, Yang, & Chen, 2013). Pendell & Cho (2013) examine the market's reactions to Korean agribusiness companies following five outbreaks of foot-and-mouth disease. The results indicate that the stock market reacted in both negative and positive ways to allied companies; negatively to pork producers, but positive to poultry and seafood companies. Wang et al. (2013) examine how the outbreak of infectious diseases (ENTEROVIRUS 71, DENGUE FEVER, SARS and H1N1) affects the performance of biotechnology stocks in Taiwan. They find a mixed effect, with negative or positive effects of infectious diseases on cumulative abnormal returns depending on the day of analysis. In Australia, Worthington (2008) indicates that bushfires and flooding have no significant impact on stock returns on the Australian stock exchange.

## 5. Conclusion

As the threats posed by nature risks to human health and activities in general get more transparent, little is known as to whether these nature risks also translate to financial risks for the financial industry. In this study, we systematically review existing literature on this subject.

Our search identifies 154 peer-reviewed articles drawn from five major scientific academic databases and published in 84 journals. These studies focus on 28 countries worldwide and were published between 1967 and 2019. For the sample period in question, we do not find any consistent changes of the findings over time. Generally, the findings are persistent over said period.

The studies cover four sectors of the financial industry (banking, insurance, real estate, and the stock market) and nine nature risks (disease, drought, erosion, flooding, invasive species, oil spills, pollution [air, groundwater, soil/land, surface water], solid waste, and bushfires). Only one study focused on banking, indicating that credit losses from drought affect capital reserves and as a result decrease the supply of credit, posting credit risk to the region. The real estate sector is most vulnerable to adverse nature risks. The worst threat to property values is flooding, followed by air pollution (and environmental contamination in general), and bushfires. The sector is generally subject to market and liquidity risks due to nature risks. Stock market performance is found to be generally affected by pollution, oil spills, and outbreaks of disease. As for insurance, the studies generally indicate that increasing nature risks causes policy subscribers to increase their coverage. This is because insurance firms work to reduce and spread risks when disaster strikes. With the rise in flooding, air pollution, erosion, and drought, individuals tend to buy insurance coverage for safety. The studies on the impact of pollution are mainly on China, and all of those on oil spills focus on the United States.

In the real estate sector in particular, nature risks are capitalized into pricing which is reflected in declining property prices. Properties located in or near areas highly prone to erosion, flooding, pollution, or bushfires usually suffer reduced prices, lower demand, and longer selling time. Discounted prices are sometimes due to the insurance that comes with these properties because they are exposed to risks.

Though this is a very comprehensive review of the existing literature, it is not free of limitations. First, the review includes only peer-reviewed published articles and has disregarded working papers, conference proceedings, unpublished papers, and indeed all gray literature. Second, the review is strictly limited to papers written in English, hence it disregards some potentially interesting papers in other languages. Third, the major databases we drew on may not capture all published papers and hence our sample does not include these.

## 6. Research Gaps

Many of the studies reviewed here find a negative effect of nature risks on the financial industry. Yet this is not entirely conclusive as the study is based on just a few nature risks. In this section we discuss some potential research gaps that can be considered in future studies. Firstly, we propose that future studies consider how nature risks influence insurance firms' cost structure. The studies we review generally indicate that the existence of nature risks largely cause affected property owners to take out more insurance. Further research is therefore needed to conduct a cost and benefit analysis of nature risks in the insurance sector in order to identify the net gain to the industry. Secondly, we propose that further studies be conducted on banking. Only one study focused on banking and as a result, it is hard to be conclusive. More research on the banking sector would provide a clearer picture of the effect of nature risk on this industry. Thirdly, future studies could also analyze the mechanisms through which nature risks translate into financial risks. Considering that the papers analyzed here are mainly empirical, these mechanisms are not well known. Though the majority of the studies discussed here provide first-hand information regarding the relation between nature risk and financial risk, the channels through which this relation is seen are far from being fully identified. Fourthly, we propose that studies on other countries than those studied should be initiated. Most of the studies identified here focus on but a few countries, particularly the United States (accounting for around 60 percent) and China (around 10 percent), which makes generalization difficult. All in all, our reviewed studies cover only 28 countries, an indication of poor geographical representation. Lastly, future studies should also look at expanding the financial areas and nature risks analyzed. Existing research considers just a few areas in the financial industry and nature risks. Little to nothing is known about other markets such as commodities, bond, derivatives, and foreign exchange. Of the over 100 nature risks searched in conjunction with related studies, only nine were connected to our objectives. Future studies should consider other nature risks such as desertification and deforestation.

A major limitation of a number of the studies reviewed here is the availability and longevity of data (Cano-Urbina et al., 2019; Eves & Wilkinson, 2014; Peeters et al., 2017; Posey & Rogers, 2010; Tang et al., 2018; Yi & Choi, 2019). This affects the accuracy of the estimations and the depth of analysis that could be done. In many cases it was also a challenge to measure the monetary value of the physical damage (Yi & Choi, 2019) posed by nature risks. The development of a comprehensive body of data on nature risks would be highly beneficial to scholars. In our search, we failed to find any empirical study specifically addressing the effect of biodiversity loss or ecosystem loss on the financial industry. A general consensus on the definition of biodiversity loss and the construction of a comprehensive database will benefit future empirical studies.

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