

07

Synthesis and policy recommendations

7.1.	Introduction	p. 132
7.2.	Better understanding of factors and policies driving risk	p. 134
7.3.	Managing risk through partnerships	p. 137
7.4.	High policy level targeted dissemination and outreach	p. 140
7.5.	Future research	p. 142
	References	p. 144

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Introduction

Climate change adaptation (CCA) and disaster risk reduction (DRR) are among the paramount goals of the UN sustainable development agenda, galvanised through major UN conferences and summits held over 2015. The ENHANCE project has contributed to achieving the goals of several new policy frameworks, such as: the UN *Sendai Framework for Disaster Risk Reduction 2015-2030*, the *Addis Ababa Action Agenda on risk financing*, and the *Paris Agreement on Climate Change on climate adaptation*.

First, the Sendai Framework for Disaster Risk Reduction 2015-2030 adopted during the Third UN World Conference on Disaster Risk Reduction laid down priority actions and policy targets to substantially reduce disaster risk and losses in lives, livelihoods and health, and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries (UN, 2015, p.5). Understanding the hazard and risk, and measuring the progress towards accomplishing the DRR targets will only be possible if substantial efforts are put in improving risk assessments and disaster impacts' records. The Sendai Framework advocated for multi-hazard, inclusive, science-based and risk-informed decision-making for which it is necessary to collect and share (non-sensitive) disaggregated risk information, including detailed records of the past events' impacts. The Sendai Framework singled out climate change and variability as drivers of disaster risk, in conjunction with poverty and inequalities, uncontrolled urbanisation, and poor land management. Consequently, the Sendai Framework pleaded for improved coherence between policy instruments fostered for the sake of addressing climate change, biodiversity, sustainable development, poverty eradication,

environment, agriculture, health, food and nutrition. The ENHANCE research endorsed an inclusive approach **for risk analysis and assessment, putting emphasis on economic and social ripple and spill-over effects; and truly contributing to enhancing resilience of communities and societies.**

The *Addis Ababa Action Agenda (AAAA)*, adopted at the Third International Conference on Financing for Development, erected a financial framework for sustainable development, fostering inclusive economic prosperity and lining up financing resources and flows with the priorities of the *2030 Agenda for Sustainable Development*. The AAAA does not only focus on official development aid (ODA), even though developed countries recommitted to meet the 0.7 per cent of ODA/GNI target of global solidarity and justice. The Framework addressed trade, investments, cooperation, science and technology, capacity building, illicit financial flows, tax reform (including harmful tax practices and subsidies), role of private sector, and other areas, essentially redesigning the global economic governance. **The ENHANCE research contributed to exploring a range of policy instruments for risk financing, including insurance and partnerships.**

The *Paris Agreement on Climate Change* agreed upon at the United Nations Framework Convention on Climate Change's twenty-first Conference of Parties (UNFCCC COP21) embraced bold actions set to curb the global temperature rise *well below 2 degrees Celsius*, and possibly below 1.5 degrees, compared to the pre-industrial levels. The Paris Agreement explicitly includes climate adaptation, a part of which are the efforts to strengthen societies' ability

