Ecological Modelling 392 (2019) 117–127

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

A first analysis on the need to integrate ecological aspects into financial insurance

Donatella Valente[a], Pier Paolo Miglietta[b], Donatella Porrini[b], Maria Rita Pasimeni[a,*], Giovanni Zurlini[a], Irene Petrosillo[a]

[a] *Lab. of Landscape Ecology, Dept. of Biological and Environmental Sciences and Technologies, University of Salento, Italy*
[b] *Dept. of Management, Economics, Mathematics and Statistics, University of Salento, Italy*

ARTICLE INFO

Keywords:
Gross insurance premiums
Gross claims payments
Resilience
Ecosystem services
Forests
Terrestrial protected areas
Financial-ecological preparedness

ABSTRACT

It is known that financial insurance can address the economic impacts of a natural disaster, but some ecological aspects can play a crucial role in mitigating the overall risks for socio-ecological systems. To better strengthen the study of these relations, the aims of this paper are: (1) to analyze the main research topics of the scientific literature on ecological and/or financial-economic insurance to face natural disasters, through a co-word network analysis; (2) to analyze the temporal trends of the total Gross Insurance Premium and Meteorological and climatological extreme events in 29 OECD countries; and (3) to carry out a Principal Component Analysis (PCA) of some selected variables in order to conceptualize a first empirical model combining financial-economic and ecological insurance to face natural disasters. The literature review has shown a predominance of topics related to financial insurance (about 60%), and the co-word map of key words has highlighted a common space where economic and ecological insurances interact. PCA highlighted three major components explaining 90.6% of the overall variation and discriminating aspects more related to the "financial" insurance, from those related to the "ecological" insurance. More in detail, PC1, which represents the financial insurance, explains the 60.4% of variation, PC2 and PC3 that represent surrogates of the "ecological" insurance explain respectively the 19.6% and the 10.6% of variation. On the basis of the application of the proposed empirical model, countries with high levels of financial and ecological preparedness have been identified. The next steps of this research will be focused on a pilot study area where a quantitative assessment will be applied to better define the landscape contribution to natural disaster risk mitigation, the analysis of the role of social capital through a cross-scales approach, in terms of policies and management strategies, and the investigation of innovative economic tools to take into account specific payment for ecosystem services in the context of natural disasters.

1. Introduction

The limits of predictability of complex, adaptive, living systems need to be recognized, and a "pragmatic modeling" philosophy of science needs to be adopted allowing new, adaptive approaches to deal with natural disasters (Costanza and Jørgensen, 2002). The devastating effects of natural disasters (e.g., earthquakes, cyclones, floods and droughts) in their sudden and shocking occurrence are source of concern and alarm (World Bank, 2017). In general, a disaster or catastrophe is a typical unexpected event that causes negative effects in many areas of daily life (communication, supply of electricity and water, etc.), but above all significant losses of goods and people (Swiss Reinsurance Institute (Swiss Re, 2017).

Although it is certainly true that these phenomena are merely outward manifestations of an inherent dynamism of our planet, and that mankind has always been exposed to their destructive action, it is equally true that we have been witnessing an intensification of calamitous events in recent years (Dankers et al., 2014; Hall et al., 2014). This trend is confirmed also by the analysis of climate data, indicating a substantial increase in the intensity and frequency of extreme weather events (IPCC, 2014). From this perspective, some recent years, like 2011, have faced so many natural disasters that they have been defined as "*annus horribilis* for natural catastrophes" by insurance leaders (Courbage and Stahel, 2012).

Despite their high and growing frequency and intensity, the enormous costs, and the numerous casualties, these disastrous events are

* Corresponding author at: Lab. of Landscape Ecology, Dept. of Biological and Environmental Sciences and Technologies, University of Salento, Ecotekne, Prov.le Lecce Monteroni, 73100, Lecce, Italy.
E-mail address: mariarita.pasimeni@unisalento.it (M.R. Pasimeni).

https://doi.org/10.1016/j.ecolmodel.2018.11.009
Received 9 April 2018; Received in revised form 30 October 2018; Accepted 18 November 2018

still generally perceived as "exceptional natural events that interrupt normal anthropic development and require humanitarian actions to mitigate losses" (Bureau for Crisis Prevention and Recovery (BCPR)/ UNDP, 2004). Furthermore, despite the scientific interest in natural hazards has seen an increase in research and publications, the governmental world is too often dormant up until the disaster has occurred (Cutter et al., 2007).

In the frame of the definition of disaster seen above, natural disasters are catastrophic events caused by nature or by the natural processes of the Earth. The severity of a disaster is measured in lost lives, economic loss, and population capacity to rebuild. Earthquakes, windstorms, floods and diseases are extreme sudden events that hit everywhere on Earth, often without notice (Hoeppe, 2016). They can also be defined as "stochastic events such as weather extremes, fires, or pest outbreaks that can often directly affect the state of the system, such as eliminating parts of populations" (Scheffer et al., 2001). When natural disasters occur, social and economic activities and the well-being of people are likely to be affected (Adeagbo et al., 2016).

According to the Centre for Research on the Epidemiology of Disasters–CRED (2014) five categories of natural disaster can be identified, covering 16 disaster types (Table 1).

Catastrophic events link environmental risks to financial, economic and social risks, where the former are often characterized by high levels of uncertainty, with far-reaching consequences, given that some of them even occur in distant places, and are therefore sustained by others. Thus, the perception of environmental hazards, which significantly influences the responses to any risk may result in a discount of such risks (Tobin and Montz, 1997; Tobin et al., 2005; Whiteford and Tobin, 2004); that is, those risks are taken less seriously than the risks with negative results that occur "for sure, now, here and for us" (Gattig and Hendrickx, 2007).

1.1. Financial-economic insurance and natural disasters

The insurance sector is highly exposed to natural disasters and climate change because of more frequent and severe extreme weather events causing more claims, which can lead to insurance market failure (Dlugolecki, 2009; Johannsdottir et al., 2014). Although recently the forecasting of extreme events and systems of disaster preparedness and response have improved significantly, the rising prosperity and the associated increased density of human settlements and economic activities have resulted in proportionally more people and more capital being placed at risk when disasters strike (Adam, 2013; Barthel and Neumayer, 2012).

The losses due to extreme natural disasters can have significant economic consequences for individual property-owners and businesses,

Table 1
Classification of natural disasters according to the Centre for Research on the Epidemiology of Disasters – CRED (2014).

Disaster Group	Disaster Subgroup	Disaster Main Type
Natural	Geophysical	Earthquake Mass Movement Volcanic activity
	Meteorological	Extreme Temperature Fog Storm
	Hydrological	Flood Landslide Wave action
	Climatological	Drought Glacial Lake Outburst Wildfire
	Biological	Epidemic Insect Infestation Animal Accident

especially when these effects exceed their current financial capacity. In this context, insurance is an instrument to tackle the economic impacts of natural disasters, representing the natural counterpart of ex-post or reactive disaster recovery funding (Adam, 2013), through a pro-active approach based on the payment of a premium. However, although the market for insurance instruments against natural disasters has developed significantly, it remains small relative to the potential demand for insurance (Borensztein et al., 2017). Insurance companies traditionally used to work making each individual or business pay a premium to protect themselves against an uncertain loss. In this sense insurance managing risks promotes recovery from disasters, because insurance reduces financial risks for households by spreading risks over many policyholders and helps economically people after a disaster occurs (Benali and Feki, 2017).

However, the insurance industry could play a significant role in different directions: not only, insurance policies cover claims of third-parties, who allege injury or property damage; but insurance can also be seen as a part of a risk management system that should include the identification, assessment and understanding of a risk in order to minimize the potential harm of natural disasters, by implementing strategies and actions to control and reduce risks.

On an economic point of view, insurance enhances social welfare while, at the same time, inducing their holders to take reasonable (i.e. cost-effective) precautions, by internalising the damage. Furthermore, insurance encourages the risk-averse insured party to make investments because the pricing of risks generates a clear economic benefit from precautionary spending (Porrini and Schwarze, 2014).

Generally, the challenge of reducing in the future the consequences of natural disasters is framed in terms of the potential strategy of “mitigation”. Disaster risk mitigation is one of the most important priorities for insurance companies and indicates any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life (Benali and Feki, 2017).