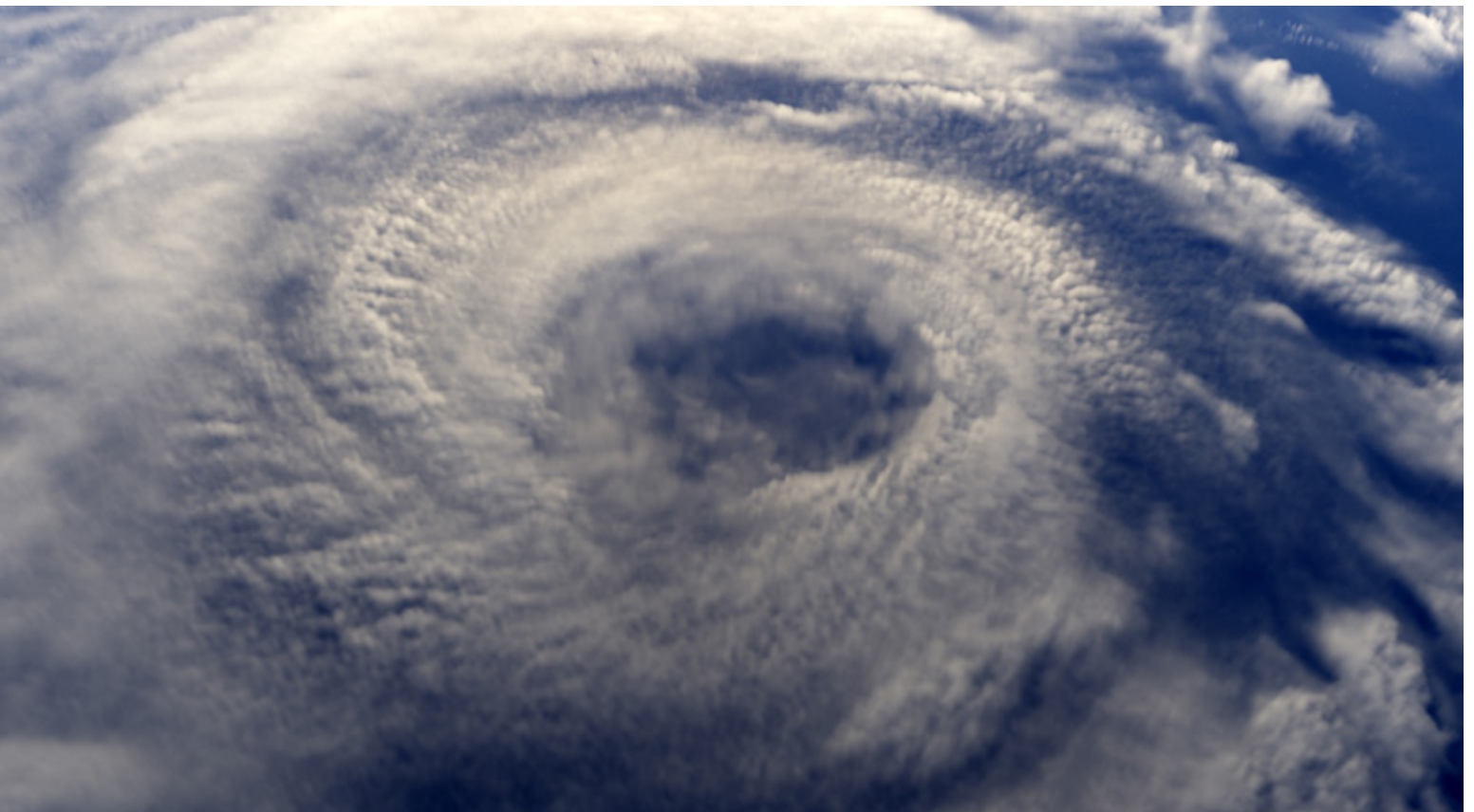


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to deal with the impacts of climate change as well as financial commitments to foster adaptation and climate resilience. The Agreement reiterated that the *Loss and Damage* mechanism should be a part of the global contract.

The UN Secretary General's *Agenda for Humanity* was prepared for the World Humanitarian Summit. It includes five Core Responsibilities (CR) of which at least three are related to natural hazard and climate risk: (i) CR3 *Leave no one behind* addresses displacement and movements of refugees; (ii) CR4 *Change people's lives* entails emphasis on risk analysis and data investments; and (iii) CR5 *Invest in humanity* recalls the Sendai Framework's and the Paris Agreement's pledges for investment in risk (reduction) and adaptation. Moreover, the Summit served as a backstage for launching a *Global Partnership for Preparedness* (GPP) to help most vulnerable countries to get ready for disasters.

The *New Urban Agenda* that will be endorsed at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) entails three *transformative* commitments: leaving no one behind and fighting against poverty; urban prosperity and opportunities for all; and ecological and resilient cities and human settlements. The latter places emphasis on a rapid and efficient recovery from natural hazard strikes. Resilient city is one that cares about safety of *individuals and cohesion of communities, while actively transforming their habitat and taking advantage of reduced risk exposure to improve its essential*

functions (UN, 2016, p.79). This is important because globally some 66% of population (in Europe 80%) are expected to live in cities by 2050 and therefore success of the 2030 Agenda for Sustainable Development will depend to a large extent on the achievements made in the urban centres.

The European Union (EU) has played an important role in devising the above multilateral frameworks and lined up the European policies to the same or more ambitious targets (EC, 2014b, 2014c, 2014d). The *EU Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030* (EC, 2016a) praised the Sendai Framework as an opportunity not only to advance disaster risk management agenda in Europe and to reinforce resilience to shocks and stresses, but also to boost up innovation, growth and job creation.

The ENHANCE project has contributed to many of the above objectives and goals, in particular (i) **better understanding of risk** and evidence-based and risk-informed public policies; (ii) **managing risk by means of partnering** and horizontal and vertical cooperation between private and public entities; through (iii) high policy level targeted dissemination and outreach. As a recommendation for further research, we believe it is critically important to analyse the contribution of the declining ecosystem services to increasing disaster risk in future, and to devise the role of insurance and risk financing in protecting ecosystem integrity.

Better understanding of factors and policies driving risk

Measured in economic damage and losses, natural hazard risk in Europe is high and tends to increase. Growing population and economic wealth are driving the upward trend in disaster losses, which is indicative of unsound disaster prevention and protection. Observed changes in extreme weather and climate events and possibly deteriorated status of natural ecosystems may have also played a role. The stochastic nature of disaster risk with uncertain tail distributions, along with rather partial observations of disaster damage and impacts, make it difficult to estimate the extent to which observed climate change has already contributed to growing disaster losses. Although detecting climate signal in disaster loss records has attracted large attention in the recent past, this is arguably neither the sole nor the most notable purpose for which the disaster impacts should be analysed. Within the project we have focussed on the following factors and policies relevant for understanding the wider consequences of natural hazards, and responding to the associated risk.

Macro-economic losses: A better understanding of natural hazard risk and ensuing economic losses is important for preventing excessive macroeconomic imbalances, and for coordinating responses to shocks and crises within the European Economic and Monetary Union. This is particularly important in countries that suffered most and did not yet fully recover from the recent economic, financial and sovereign debt crises. For example, Italy's high sovereign debt makes the national and regional economies susceptible to shocks caused by natural hazards. The debt sustainability analysis (DSA) showed that even a marginal change in GDP growth and subsequent

interest rates can sizably influence the country's ability to reach the commitments made under the Stability and Growth Pact (SGP, see also chapter 14). The stochastic debt projection that considered the size and correlation of past shocks yielded a relatively high probability (11%) that the Italian debt ratio will be greater in 2020 than in 2015 (EC, 2016b). Furthermore, Standard & Poor's simulated the impact of low-intensity/high-impact disasters on credit trustworthiness rating (S&P, 2015), demonstrating that in some countries the disasters may downgrade the rating by more than 0.25 notches.

Post-disaster recovery and insurance: A better understanding of disaster risk is also important for post-disaster recovery, and within the context of the internal market regulation on state-aid conferred to business enterprises. State aid on selective basis that distorts (or threatens to distort) free-market competition is incompatible with the EU internal (single) market, except for cases in which the aid is to make good the damage caused by natural disasters. The Flood Reinsurance Pool (Flood Re) successfully passed the compatibility check with the internal market regulation. The Commission recognised the goal of ensuring affordable insurance against flood risk as a legitimate scope of public policy, and accepted the motivation for setting up the scheme as well as the underlying assessment of the baseline with no action taken by the UK Government. The EC concluded that Flood Re was both appropriate and necessary. The scheme was designed to promote free flood insurance market, and rectify market failures that could compel insurers to stop providing insurance cover in some areas or to increase insurance premiums beyond affordable levels to many

households. Most importantly, the Scheme was designed so as to minimise the (competitive) advantage granted to the insurers.

EU Solidarity Fund: Exposure to natural hazards exemplifies natural handicaps, which threatens economic, social and territorial cohesion. As an expression of solidarity that is pinned down in the EU Treaty, the EU Solidarity Fund (EUSF; EC, 2014d; ECo, 2002) was set up as a way to respond with financial assistance in an efficient and flexible manner in the event of a major natural disaster in a Member State or in a country negotiating membership. Since 2002 and until March 2015, the solidarity aid was mobilised in 63 cases for a total amount of €4.037 billion (2014 Euro value). The EUSF was reformed over 2013-2014. By choosing to reinstall the absolute damage threshold criterion of €3 billion in 2011 instead of 2002 prices, the legislator made it easier for the largest (six) EU economies to access the post-disaster solidarity aid. Because the relative threshold of 0.6 per cent of the gross national income (GNI) remained unchanged, the access hurdle for the smaller economies are in 2015 considerably higher than in 2002, even if in part the real economic growth was lost to the post-2008 economic and financial crisis. Our analysis in Hochrainer-Stigler et al. (2015) showed that the risk of depletion of the EUSF could be reduced by increasing member state contributions and/or engaging in risk transfer. In the current form, the EUSF does not entail 'needs-based solidarity'. Lower-income member states received disproportionately lower compensation although they received larger disaster aid than their own contributions to the Fund. Solidarity could be enhanced by changing the rules for disbursing aid.