Studies on risk reduction of the impact of natural catastrophes have focused on (Pérez-Maqueo et al., 2007): (a) the analyses of social processes and possible underlying causes of the disaster event (Alexander, 2000; Holzmann and Jørgensen, 2004); (b) the economics and strategies for financing post-disaster infrastructures able to support their recovery (Berz, 2004; Gollier, 2005); (c) the role of the Government, private sector, and NGOs for disaster preparedness and risk prevention (Benson et al., 2001; Daniels et al., 2006); and (d) a modeling approach to analyze the interplay between investment in mitigation and risk-sharing measures (Amendola et al., 2000). In the last case, the premiums provide a clear signal and encourage insurers to engage in mitigation measures to reduce vulnerabilities to disasters. In addition, premiums allow insurers to offer discounts to owners and businesses that invest in preventive measures (Benali and Feki, 2017).

A risk reduction strategy should sustain the mitigation of the impacts of natural disasters with less risks for economic systems. Therefore, the target could be to tackle the consequences of natural disasters by the promotion of ways to support an effective limitation of economic losses and the management of risks from extreme hazards.

If and how insurance plays a role in a country is influenced by local traditions, cultural factors, experience with disasters, availability of data, as well as the engagement of the public and private sectors (Porrini and Schwarze, 2014). In any case, the time taken to recover from the impact of disasters, natural or man-made, is a function of preparedness. In fact, individuals and households with some form of contingency plan in place are likely to recover more quickly than those without any such plans. In this perspective, insurance policies and/or other savings schemes, formal or informal will prove to be useful for quick recovery and reconstruction (Adeagbo et al., 2016).

Finally, it is crucial to consider how resilient (robust) are the insurance arrangements, otherwise insurance companies will fail if there are multiple claims, as in the case of the United States of America in the 1920s, when youthful companies have incurred substantial losses in paying out large claims before they had built up reserves (González Dávila et al., 2014). However, if individuals are risk-averse and insurance against a risk is offered at an actuarially fair price expected utility theory predicts that individuals would buy it. In the same way, when the perception of natural risk increases, the insurance penetration increases as well (Breckner et al., 2016), and the demand for innovative insurance solutions are expected to grow and to develop.

1.2. Ecological insurance and natural disasters

Rarely the role of natural and man-made ecosystems and the ecosystem services provided to human societies are considered in the programs of development and reduction of risks related to natural disasters (Pérez-Maqueo et al., 2007). In this context, the ecosystem service of disturbance regulation provided by some natural, semi-natural or man-managed ecosystems, like forests, is identified as a priority for hazard mitigation and risk reduction (Bronstert, 2003; Hook, 2000; Kreimer and Arnold, 2000). Forests provide ecological, economic, social, and aesthetic services to natural systems and humankind (Bonan, 2008). Well-managed forest protection, for example, can be effective in protecting against rock fall and reducing the risk of avalanches (Bebi et al., 2009). The growing awareness of the roles that forests play in climate change mitigation has raised global interest in understanding the processes that lead to deforestation and forest restoration (Chazdon, 2008; Foley et al.,2005; Harris et al., 2012), and multiple factors from natural and human systems are drivers of the processes (Geist and Lambin, 2002; Hansen et al., 2013; Meyfroidt and Lambin,2011; Miyamoto et al., 2014). It is important that the policy makers and the masses are aware of the significance of forests in preventing and mitigating natural disasters (Zhang et al., 2017).

In view of these considerations, in the context of natural disasters, the term "ecological insurance" can be adopted, which includes the three main concepts relating to a set of mechanisms capable of stimulating intrinsic characteristics of self-determination of nature. The defining elements of "ecological insurance" include the concepts of resilience (Carpenter et al., 2001; Holling, 1973), adaptive capacity (Deutsch et al., 2003), and biodiversity (in terms of functional diversity) (Baumgärtner, 2007; Swanson, 1992; Yachi and Loreau, 1999), which all act as insurance against an undesirable change of the system.

Ecological insurance will allow for new, adaptive approaches to environmental management and better links with social decision-making. These linkages are particularly important in the real ever-changing world so that biodiversity, as a manifestation of functional diversity and diversity across scales, has a definite value in insuring society against the loss of ecosystem services through the maintenance of the adaptive capacity of socio-ecological systems to adjust to biotic and abiotic stresses, and to prevent systems shifting to another undesirable state (Scheffer et al., 2001; Admiraal et al., 2013; Adger et al., 2005; Müller et al., 2017).

Ecosystem services are the direct and indirect contributions of ecosystems to human well-being, and they support our survival and quality of life (Millennium Ecosystem Assessment (MEA, 2005), constituting the base of human needs (Mäler, 2008). The ecosystems, which represent the providers of services, may exhibit multiple stability domains ("basins of attraction") that differ in fundamental system structure and behavior (Baumgärtner and Strunz, 2014; Quaas and Baumgärtner, 2008). The maximum amount that a system can absorb while maintaining its stability domain without flipping into a different one is called resilience (Holling, 1973, 1996). Resilience is the ability of a system, whether it is an individual, a forest, a city or an economy, to face changes and disturbances and continue to develop. In addition, resilience may also concern the degree to which the system is capable of self-organization and its capacity to learn and adapt (Gunderson and Holling, 2002).

Since different stability domains exist in nature, any system can experience the so-called thresholds (Dasgupta and Mäler, 2003; Holling, 1973; Mäler, 2008), which the system does not usually cross thanks to its "buffering capacity" (Mäler, 2008). The buffer concept is explained in relation to the fact that a slightly disturbed system is characterized by a high resilience avoiding the thresholds. When disturbance continues to increase, the resilience decreases, and the threshold limit approaches a point where it is overcome (Mäler, 2008). Therefore, resilience can be considered as a capital stock or rather a "kind of insurance against reaching an undesirable state" (Mäler and Li, 2010; Perrings, 1995), by "keeping an ecosystem in a desirable domain" (Baumgärtner and Strunz, 2014; Trærup, 2012) ensuring that the flow of ecosystem services is not reduced by unforeseen and catastrophic events.

Resilience and adaptive capacity of a system are strongly interconnected, so that the higher its ability to adapt, the higher its resilience. In addition to resilience, adaptive capacity is related to a series of concepts such as adaptability, coping ability, management capacity, stability, robustness, and flexibility (Adger and Kelly, 1999; Brooks, 2003; Fraser et al., 2003; Füssel and Klein, 2006; Jones, 2001; Smit et al., 1999; Smithers and Smit, 1997; Tompkins and Adger, 2004). The key concept of adaptation today is of vital importance to address how the human population can face changes (Müller and Li, 2004). Adaptive capacity should be conceptualized in terms of the capacity of the social actors in integrated systems to recover from disaster losses. This state can be achieved through the adoption of alternative livelihood and construction strategies for the future, despite the losses and the stress imposed by disastrous events (Choudhury and Haque, 2016).

Resilience and adaptive capacity are backed by biodiversity, which is a form of natural insurance due to functional diversity because it is the basis that supports the supply of ecosystem services from natural and man-managed systems such as biomass production, pollination, nitrogen fixation, soil regeneration, etc. (Costanza et al., 1997; Daily, 1997; Millennium Ecosystem Assessment (MEA, 2005). The biodiversity, in essence, constitutes a form of insurance as it ensures a functional complementarity in space and time (Loreau et al., 2003). System protection from environmental risks is directly related to the most species in terms of functional redundancy that can be considered an effective defense against the unpredictability of dangerous events (Gonzalez et al., 2009; Loreau et al., 2003; Norberg et al., 2001; Yachi and Loreau, 1999). The presence of the best species performer in different environments promotes greater insurance because it stabilizes the ecosystem and maximizes productivity (Loreau et al., 2003; Yachi and Loreau, 1999).

2. Aims of the paper

Given the above mentioned considerations, the aims of this paper are: (1) to analyze the main research topics coming from the scientific literature focused on ecological and/or financial-economic insurance to face natural disasters, through a co-word network analysis; (2) to analyze the temporal trends of the total Gross Insurance Premium and Meteorological and climatological extreme events in 29 OECD countries, given data availability and that meteorological events (flood, droughts and wind storms) typically represent the majority of reported disasters (Guha-Sapir et al., 2011; Rodriguez et al., 2009; Scheuren et al., 2008); and (3) to carry out a Principal Component Analysis (PCA) of some selected variables in order to conceptualize a first empirical model combining financial-economic and ecological insurance to implement the preparedness for facing natural disasters.