Need for complete and accessible loss data: Notwithstanding the importance of the quality-assured, systematically collected and thorough datasets on impacts of natural hazards, the loss data systems (LDS) in Europe are fragmented and inconsistent. Because open and accessible records on disaster impacts and losses are prejudiced by data gaps, European policy makers have little choice but to resort to proprietary data collection. The Sendai Framework for Disaster Risk Reduction 2015-2030 attempts to break up with the evidence-negligent practice. To demonstrate progress in reducing disaster risks, the Framework calls on the national and regional governments to better appreciate the (knowledge of) risk. Empirical and evidence-based risk analysis and assessment are a vital part of the disaster risk reduction efforts. The Open-Ended Intergovernmental Expert Working Group (OEIWG) was instituted to develop a set of indicators for measuring global progress. The Sendai Framework is

not alone in this quest. The OECD invited the member countries to better prepare for and collect data on catastrophic and critical risks (OECD, 2010, 2014). Unlike the Sendai Framework indicators that focus on exclusively on direct damage and structural/physical losses, OECD recommended considering the whole distributional and implied ripple or spill-over effects of natural hazards.

Risk assessment: A sound understanding of risk does not only imply accounting for the past damage and losses. We also need to assess current and future risks, to assess whether our risk management policies are robust to future developments such as climate change. This needs new modelling approaches, using multiple stochastic methods and addressing the low probability character of extreme disasters. On temporal scale, the probability distributions of such models span over years, decades and centuries. In some cases, the probabilities of once-in-millennia or even rarer events are still relevant for today's decision-making. These stochastic processes are often not stationary but respond to environmental changes, including climate change. Hazard manifestations of the same intensity and magnitude may also lead to diverse, sometimes significantly so, damage and losses, depending on the circumstantial factors. Vulnerability of people and societies in risk assessments is still poorly understood, and more data is needed to better understand how our societies respond to natural hazard risk, and transform in demography, wealth, cohesion and use of technology (e.g. Mysiak et al., 2015). The European Union Civil Protection Mechanism (EC, 2013) acknowledges the importance of such modelling approaches and compels the EU member states to conduct risk assessments, where possible also in economic terms, at national or appropriate sub-national level. Member states had to make a summary of the relevant elements thereof available to the Commission by December 2015 and will have to do one every three years thereafter. For both purposes, the Joint Research Centre (JRC) is developing loss indicators that should be part of operational disaster loss databases (De Groot et al., 2013, 2014; JRC, 2015).

The ENHANCE research led or contributed to a number of seminal publications on novel risk assessment and management methods. Jongman et al. (2015) showed that vulnerability is an important driver of disaster damage and annual hazard variability alone only explains a minor part of the observed variation in the recorded damage. Ward et al. (2014) contributed to determining the influence of El Niño Southern Oscillation on flood risk around the world. Mechler et al. (2014) explored the risk management and financing choices within the UNFCCC

Warsaw International Mechanism for Loss and Damage. Carrera et al. (under review) analysed flood risk in Italy in terms of economic losses (as opposite to damage and financial loss) using an innovative assessment methodology. Koks et al. (2015) compared disaster impacts using different model types in a systematic way and for the same geographical area, using similar input data. Koks et al. (2015a) analysed social vulnerability within flood hazard zones and showed that flood hazard zones are home to disproportionately large share of socially vulnerable households. Poussin et al. (2015) estimated potential damage savings and the cost effectiveness of

specific flood damage mitigation measures that were implemented by households during major flood events in France. Kellermann et al. (2015) and Amadio et al. (2016) developed empirically driven flood damage assessment models. Veldkamp et al. (2015) assessed water scarcity by taking into account temporal changes in socio-economic conditions and hydro-climatic variability, and Perez-Blanco et al. (2015) explored the use of incremental water charging for reducing the environmental costs that arise during drought events. Surminski (2014) shed light on the ability of flood insurance to contribute to direct risk reduction.

Flood in Budapest, Hungary. Copyright: UNISDR.



Managing risk through partnerships

International and multi-stakeholder partnerships (MSPs) are an important component of the transformative change and vehicles of development, environmental, and disaster risk reduction agendas. The MSPs represent a step change away from solely government-centred to multilevel modes of risk governance (Calliari and Mysiak, 2013). The ENHANCE project has analysed various MSPs in different contexts and situations (see chapter 6). We have found that despite broad agreement for closer collaboration between public and private actors in response to rising risk levels many challenges remain for translating this into innovative solutions. Public-Private Partnerships (PPP) in disaster insurance can serve as role models for a joint bearing of responsibilities and efficient risk-sharing. The principles and preconditions of successful PPPs as (i) being shaped through constructive dialogues (between public and private entities) and conscious of mutual principles and limitations, (ii) safeguarding competitive environment; and (iii) respecting, if not exploiting, risk-differentiated prices as incentive and reward for individual or collective risk prevention and protection (Johansen 2006).

Our findings exemplify that public and private stakeholders have very different constellations and problem definitions. Therefore, stakeholder engagement is important to discover current barriers, perceived or otherwise, which may be inhibiting innovative solutions or the development of new partnerships. For example, it may be that the level of risk itself is seen as already too high for the private sector to engage, or the stakeholders may not have a suitable platform upon which to engage. We have further explored this in the context of disaster insurance: The current discourse about disaster insurance highlights the key

challenges of managing current risks and preparing for future climate risks: at the core lies the issue of collective versus individual responsibility, and solidarity versus market-based approaches. This is where the biggest potential for global policy lies - in the facilitation of DRR and adaptation, which will determine risk levels and viability of insurance going forward. However, the design and operation of insurance can also play a role in this. As the ENHANCE examples show, there are significant barriers facing public and private stakeholders. This requires policy action—at global and national, even regional level. The key question therefore is how to determine and define the roles of industry and policy-makers, recognising that this is likely to differ from country to country. This is an area where closer collaboration between academia, industry and government is needed to proceed (Surminski et al., 2015).

The received responses to the EC-initiated consultation cautioned against harmonising the regulation on natural hazard insurance across the EU (EC, 2014f). Both, the uneven-distribution of hazard risk and the diversity of economic standing and requirements of the customers have been brought up by the UK Government, and echoed by others, as reasons against an EU intervention (HM Treasury, 2013). Consequently, harmonised regulations could harm innovation and competition in insurance products. The Dutch government underlined that a concerted EU action in this policy area was neither warranted nor in line with the subsidiarity principle of the EU governance (NL, 2013). Mandatory product bundling, suggested as a way of dealing with insurability of certain natural hazard risks, was seen with skepticism by insurers and public authorities alike, for similar reasons. The European

Parliament (EP) expressed analogous opinion (EP, 2014) while underlining that flexible markets should operate in non-mandatory framework and that no one-size-fits-all solution would serve the magnitude of different risk and economic conditions in Europe. On the opposite side, the risk-based insurance pricing received high support across all categories of consulted stakeholders, and so did a better collaboration between public and private entities on improved risk analysis and assessment. Almost unanimous agreement was voiced for making disaster loss data publicly accessible in detailed and disaggregated form.

In a 2014 speech, Kristalina Georgieva (at that time the EU Commissioner for international cooperation, Humanitarian Aid and Crisis Response) said that the European Commission would seek to address low uptake of disaster insurance, while encouraging transition to a higher degree of risk-based pricing and improving the accuracy and comparability of risk data and risk modelling. So far, the EC has not disclosed whether it intends to take any follow-up actions based on the results of the Green Paper, and what those actions may be. Disaster insurance however is unlikely to be off the table entirely. In summer 2015, the Five President's report⁸ (5PR, Juncker et al., 2015) anticipated further steps to deepen the Economic and Monetary Union. The report, released amidst deteriorating Greek sovereign debt crisis, laid out an ambitious agenda for integration of economic, financial, fiscal and political policies across the EU. It included, among others, a proposal to institute a European Deposit Insurance Scheme (EDIS) acting as a re-insurance system at the European level for the national deposit guarantee schemes. Disaster risk has already been addressed under the Greening the European Semester initiative (Fenn et al., 2014). The 5PR sets to bring the EU on top form for overcoming shocks and crises of whichever cause, including large disasters with lasting repercussions.

Partnerships are promoted either indirectly, through stimulating a culture of consultation and dialogue, or directly through cooperation and shared responsibilities. The regulation 240/2014 (EC, 2014a) for example makes compulsory partnerships between public authorities, economic and social partners and bodies representing civil society when it comes to deployment of resources from the European structural and investment (ESI) funds. The lack of an unambiguous specification of partnerships, here especially those designed for DRR, does not