3. Materials and methods

3.1. Systematic review

The first step in this research was a literature survey, conducted through academic library databases (ScienceDirect and Google Scholar). The screening of all titles, abstracts, and keywords was done

Table 2
The list and description of the variables acquired from each paper included in the review.

Variable	Description
Author	Name of Author(s)
Year	Year of publication
Journal	Name of the peer-reviewed Journal
Study Area	Name of the study area
Country	Name of the country of the study area
Typology of insurance analyzed by the article	Financial Insurance Ecological Insurance
Typology of the model used	Mathematical/Statistical Model Conceptual Model No model
Keywords	List of keywords for each article

by searching and combining the terms "ecological insurance", "economic insurance" and "natural disasters". In this review only works published in English and in scientific journals have been included, excluding gray literature such as reports, books, and lectures. Although this review did not include any single article focusing on how economic and environmental health insurance can address natural disasters, it can represent a significant sample of the most relevant scientific literature on these topics. Some basic variables have been collected from each article (Table 2).

To assure the scientific relevance of selected papers in analyzing the main findings on the relations between the different forms of ecological and financial insurance and natural disasters, the established guidelines for systematic review (Pullin and Stewart, 2006) were applied. Then, to better verify the accuracy and reliability of the screening process, another reviewer analyzed the first filter of titles and abstracts on a random subsample of 10% of the references. Finally, the level of agreement among the reviewers was measured through Cohen's kappa analysis (Cohen, 1960). Given a kappa value of 0.803 ($p < 0.001$), according to Landis and Koch (1977) there is a substantial strength of agreement of the screening process among the reviewers. In addition to the descriptive statistical analysis, a co-word analysis (Ding et al., 2001) was carried out through R (Venables et al., 2018). This technique is useful to explore the conceptual network and the development tendency in different fields and is based on the principle that when two or more keywords representing specific research topics appear in the same article, it is assumed that they have a relationship. The more the co-occurrence between the two keywords, the closer their relationship is (Yang et al., 2012). Given the literature collected, the co-word analysis is based on the following steps: (1) the data extraction of the high frequency keywords; (2) the data processing by building the high frequency keywords matrix; (3) data analysis, based on multivariate analysis methods to find the composition, similarity, and relationship among keywords; and (4) the visualization of the results.

To determine the cut-off point of high-low frequency words, the high-low frequency words boundary fraction proposed by Donohue (1973) was applied:

$$T = -1 + 0.5 * \sqrt{1 + 8 * I}$$

where I is the total number of keywords. T, which is the lowest frequency among the high-frequency keywords, assumes the value of 37 according to the number of keywords resulting from the literature review. However, only two keywords overcome this frequency, for this reason this study selected the keywords with frequency higher than or equal to 10, forming a similarity matrix 9 × 9.

In particular, the calculation method of similarity matrix is conducted through the Ochiai coefficient formula:

$$Ochiai\ coefficient = \frac{C_{AB}}{\sqrt{AB}}$$

where A and B are, respectively, the number of keywords A and keywords B, and C_{AB} is the number of keywords A and keywords B appearing together.

3.2. Data acquisition and multivariate analysis

Table 3 reports the list of acquired data for twenty-nine OECD countries (Fig. 1), for which the OECD Insurance Statistics provide reliable financial data, together with information about the temporal range (1993–2015), and their sources. These data have been used in the following trend and multivariate analyses. Therefore, in each country, the gross insurance premiums, which represent the total insurance premiums, and the gross claims payments, which cover all gross payments made during each financial year, have been acquired from OECD Insurance Statistics.

In particular, data about the catastrophic events for the same time frame and countries of financial data have been acquired from EM-DAT, a database launched in 1988 by the Centre for Research on the Epidemiology of Disasters (CRED) with the initial support of the World Health Organization (WHO) and the Belgian Government. This database integrates several sources of data, including UN agencies, NGOs, insurance companies, research institutes and press agencies, and it makes the data available online. Detailed data about climatological and meteorological disasters were acquired from this database (Table 3).

Data about GDP per capita, extracted from World Bank database, refer to gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for

Table 3
List of acquired data with information on the temporal range (1993–2015), the spatial reference (29 OECD countries), and the data sources.

List of data	Period	Countries	Source of data
Gross insurance premiums – GIP (million US$) Gross claims payments – GCP (million US$)	From 1993 to 2015	OECD countries	OECD Insurance Statistics http://www.oecd-ilibrary.org/finance-and-investment/oecd-insurance-statistics_2307843x
Climatological and meteorological disasters at the country levels			EM-DAT database http://www.emdat.be/database
Gross Domestic Products – GDP per capita (US$)			World Bank https://data.worldbank.org/indicator/NY.GDP.PCAP.KD
Average life expectancy			World Bank https://data.worldbank.org/indicator/SP.DYN.LE00.IN
Expected inflation rate (%)			World Bank https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
Forest Area (%)			World Bank https://data.worldbank.org/indicator/AG.LND.FRST.ZS
Forest Rents (% of GDP)			World Bank https://data.worldbank.org/indicator/NY.GDP.FRST.RT.ZS
Terrestrial Protected Areas (%)			World Bank https://data.worldbank.org/indicator/ER.LND.PTLD.ZS

Fig. 1. Map of the 29 OECD countries under study.

depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars (Table 3).

Average life expectancy data, which is positively related to insurance premiums and claims payments (Johannesson and Johansson, 1997), represent the average number of years an individual in a country is expected to live.

The expected inflation rates in line with Choate and Archer (1975) are established by the inflation rate in previous years extracted from the World Bank database. For this reason, in this study the average inflation rate over the previous eight years is used as a proxy for the expected rate of inflation in each country.

Forested area, Forest Rents, and Terrestrial Protected Areas are the last variables included in the analysis acquired from the World Bank database. The forested area represents the percentage of the area covered by forests in each of the 29 OECD countries in a given year, the Forest Rents represents a percentage of GDP, and Terrestrial Protected Areas represent the percentage of the area covered by terrestrial protected areas in each of the 29 OECD countries in a given year.

At present, economic insurance does not consider the role played by ecosystem services in risk mitigation of natural disasters' effects, which remains economically uninvestigated and unknown (Hook, 2000; Pérez-Maqueo et al., 2007). However, there are some studies on the role of natural ecosystems, such as forests, coastal mangroves, coral reefs, riparian habitats, and protected areas in risk reduction programs (Bronstert, 2003; Danielsen et al., 2005; Deboudt, 2010; Hiraishi and Harada, 2003; Hook, 2000; Kreimer and Arnold, 2000; Mouillot et al., 2008) as well as a more complex and integrated approach shown by Pérez-Maqueo et al. (2007). The extent of forests, for instance, could provide a more effective natural insurance against climatic variability, particularly against extreme weather events, providing an added value to the conventional (more extensively studied) economic one (Figueroa and Pasten, 2015). Therefore, a PCA was performed on these variables to check any existing correlation among the "economic" variables, typical of the traditional context of financial insurance, and some available "ecological" variables that can represent a surrogate of some regulation service useful to face natural disasters like meteorological extreme events.

4. Results and discussion

4.1. Results of the review

The literature review was based on 174 scientific papers focused on financial & ecological insurances and natural disasters, covering a period from 1983 to January 2018. Although there was only one paper published in 1983 followed by an absence of publications till 1993–1995, after a limited research interest from 1983 to 2006, it was possible to highlight a first peak of number of papers in 2007. Then, it was possible to notice an increasing trend until 2014, when the number of papers showed an outbreak exceeding 30 published articles (Fig. 2).

Articles were classified on the basis of the types of insurance (financial-economic and/or ecological) they are focused on. The results highlighted that only 18% of the papers dealt with the integration between financial-economic and ecological insurances, 62% was focused only on "Financial-economic insurance", given the economic origin of the concept, and 20% was focused only on "Ecological insurance" (Fig. 3). However, there was an increase in the percentage of papers based on an integrated approach between financial-economic and ecological insurance from 2007 to 2016.