necessarily mean that there is no normative guidance so as how to build or judge them. The guiding principles can be inferred from the copious rules, standards and practices that characterise European governance on matters related to internal market, competition, cross-border and trans-national cooperation, environment, and risk management, to name but a few (Calliari and Mysiak, 2015; Mysiak and Perez-Blanco, 2015). The ENHANCE research has shown that the MSPs ought to be seen and evaluated from either *instrumental* or procedural point of view, or both. Instrumental when the MSPs are conceded by discretion of public authorities as equivalent to other public policy choices. An example is co- or self-regulation when the attainment of the public policy objectives is entrusted to parties recognised in the field (EC, 2003). When MSPs supplant or complement the choices of competent authorities, the same normative standards apply as in the case of public decision-making, i.e. openness, transparency, accountability, flexibility, and effectiveness. *Procedural* when the MSPs are conceived by quests of making public policy choices more accountable and inclusive. In the former sense the MSPs are legitimised when they yield outcomes at least as effective and/or efficient as alternative policy courses, and better on other accounts.

⁸ Report written by the President of the European Commission, in close cooperation with the President of the Euro Summit, the President of the Eurogroup, the President of the European Central Bank, and the President of the European Parliament.

Public-Private Partnerships (PPPs)	Public-Public Partnerships (PuPs)
Mutually beneficial cost and/or risk sharing arrangements	Collective benefits with no direct individual financial or competitive gains contemplated
Scope: partnership targeted at market failures or where public investments or performance are likely less effective or successful	Openness: sincere efforts to engage all relevant or representative parties, both public and private, in a genuinely concerted and collaborative pursuit; allowing other parties to join in
Additionality: where substitute or sustain actions would not materialise anyway	Flexibility: enable redefinition as the scope of collaboration evolves
Consistency: partnerships not to harm the incentive for risk reduction	Transparency: partners sponsor the partnership with their knowledge and skills, competences and standpoints in good faith, and share the outcomes in plain way
Efficiency: sound use of public resources and limiting to the extent possible the distortion of competition	Accountability: objectives and principles of the partnership are well specified and respected
Transparency, equal treatment, effective analysis and monitoring	Constructive dialog: partners preserve the sense of common purpose, while accommodating the dissents and fertile divergences
Sustainability of the partnership based on clear rules of viability and legitimacy	

High policy level targeted dissemination and outreach

During the course of the project, the ENHANCE team participated in, and organised or co-organised numerous workshops and side events in major scientific and science-policy conferences to further develop the ideas on MSPs and DRR. These meetings include *the Third UN World Conference on Disaster Risk Reduction (WCDRR, Sendai/Japan, March 14-18, 2015)*; *the European Climate Change Adaptation Conference (Copenhagen, May 2015)*; *the Understanding Risk Forum 2016 (UR2016, Venice/Italy, May 16-20 2016⁹)*; the Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) conference *Adaptation Futures (Delft, May 10-13 2016)*; the OECD High level conference on flood risk (Paris, May 12-13 2016); and the UNISDR *High Level Forum on implementing the Sendai Framework for Disaster Risk Reduction at Local Level (Florence, June 16-17, 2016)*.

The ENHANCE research was presented at the high policy level workshop on possible reform of the European Solidarity Fund (Brussels, October 2015), the European Forum for Disaster Risk Reduction (EFDRR, October 7-9, 2015); the 7th EU-Japan Climate Change Research (Tokyo, April 26-27, 2016); and at the meetings of the EU *Loss Data Systems*¹⁰ initiative under auspices of the DRMKC, to mention but a few international policy workshops. ENHANCE was

referred to in the EEA's review of the disaster losses in Europe¹¹. Furthermore, we have contributed to the consultation initiated by the UN Open-Ended Intergovernmental Expert Working Group on Indicators and Terminology (Mysiak et al., 2015), and developed recommendations of how to integrate and reform various European and international policies on sharing and storing disaster loss data. Furthermore, we held summer schools, capacity building workshops, stakeholder meetings and webinars.

Our research contributed to, otherwise informed, or has been acknowledged in a number of high policy level reports and/or outcome documents, such as the Global Water Partnership & OECD report *Securing water, sustaining growth* (Sadoff et al., 2015), the Outcome document of the *European Forum for Disaster Risk Reduction 2015*¹², the 2016 Report of the European Environment Agency's (EEA) *Flood risks and environmental vulnerability - Exploring the synergies between floodplain restoration, water policies and thematic policies* (EEA, 2015); the Bank of England's 2015 report *The impact of climate change on the UK insurance sector* (PRA, 2015); the upcoming 2017 EEA Report on *Disaster Risk Management and Climate Adaptation policies*; the River Basin District Management Plan (RBD-MP) of the Po river in Italy; and the first edition of the *State of Science*

⁹ During the UR2016, ENHANCE liaised with another EC funded project Placard to organise a workshop/side event (Learning across communities of practice: risk assessment for disaster risk reduction and climate risk management) and a technical session of the conference (Climate extremes and economic derail).

¹⁰ <http://drr.jrc.ec.europa.eu/Loss-Data>

¹¹ Clim039 indicator Economic losses from climate-related extremes, www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-2/assessment

¹² 2015 EFDRR was held in Paris, October 7-9. The outcome document can be found here: www.unisdr.org/files/43847_efdr2015franceoutcomesfinal.pdf

¹³ drmkc.jrc.ec.europa.eu

¹⁴ Strengthening and redesigning European flood risk practices: towards appropriate and resilient flood risk governance arrangements, FP7, www.starflood.eu/

¹⁵ The economics of climate change adaptation, FP7, econadapt.eu/

¹⁶ Platform for climate adaptation and risk reduction, Horizon 2020, www.placard-network.eu/

Report on Disaster Risk Reduction of the EC Disaster Risk Management Knowledge Centre (DRMKC¹³). ENHANCE research is also poised to inform and contribute to the Italian National Climate Adaptation Plan (PNACC) and the National Flood Risk Management Plan.

Our research has inspired, set off, or otherwise informed new research and innovation actions, including the Climate-KIC funded pathfinder *Cost Adapt* (FEEM), the *Copernicus Climate Change Services* (IVM), the H2020 proposal *NATURANCE* (Nature for insurance, and insurance for nature) and others. Motivated by our results, the Port of Rotterdam Authority - a private company - has invested more than €200 000 in research to further investigate the risk from flood and climate change. The Wadden Sea Forum,

established to advise the Trilateral Wadden Sea Convention, extended its focus to include disaster risk, as a result of the ENHANCE research. These are major acknowledgements of the impacts our research has had on public and private choices, and a proof of broad knowledge-transfer.

ENHANCE has regularly produced policy briefs and a booklet summarising the results and methods of the project for the broad public and policy makers. We have liaised with other European research projects such as STARFLOOD¹⁴ and ECONADAPT¹⁵, with whom we have organised a joint session during the ECCA 2015 conference, and other projects such as PLACARD¹⁶. We have used extensively the social media (twitter) to engage high level policy officials from the European Union in the project's activities.

Photo by Andrey Yurlov/Shutterstock.



Future research

The ENHANCE project set the stage for further innovative research on DRR and partnerships. As one of the important topics, we have focussed on the role of insurance and the ecosystems and nature-based solutions for DRR. Ecosystems can provide means to mitigate natural hazard risks, by mediation of flows and nuisances; or through maintenance of physical, chemical, biological conditions in the face of pressures. Ecosystem services for disaster risk reduction are most frequently associated with mass stabilisation, water flow regulation especially flood control, wind dissipation, and (micro- and regional) temperature regulation. Other, equally important hazard mitigating services include control of pest, disease and alien species; water filtration; dilution and detoxification of hazardous substances. Compared to engineered or built solutions, ecosystem-based approaches may be cost-effective, have certain co-benefits, and may become increasingly valuable in the face of more frequent and/or severe extreme events. They have an economic value in the context of natural disaster risk reduction and insurance, even if no price actually is paid for their provision and/or maintenance.

Ecosystem services are often 'taken for granted' in risk assessments. But many changes to ecosystems, for example to increase agricultural production or to provide land for infrastructure development (buildings, railways, roads...) may have the unintended consequence of reducing these regulating functions, potentially leading to growing societal vulnerability and susceptibility to harm that is expensive and/or difficult to reverse. The combination of increasing intensity and frequency of natural hazards, continuing conversion, homogenisation and simpli-

fication of (semi-)natural ecosystems, and the increasing footprint of built infrastructure may be contributing to the observed rapid increase in the costs and damage from natural hazards. It appears sensible to harness insurance and other financial instruments to protect or restore risk-mitigating ecosystem services. In theory, the recognition of ecosystem services could motivate insurers and other stakeholders to protect or restore the ecosystems. However, the combination of financial risk transfer mechanisms and ecosystem restoration is not straightforward because of the widely variable funding habits and traditions that cut across public and private sectors. Many conceptual, legal and financial barriers exist. Where insurance is primarily offered to individuals, such as farmers and homeowners, there is limited scope for using insurance (for example through risk pricing) to incentivise behaviour change. The example of flood insurance, and efforts to motivate property level protection and resilience-building, amply illustrate the challenges (Surminski and Eldridge, 2015). Marginal ecosystem improvements may not be enough to substantially reduce hazard risk. Purposeful ecosystem service provision often requires management intervention at the landscape scale, rather than the individual property. The return on investment may take decades to be profitable. And because ecosystem services are public goods, the cumulative effects generated through insurance-based incentives will also benefit uninsured proprietors. Collective insurance schemes appear better equipped to deliver sizeable improvements of ecosystem services and to get around concerns about free-riding. But collective insurance implies a dominant position or a (quasi-) monopoly of a local insurance market that undermines competition