The modeling approach was used in 72% of articles dealing with financial-economic and/or ecological insurances, of which 69% used mathematical-statistical models, 22% conceptual models and only 9% used the two models in an integrated way (Fig. 4). The temporal trend showed that the integration of models was rather recent as well as the integration between financial-economic and ecological insurances (Figs. 3 and 4). As a first indication, papers dealing with only ecological insurance were usually based on conceptual models, while the financial-economic insurance seemed to be addressed through mathematical/statistical models.

The results of co-word similarity matrix based on Ochiai coefficients and combined with keywords' frequency higher than or equal to 10 are shown in Fig. 5.

The size and color of dots reflect the number of papers associated with each keyword, while the line width of the links is the density of linkages between two different keywords. The wider the line, the more significant the link between the keywords.

"Risk" resulted the most frequent and predominant keyword, reflecting the strength of its associations with the other keywords included in the co-word analysis. This frequency is justified by its use both in ecological and economic papers. "Insurance" resulted very

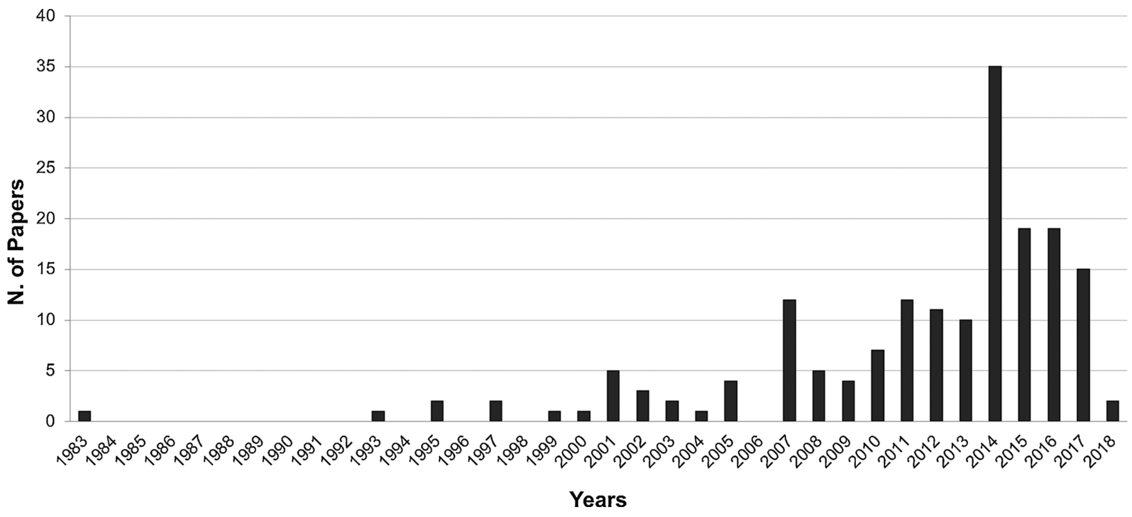

Fig. 2. Number of papers published from 1983 to January 2018 (Total number = 174).

strongly related to "Economic development and growth", given the economic connotation of this topic, in addition to a close connection with "Natural disasters", which represents a new challenge for the insurance world. Low levels of association characterized the interplay between "Insurance" and the typically ecological concepts such as "Resilience", "Ecosystem services", and "Climate change". Surprisingly, there were no significant connections between "Insurance" and "Vulnerability", although vulnerability represents the risk susceptibility to natural disasters.

In general, distinct domains of ecological and economic interest were identified as well as an overlap of keywords characterizing both topics. Given these common keywords, it was possible to argue some links among the basic concepts of financial-economic and ecological insurances, mainly related to the risks of natural disasters and socio-ecological management and vulnerability. However, aspects related to the resilience of socio-ecological systems and the possible role of ecosystem services in facing the effects of climate change are topics still far away from the focus of current financial insurances.

4.2. Trends and multivariate analysis

There was an increasing trend of the total Gross Insurance Premium of the 29 OECD countries under study, with its doubling from 2001 to 2015 (Fig. 6a). At the same time, there was an increasing trend of the total meteorological and climatological disasters from 1993 to 2015 in the 29 OECD countries (Fig. 6b).

The PCA extracted eight principal components (PC) with the first three components explaining 90.6% of the overall variation (Fig. 7). In particular, PC1 was mainly represented by indices typical of financial insurance like Gross Insurance Premium and Gross Claims Payments explaining the 60.4% of variation. PC2 was represented by Forested areas and Forest rents, both surrogates of the "ecological" insurance explaining 19.6% of variation. PC3 was mainly represented by Terrestrial Protected Areas explaining the 10.6% of the overall variation.

Therefore, on the basis of the results of the temporal trends, where it is evident an increase both in the Gross Insurance Premium and in the total meteorological and climatological disasters, and the results of PCA demonstrating how current financial-economic insurances do not yet take into account the ecological components, a new perspective for insurance predictive model is proposed. Disaster risk mitigation is one of the most important priorities for insurance companies, but this task is not easy, so that several large insurance companies do not invest in high-risk or high-exposure areas (Benali and Feki, 2017) or propose very high insurance premiums, which could lead to significant levels of

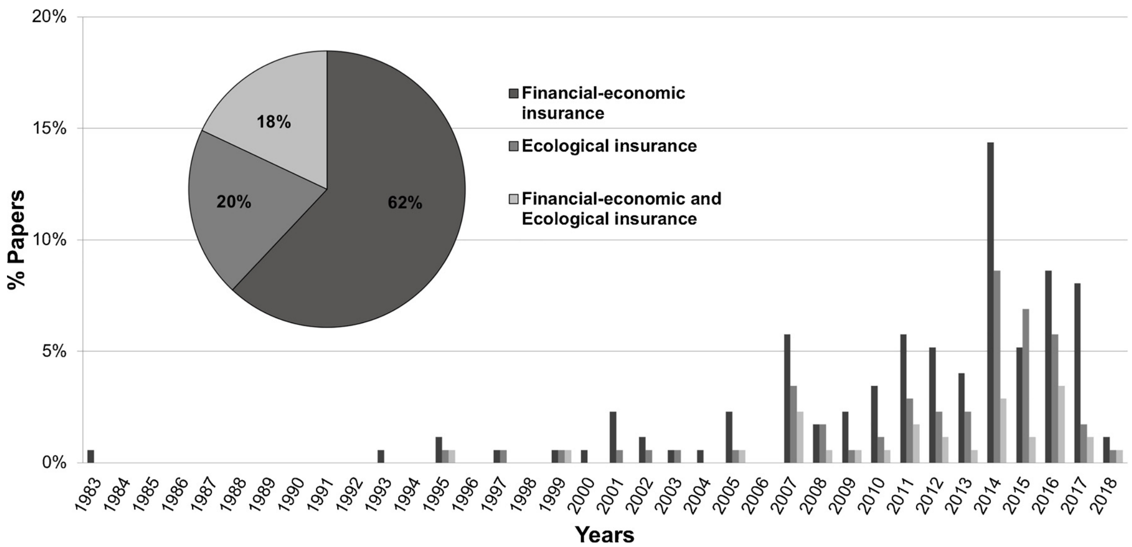

Fig. 3. Percentage distribution of the papers classified according to the typology of insurance analyzed and their temporal trend (N. of papers = 174).

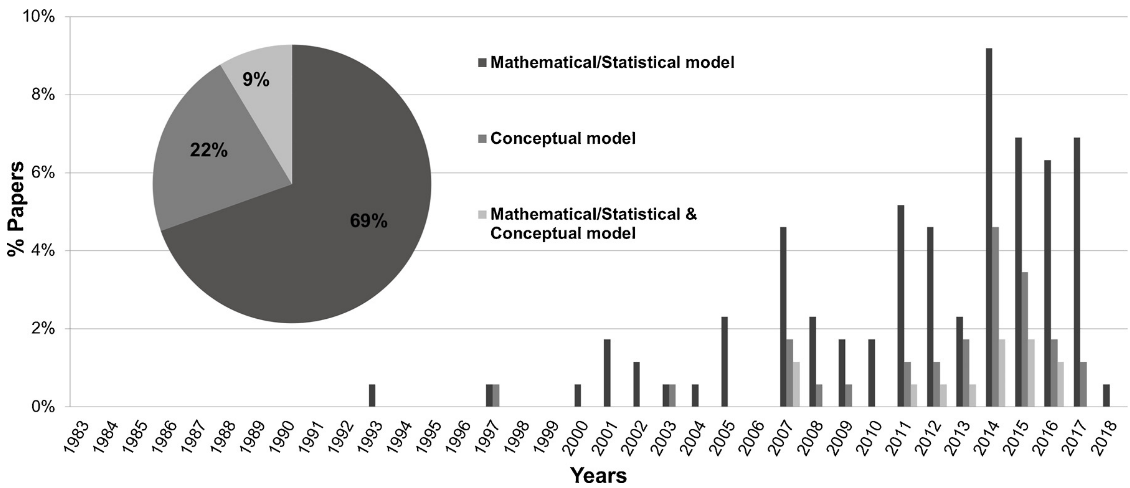

Fig. 4. Percentage distribution of the papers classified according to the typology of model adopted to deal with financial-economic and ecological insurances, and their temporal trend (N. of papers = 125).

under- and self-insurance (McAneney et al., 2016). The results of this research tend to highlight how some ecological components can mitigate the possible risks of negative consequences of natural disasters in socio-ecological systems, in other words they can enhance system resilience, which could represent the overall ecological insurance. The presence of forests and terrestrial protected areas can contribute to keep low the risk of damages in the case of climatological and meteorological disasters, and sustain the resilience, with positive effects on local socio-economic(financial)-ecological preparedness to face natural disasters. On the basis of these considerations, a first empirical model has been proposed as follows:

$$FEP = FI + EI$$

where FEP represents the Financial-Ecological Preparedness Index, FI is the financial insurance, given by the Gross Insurance Premium and the Gross Claims Payments, which can be a surrogate of the financial-economic preparedeness to natural disasters, and EI is the ecological insurance, given by the amount of forests and natural protected areas, which can represent the ecological preparedness to natural disasters.

The results of the application of the present model to the OECD countries under study show that countries like USA, Japan, Germany, United Kingdom, Korea, France, and Italy have a high FEP index, given their high ecological insurance in terms of ecological preparedness to natural disasters (Fig. 8). Therefore, countries with the same investments in the financial insurance sector, can be differentiated for their ecological potential to properly mitigate the risks associated to natural disasters.

5. Conclusions

Despite the growing evidence of the influence of land-cover pattern on local, regional and global climate in the last decade, few insurance and environmental economic studies have investigated its role in providing ecosystem services, which could represent an insurance against catastrophic meteorological events.

The traditional concept of risk mitigation in the field of financial insurance can be innovated by recognizing the role played by the ecological insurance that, in the case of meteorological disasters, can be mainly represented by the ecosystem services provided by forests and natural protected areas, as highlighted by the results. However, the coarseness of the present approach, taking into account only the amount of forested area, the forest rents and the amount of terrestrial

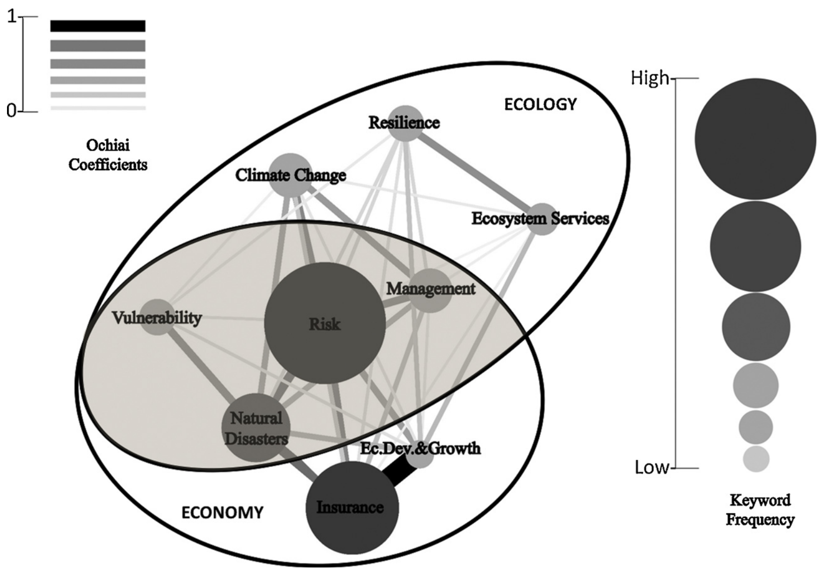

Fig. 5. Co-word map of the keywords (dots) and the identification of the economic, ecological, and overlapping domains.

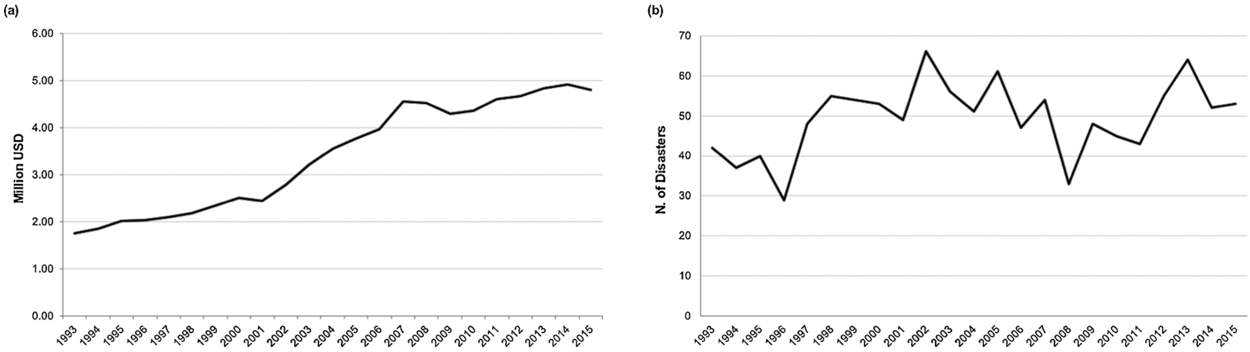

Fig. 6. Trend of the total Gross Insurance Premium (a) and the total meteorological and climatological disasters (b) in the 29 OECD Countries under study from 1993 to 2015.

protected areas in each country, should be implemented by adopting a landscape perspective with the spatial composition (which kind of forests), the configuration (how they are spatially arranged), and the state of health of the forests, when analyzing the role of ecological insurance in mitigating the risk of meteorological disasters.