and demands close public control. An example of collective insurance reward under state-subsidised insurance scheme is the Community Rating System (CRS) under the US National Flood Insurance Program (NFIP), where households receive a premium discount if their community takes specified flood mitigation measures. These can include nature-based solutions. Financial incentives through risk pricing are not the only way of harnessing the latent potential of disaster insurance. Other means, even less explored, include taxation, public procurements and concessions, large-scale investment programs and public-private partnerships (PPPs). Individually or together the ENHANCE team members are committed to analyse the potential for cost-effective investments in protecting, enhancing or restoring ecosystems by developing and applying methodologies for estimating the 'insurance value of ecosystems', exploring ways in which insurance and public policy instruments can incentivise cost-effective investments in ecosystem maintenance and restoration, and assessing the legal, economic, social and institutional feasibility of insurance and other financial and economic instruments for promoting cost-effective investments in protecting, enhancing or restoring ecosystems.

There is also further research needed on full economic impacts of disaster risks, including distributional and spill-over effects of natural hazards. This need has been echoed by the scientific community (Jonkman, 2013; Mechler et al., 2014; Ward et al., 2015). While many existing disaster risk models focus on direct (material) damage on tangible assets such as residential properties and infrastructure, few models address the so-called 'indirect economic consequences', including production losses in areas affected through supply chain networks, or the cost of economic recovery after a flood. Research within the ENHANCE project shows that conventional risk modelling may severely underestimate disaster risk (Koks, 2016). One of the most important reasons for this underestimation is the degree of dependency of economic systems on critical infrastructure. One of the current focus points for policy makers is the vulnerability of this critical infrastructure to natural disasters. Infrastructure is the backbone of economic growth and social cohesion. The disruption of (critical) infrastructure, as a result of natural hazards, may be estimated through productivity losses and increased cost of production, which are set in motion by the substitution of more efficient and competitive supplies with lesser efficient supplies. For impact assessments, it is essential to outline the spatial extent of regions physically unaffected by the extreme event(s) that are disrupted as a result of damaged infrastructure.

Besides the impacts of large-scale disaster events, such as floods and earthquakes, there is an increased interest in the economic effects of extreme weather events, such as extreme rainfall, wind and hail. In north-western Europe, for instance, wind and hail storms are the most costly events for the insurance sector and have a much larger probability of occurrence in comparison to large-scale river or coastal flooding. Moreover, in relation to the failure of critical infrastructures, the modelling frameworks presented in the ENHANCE project serve as a good starting point to develop methods to assess the economic consequences of extreme weather events.

Finally, the ENHANCE project has pointed to the need for a greater research focus on options to address the residual impacts associated with both extreme and slow onset hazards. The topic has gained increasing visibility within recent climate change talks, eventually resulting in the creation at COP 19 of a specific 'Loss and Damage Mechanism' to deal with unavoidable climate-related effects (UNFCCC, 2014). In 2014, the UNFCCC set up an Executive Committee and devised a work programme to inform the deliberations. The mechanism was eventually endorsed as a stand-alone article of the Paris agreement (2015): Parties are called to work 'on a cooperative and facilitative basis' to 'enhance understanding, action and support' in areas including early warning systems, comprehensive risk assessment and management, risk insurance facilities, climate risk pooling, and non-economic losses. Yet, the mechanism features a mere explorative mandate and options for making it operational are currently subject to a vibrant debate.

There is need and scope for more broad-based discussions taking a research focus while aiming to inform policy. A number of promising avenues exist and have been preliminarily identified for taking the debate further, such as focussing on climate risk management and current international efforts for promoting disaster risk management. There have been a few studies reporting on empirical assessments. Yet, overall a comprehensive assessment exercise to identify the grounds for Loss and Damage (e.g., compared to adaptation), key principles to build on, as well as evidence regarding risk 'beyond adaptation' is currently missing. Further research is needed to support the science-policy dialogue on the Loss and Damage mechanism, and to identify practical and evidence-based policy and implementation options for its operationalisation.

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