Economic insurance is one tool among many in a portfolio of

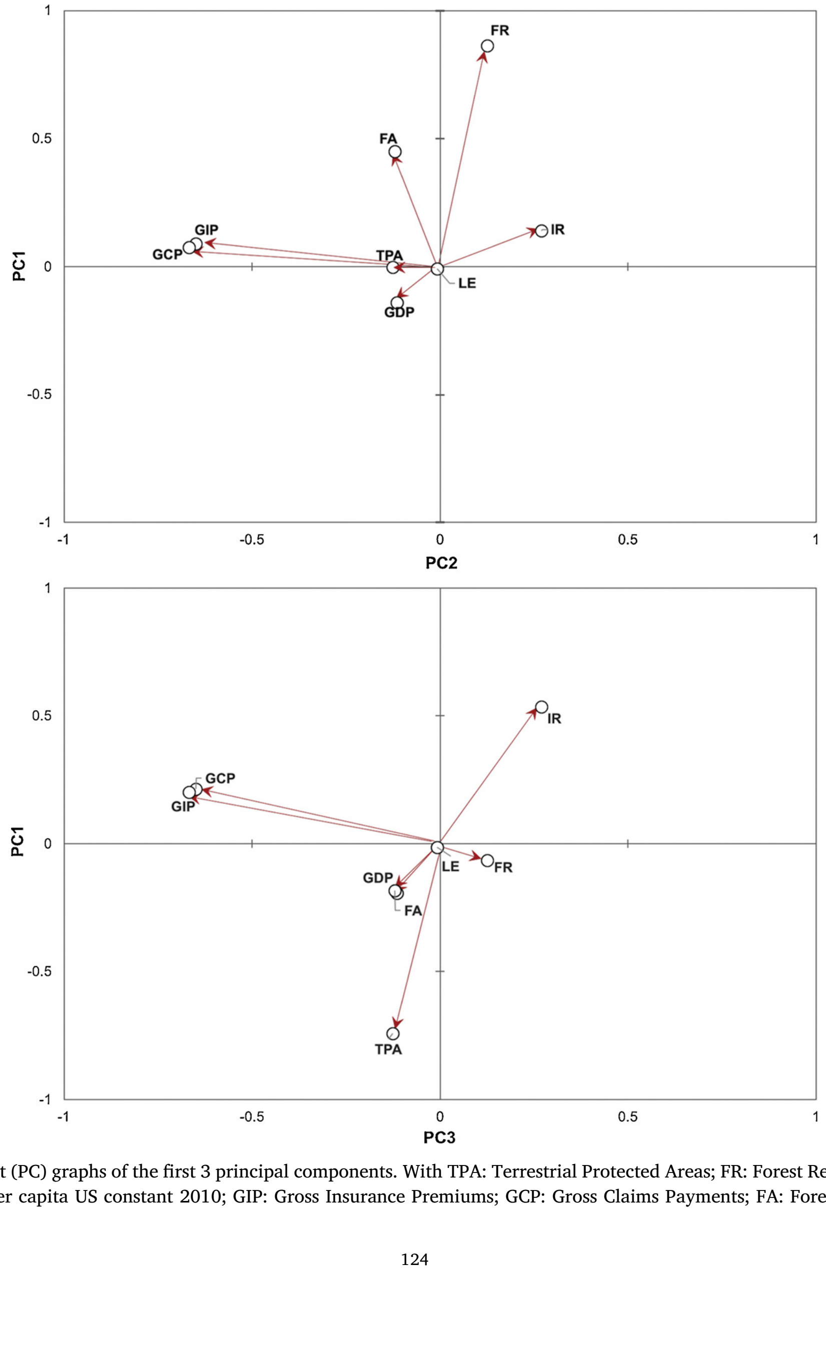

Fig. 7. The principal component (PC) graphs of the first 3 principal components. With TPA: Terrestrial Protected Areas; FR: Forest Rents of GDP; LE: Life Expectancy; IR: Inflation Rate; GDP: GDP per capita US constant 2010; GIP: Gross Insurance Premiums; GCP: Gross Claims Payments; FA: Forested Area.

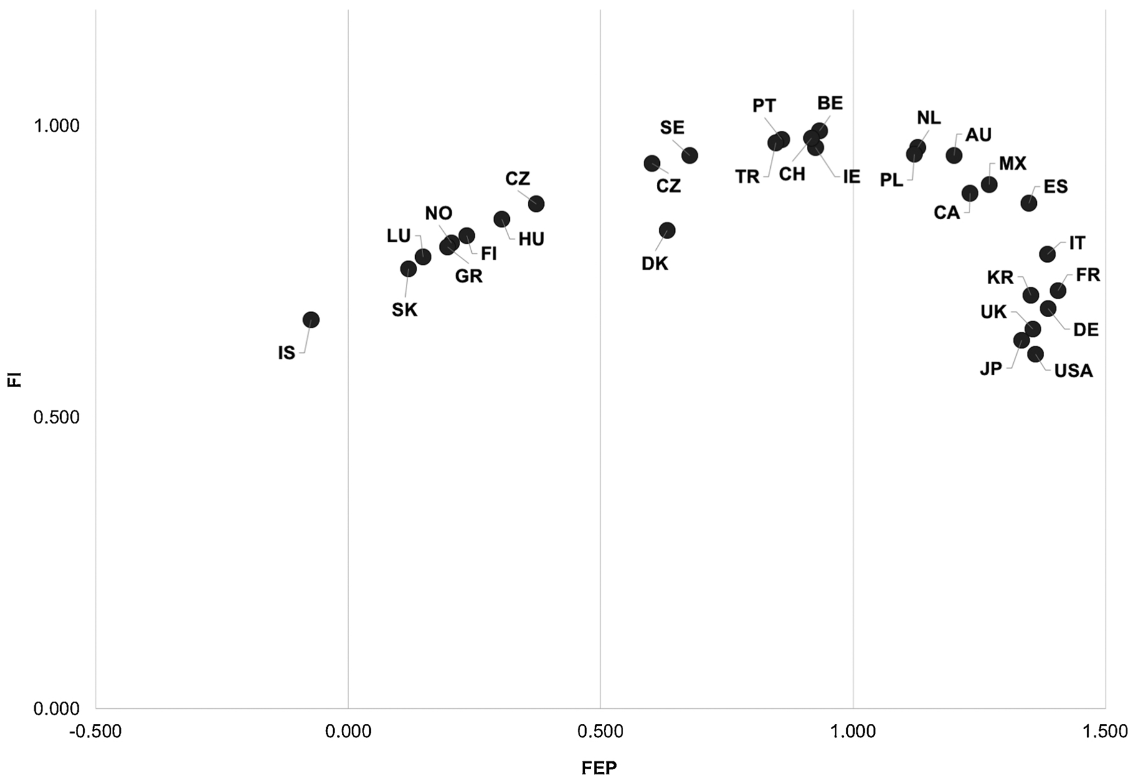

Fig. 8. Representation of the 29 OECD countries according to the FEP index, where FEP is the Financial-Ecological Prepardeness, FI is the Financial Insurance.

strategies to manage and reduce risks and uncertainties. Ecological insurance, the assessment of economic and ecological vulnerability and/or resilience, and the adaptive management of socio-ecological systems can represent key and interacting elements able to mitigate risk of damages due to meteorological disasters. On the basis of these considerations, a crucial attribute of resilience thinking is, however, the focus on the coupling of social and ecological systems as proposed in the empirical model. Therefore, this paper proposes to rid the concept of insurance of its purely economic connotation, integrating it with ecological insurance, given by the flow of ecosystem services. However, this model did not consider in its current form the social insurance, represented by the risk perception and supported by the so-called risk-sharing informal networks that can be seen as a form of social capital. In this context, the traditional (economic) insurance should base the payouts on a socio-ecological index instead of measured losses, trying to quantify the effects of both natural and social capitals on natural disaster risk mitigation.

The next steps of this research will be focused on a pilot study area where a landscape approach will be applied in terms of forest spatial composition and configuration, in order to better define the landscape contribution to natural disaster risk mitigation, the analysis of the role of social capital through a cross-scales approach, in terms of policies and management strategies, and the investigation of innovative economic tools to take into account the payment for ecosystem services in the context of natural disasters.

Aknowledgements

We strongly thank the anonymous reviewers for their helpful and targeted comments and for their precious contribution in improving the original version of the manuscript.

References

Adam, C., 2013. Coping with adversity: the macroeconomic management of natural disasters. Environ. Sci. Policy 27, 99–111.
Adeagbo, A., Daramola, A., Carim-Sanni, A., Akujobi, C., Ukpong, C., 2016. Effects of natural disasters on social and economic well being: a study in Nigeria. Int. J. Disaster Risk Reduct. 17, 1–12.
Adger, W.N., Kelly, P.M., 1999. Social vulnerability to climate change and the architecture of entitlements. Mitig. Adapt. Strateg. Glob. Chang. 4, 253–266.
Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. Glob. Environ. Chang. 15, 77–86.
Admiraal, J.F., Wossink, A., de Groot, W.T., de Snoo, G.R., 2013. More than total economic value: how to combine economic valuation of biodiversity with ecological resilience. Ecol. Econ. 89, 115–122.
Alexander, D., 2000. Confronting Catastrophe: New Perspectives on Natural Disasters. Oxford University Press, Oxford, USA.
Amendola, A., Ermoliev, Y., Ermolieva, T.Y., Gitis, V., Koff, G., Linnerooth-Bayer, J., 2000. A systems approach to modeling catastrophic risk and insurability. Nat. Hazards Dordr. (Dordr) 21, 381–393.
Barthel, F., Neumayer, E., 2012. A trend analysis of normalized insured damage from natural disasters. Climate Change 113, 215–237.
Baumgärtner, S., 2007. The insurance value of biodiversity in the provision of ecosystem services. Nat. Resour. Model. 20, 87–127.
Baumgärtner, S., Strunz, S., 2014. The economic insurance value of ecosystem resilience. Ecol. Econ. 101, 21–32.
Bebi, P., Kulakowski, D., Christian, R., 2009. Snow avalanches disturbances in forest ecosystems – state of research and implications for management. For. Ecol. Manage. 257 (1883), 1892.
Benali, N., Feki, R., 2017. The impact of natural disasters on insurers' profitability: evidence from Property/Casualty Insurance company in United States. Res. Int. Bus. Financ. 42, 1394–1400.
Benson, C., Twigg, J., Myers, M., 2001. NGO initiatives in risk reduction: an overview. Disasters 25, 199–215.
Berz, G.A., 2004. Catastrophes and climate change: concerns and possible countermeasures of the insurance industry. Mitig. Adapt. Strategies Glob. Chang. 4, 283–293.
Bonan, G., 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. Science 320, 1444–1449.
Borensztein, E., Cavallo, E., Jeanne, O., 2017. The welfare gains from macro-insurance against natural disasters. J. Dev. Econ. 124, 142–156.
Breckner, M., Englmaier, F., Stowasser, T., Sunde, U., 2016. Resilience to natural disasters — insurance penetration, institutions, and disaster types. Econ. Lett. 148, 106–110.
Bronstert, A., 2003. Floods and climate change: interactions and impacts. Risk Anal. 23 (3), 545–558.
Brooks, N., 2003. Vulnerability, Risk and Adaptation: A Conceptual Framework. Working Paper 38, Tyndall Centre for Climate Change Research. University of East Anglia, Norwich.
Bureau for Crisis Prevention and Recovery (BCPR)/UNDP, 2004. Reducing Disaster Risk. A Challenge for Development, UNDP/Bureau for Crisis Prevention and Recovery,

New York.
Carpenter, S.R., Walker, B., Anderies, J.M., Abel, N., 2001. From metaphor to measurement: resilience of what to what? Ecosystems 4, 765–781.
Centre for Research on the Epidemiology of Disasters–CRED, 2014. The Disasters Classification Used in EM-DAT. [online]. http://www.emdat.be/guidelines.
Chazdon, R.L., 2008. Beyond deforestation: restoring forests and ecosystem services on degraded lands. Science 320, 1458–1460.
Choate, G., Archer, S., 1975. Irving Fisher, inflation, and the nominal rate of interest. J. Financ. Quant. Anal. 10 (4), 675–685.
Choudhury, M.-Ul-I., Haque, C.E., 2016. "We are more scared of the power elites than the floods": adaptive capacity and resilience of wetland community to flash flood disasters in Bangladesh. Int. J. Disaster Risk Reduct. 19, 145–158.
Cohen, J., 1960. A coefficient of agreement for nominal scales. Educ. Psychol. Meas. 20, 37–46.
Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.
Costanza, R., Jørgensen, S.E., 2002. Introduction: understanding and solving environmental problems in the 21st century: toward a new, integrated "hard problem science. In: Costanza, R., Jørgensen, S.E. (Eds.), Understanding and Solving Environmental Problems in the 21st Century. Elsevier Science Ltd., Amsterdam, pp. 1–3.
Courbage, C., Stahel, W.R., 2012. The Geneva Reports—Risk and Insurance Research No. 5 Extreme Events and Insurance: 2011annus Horribilis. The Geneva Association (The International Association for the Study of Insurance Economics) ISSN 1662-3738.
Cutter, S.L., Johnson, L.A., Finch, C., Berry, M., 2007. The U.S. Hurricane Coast: Increasingly Vulnerable? Environment 49 (7), 8–20.
Daily, G.C., 1997. Introduction: what are ecosystem services? In: Daily, G. (Ed.), Nature'S Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C, pp. 1–10.
Daniels, R.J., Kettl, D.F., Kunreuther, H. (Eds.), 2006. On Risk and Disaster: Lessons from Hurricane Katrina. University of Pennsylvania Press, Philadelphia, USA.
Danielsen, F., Sorensen, M.K., Olwig, M.F., Selvam, V., Parish, F., Burgess, N.D., Hiraishi, T., Karunagaran, V.M., Rasmussen, M.S., Hansen, L.B., Quarto, A., Suryadiputra, N., 2005. The Asian tsunami: a protective role for coastal vegetation. Science 310, 643.
Dankers, R., Arnell, N.W., Clark, D.B., Falloon, P.D., Fekete, B.M., Gosling, S.N., Heinke, J., Kim, H., Masaki, Y., Satoh, Y., Stacke, T., Wada, Y., Wisser, D., 2014. First look at changes in flood hazard in the inter-sectoral impact model inter- comparison project ensemble. P. Natl. Acad. Sci. U. S. A. 111, 3257–3261.
Dasgupta, P., Mäler, K.G. (Eds.), 2003. The Economics of non-Convex Ecosystems. Kluwer Academic Publishers, Dordrecht.
Deboudt, P., 2010. Towards coastal risk management in France. Ocean Coast. Manag. 53, 366–378.
Deutsch, L., Folke, C., Skånberg, K., 2003. The critical natural capital of ecosystem performance as insurance for human well-being. Ecol. Econ. 44, 205–217.
Ding, Y., Chowdhury, G.G., Foo, S., 2001. Bibliometric cartography of information retrieval research by using co-word analysis. Inform. Process. Manag. 37 (6), 817–842.
Dlugolecki, A. (Ed.), 2009. Coping With Climate Change: Risks and Opportunities for Insurers. The Chartered Insurance Institute (CII), London.
Donohue, J.C., 1973. Understanding Scientific Literature: A Bibliographic Approach. The MIT press, Cambridge, UK.
Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, C.I., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. Science 309, 570–574.
Figueroa, E., Pasten, R., 2015. The economic value of forests in supplying local climate regulation. Aust. J. Agric. Resour. Ec. 59 (3), 446–457.
Fraser, E., Mabee, W., Slaymaker, O., 2003. Mutual vulnerability, mutual dependence: the reflective notion between human society and the environment. Glob. Environ. Change 13, 137–144.
Füssel, H.-M., Klein, R.J.T., 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. Clim. Change 75, 301–329.
Gattig, A., Hendrickx, L., 2007. Judgmental discounting and environmental risk perception: dimensional similarities, domain differences, and implications for sustainability. J. Soc. Issues 63 (1), 21–39.
Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52, 143–150.
Gollier, C., 2005. Some aspects of the economics of catastrophe risk insurance. CESIFO Working Paper, 1409.
Gonzalez, A., Mouquet, N., Loreau, M., 2009. Biodiversity as spatial insurance: the effects of habitat fragmentation and dispersal on ecosystem functioning. In: Naeem, S., Bunker, D.E., Hector, A., Loreau, M., Perrings, C. (Eds.), Biodiversity, Ecosystem Functioning, and Human Wellbeing. An Ecological and Economic Perspective. Oxford University Press, New York, pp. 134–146.
González Dávila, O., Stithou, M., Pescaroli, G., Pietrantoni, L., Koundouri, P., Díaz-Simal, P., Rulleau, B., Touili, N., Hissel, F., Penning-Rowsell, E., 2014. Promoting resilient economies by exploring insurance potential for facing coastal flooding and erosion: evidence from Italy, Spain, France and United Kingdom. Coast Eng. 87, 183–192.
Guha-Sapir, D., Vos, F., Below, R., Ponserre, S., 2011. Annual Disaster Statistical Review 2010. The Numbers and Trends. CRED, Brussels.
Gunderson, L.H., Holling, C.S. (Eds.), 2002. Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, D.C., USA.
Hall, J., Arheimer, B., Borga, M., Brázdil, R., Claps, P., Kiss, A., Kjeldsen, T.R., Kriaučiūnienė, J., Kundzewicz, Z.W., Lang, M., Llasat, M.C., Macdonald, N., McIntyre, N., Mediero, L., Merz, B., Merz, R., Molnar, P., Montanari, A., Neuhold, C., Parajka, J., Perdigão, R.A.P., Plavcovà, L., Rogger, M., Salinas, J.L., Sauquet, E., Schär, C., Szolgay, J., Viglione, A., Blöschl, G., 2014. Understanding flood regime changes in Europe: a state-of-the-art assessment. Hydrol. Earth Syst. Sci. Discuss. 18 (7), 2735–2772.
Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G., 2013. High-resolution global maps of 21st-century forest cover change. Science 342, 850–853.
Harris, N.L., Brown, S., Hagen, S.C., Saatchi, S.S., Petrova, S., Salas, W., Hansen, M.C., Potapov, P.V., Lotsch, A., 2012. Baseline map of carbon emissions from deforestation in tropical regions. Science 336, 1573–1576.
Hiraishi, T., Harada, K., 2003. Greenbelt tsunami prevention in south-pacific region. Rep. Port Airpt. Res. Inst. 42, 1–23.
Hoeppe, P., 2016. Trends in weather related disasters – consequences for insurers and Society. Weather Clim. Extremes 11, 70–79.
Holling, C.S., 1973. Resilience and stability of ecological systems. Annu. Rev. Ecol. Syst. 4, 1–23.
Holling, C.S., 1996. Engineering resilience versus ecological resilience. In: Schulze, P. (Ed.), Engineering Within Ecological Constraints. National Academy Press, Washington DC, pp. 31–44.
Holzmann, R., Jørgensen, S., 2004. Social risk management: a new conceptual framework for social protection, and beyond. Int. Tax Publ. Financ 8, 529–556.
Hook, W.H., 2000. U.S. Participation in international decade for natural disaster reduction. Nat. Hazard. Rev. 1, 2–9.
IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the IPCC 5th Assessment Report. IPCC Working Group II: Stanford, USA.
Johannesson, M., Johansson, P.-O., 1997. Quality of life and the WTP for an increased life expectancy at an advanced age. J. Publ. Econ. 65, 219–228.
Johannsdottir, L., Davidsdottir, B., Goodsite, M.E., Olafsson, S., 2014. What is the potential and demonstrated role of non-life insurers in fulfilling climate commitments? A case study of Nordic insurers. Environ. Sci. Policy 38, 87–106.
Jones, R., 2001. An environmental risk assessment/management framework for climate change impact assessments. Nat. Hazards Dordr. (Dordr) 23, 197–230.
Kreimer, A., Arnold, M., 2000. World Bank's role in reducing impacts of disasters. Nat. Hazard. Rev. 1, 37–42.
Landis, J.R., Koch, G.G., 1977. The measurement of observer agreement for categorical data. Biometrics 33, 159–174.
Loreau, M., Mouquet, N., Gonzalez, A., 2003. Biodiversity as spatial insurance in heterogeneous landscapes. P. Natl. Acad. Sci. U. S. A. 100, 12765–12770.
Mäler, K.-G., Li, C.-Z., 2010. Measuring sustainability under regime shift uncertainty: a resilience pricing approach. Environ. Dev. Econ. 15 (6), 707–719.
Mäler, K.G., 2008. Sustainable development and resilience in ecosystems. Environ. Resour. Econ. (Dordr) 39, 17–24.
McAneney, J., McAneney, D., Musulin, R., Walker, G., Crompton, R., 2016. Government-sponsored natural disaster insurance pools: a view from down-under. Int. J. Disaster Risk Reduct. 15, 1–9.
Meyfroidt, P., Lambin, E.F., 2011. Global forest transition: prospects for an end to deforestation. Annu. Rev. Environ. Resour. 36, 343–371.
Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and Human Well-being: General Synthesis. World Resources Institute, Washington, DC.
Miyamoto, M., Parid, M.M., Aini, Z.N., Michinaka, T., 2014. Proximate and underlying causes of forest cover change in peninsular Malaysia for. Policy Econ. 44, 18–25.
Mouillot, D., Culioli, J.M., Pelletier, D., Tomasini, J.A., 2008. Do we protect biological originality in protected areas? A new index and an application to the Bonifacio Strait Natural Reserve. Biol. Conserv. 141, 1569–1580.
Müller, F., Li, B.L., 2004. Complex systems approaches to study human-environmental interactions: issues and problems. In: Hong, S.-K., Lee, J., Ihm, B.S., Farina, A., Son, Y., Kim, E.S., Choe, J.C. (Eds.), Ecological Issues in a Changing World – Status, Response and Strategy. Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 31–46.
Müller, B., Johnson, L., Kreuer, D., 2017. Maladaptive outcomes of climate insurance in agriculture. Glob. Environ. Chang. 46, 23–33.
Norberg, J., Swaney, D.P., Dushoff, J., Lin, J., Casagrandi, R., Levin, S.A., 2001. Phenotypic diversity and ecosystem functioning in changing environments: a theoretical framework. P. Natl. Acad. Sci. U. S A. 98, 11376–11381.
Pérez-Maqueo, O., Intralawan, A., Martínez, M.L., 2007. Coastal disasters from the perspective of ecological economics. Ecol. Econ. 63, 273–284.
Perrings, C., 1995. Ecological resilience in the sustainability of economic development. Economie Appliquée 48 (2), 121–142.
Porrini, D., Schwarze, R., 2014. Insurance models and European climate change policies: an assessment. Eur. J. Law Econ. 38, 7–28.
Pullin, A.S., Stewart, G.B., 2006. Guidelines for systematic review in conservation and environmental management. Conserv. Biol. 20, 1647–1656.
Quaas, M.F., Baumgärtner, S., 2008. Natural vs. Financial insurance in the management of public-good ecosystems. Ecol. Econ. 65, 397–406.
Rodriguez, J., Vos, F., Below, R., Guha-Sapir, D., 2009. Annual Disaster Statistical Review 2008. The Numbers and Trends. CRED, Brussels.
Scheffer, M., Carpenter, S.R., Foley, J., Folke, C., Walker, B., 2001. Catastrophic shifts in ecosystems. Nature 413, 591–696.
Scheuren, J.-M., Le Polain de Waroux, O., Below, D., Guha-Sapir, D., Ponserre, S., 2008. Annual Disaster Statistical Review 2007. The Numbers and Trends. CRED, Brussels.
Smit, B., Burton, I., Klein, R.J.T., Street, R., 1999. The science of adaptation: a framework for assessment. Mitig. Adapt. Strateg. Glob. Chang. 4, 199–213.
Smithers, J., Smit, B., 1997. Human adaptation to climatic variability and change. Glob. Environ. Chang. 7, 129–146.

Swanson, T.M., 1992. Economics of a biodiversity convention. Ambio 21, 250–257.
Swiss Reinsurance Institute (Swiss Re), 2017. . Natural Catastrophes and Man-made Disasters in 2016: a Year of Widespread Damages. Swiss Re SIGMA series 2/2017. Zurich, Swiss Reinsurance Company.
Tobin, G.A., Montz, B.E., 1997. Natural Hazards: Explanation and Integration. Guilford Press, New York, USA.
Tobin, G.A., Whiteford, L.M., Laspina, C., Bell, H.M., Freidus, A.L., Yepes, H., 2005. Perception, Social Support and Chronic Exposure to Hazards: Human Health and Community Well-being. Technical Report: Prepared for the Global Center for Disaster Management and Humanitarian Action. University of South Florida.
Tompkins, E.L., Adger, W.N., 2004. Does adaptive management of natural resources enhance resilience to climate change? Ecol. Soc. 9 (10) [online]. http://www.ecologyandsociety.org/vol9/iss2/art10.
Trærup, S.L.M., 2012. Informal networks and resilience to climate change impacts: a collective approach to index insurance. Global Environ. Chang. 22, 255–267.
Venables, W.N., Smith, D.M., R Development Core Team, 2018. An Introduction to R - Notes on R: a Programming Environment for Data Analysis and Graphics Version 3.5.1. [online]. https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf.
Whiteford, L.M., Tobin, G.A., 2004. Saving lives, destroying livelihoods: emergency evacuation and resettlement policies. In: Castro, A., Springer, M. (Eds.), Unhealthy Health Policies: A Critical Anthropological Examination. AltaMira Press, Walnut Creek, California, pp. 189–202.
Bank, World, 2017. Europe and Central Asia Country Risk Profiles for Floods and Earthquakes. World Bank Group, Washington, D.C.
Yachi, S., Loreau, M., 1999. Biodiversity and ecosystem productivity in a fluctuating environment: the insurance hypothesis. P. Natl. Acad. Sci. U. S. A. 96, 1463–1468.
Yang, Y., Wu, M., Cui, L., 2012. Integration of three visualization methods based on co-word analysis. Scientometrics 90, 659–673.
Zhang, K., Song, C., Zhang, Y., Zhang, Q., 2017. Natural disasters and economic development drive forest dynamics and transition in China. For. Policy Econ. 76, 56–64.