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Beyond ESPREssO - Integrative risk assessment 2025 synergies and gaps in climate change adaptation and disaster risk reduction

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ABSTRACT

Climate change including the more frequent occurrence and increased intensity of extreme climate events are important drivers of disaster events. This causality is accompanied by the fact that long-term impacts of climate change are connected with a high-level of uncertainty: complex interactions, feedback loops and underlying nonlinear effects that describe the consequences in this dynamic context.

Special modelling approaches are required to increase understanding of these connections with climate change and related global issues, like environmental, social, economic and political matters. Resilience is a concept that can be used when tackling climate change impacts and decrease vulnerabilities. The holistic concept goes parallel with the understanding of "managing risks instead of managing disasters"!

This contribution elaborates now this line of thought and characterizes a risk-oriented modelling and design-oriented perspective. We present overviews on climate change adaptation (CCA) and disaster risk reduction (DRR), respectively, and the related frameworks and methods. Finally, we consider the links between the ESPREssO project with the PLACARD experience as coordination action. Similarities and differences are characterized in detail. Based on this specific comparison, we propose a solution-oriented approach which might overcome the distinctions regarding the different approaches of the projects towards a transformational resilience management perspective, summarizing synergies and gaps as an example for integrative risk assessment beyond ESPREssO.

We conclude with a comprehensive framework based on the 5 priority areas (referred as "mission", terminology introduced in the Horizon Europe Framework) included in the final document of ESPREssO, which could be seen as an example for an integrative risk management combining quantitative and qualitative approaches.

1. Introduction: climate change adaptation

In recent years, climate change has become a public issue discussed in societies worldwide. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as 'a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.'([1]: 39).

In general, climate change is understood to be an important driver of disasters. Extreme weather and climate related events can also be regarded as disasters themselves due to their impact on humans and ecosystems [2]. They are the most impactful type of natural disasters and are identified by some as being the greatest risk to society today [2, 3].

Although the long-term impacts of climate change are still uncertain ([3]: 13), recent observations and projections are pointing to an increased frequency and intensity of disasters ([4]: 7). The effects of climate change will mainly result from the climate variability and extreme weather events [5]. In Europe, climate change is understood to already have noticeable effects on human (e.g. human health) and natural systems due to extreme events such as an increase in

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climate-sensitive diseases and a deterioration of environmental and societal conditions [3,6]. The heat waves of the past years have been among the deadliest disasters in Europe in this century [3].

There is a broad consensus in the scientific community that climate change contributes to increased climate extremes and exacerbates their adverse impacts [7] after Birkmann und Mechler 2015). Zuccaro et al. [8] note that the observed increase in temperatures affect seasonal rainfall distribution patterns and that Europe has seen a substantial increase in extremes precipitation events in some regions.

EEA [3] concludes that climate change has increased the frequency and severity of certain extreme weather- and climate-related events, such as droughts, heat waves and heavy precipitation events, in some regions across Europe, and that these trends are projected to continue, unless climate change is mitigated and society adapts ([3]: 16). If global climate change continues, climate risks are likely to increase in the future [4]. As an additional result, future risks will grow, also due to the complex interactions and feedback loops between climate change trends, ecosystem fragility, disease outbreaks, rapid urbanization, mass displacement and geopolitical instability, which are fueled by the interconnectedness of communications, trade, financial systems and politics, that are finally leading to shocks, stresses and crisis reverberate globally [9].

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 b y the Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide scientific, technical and socio-economic knowledge on climate change and its impacts [10].

In its first Assessment Report in the 1990s the IPCC highlighted the challenges of climate change. It stated that international cooperation was necessary to tackle climate change consequences.

Consequently, the United Nations Framework Convention on Climate Change (UNFCCC) was established, an international treaty to stabilize greenhouse gas concentrations (ibid). Following several conferences, the Kyoto Protocol, the Copenhagen Accord and the Paris Agreement on Climate Change were adopted and published [11]. Amongst them, the Paris Agreement [12] on Climate Change is the latest global climate agreement.

Besides the agreement's long-term goal of limiting the change of global warming below 2° Celsius, the agreement also puts forward a global adaptation goal that includes resilience as a concept to tackle climate change impacts and decrease vulnerabilities in the context of cities, regions and local authorities [13].

The three specifically identified components of adaptation within the global adaptation goal are "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" [11]. By doing so, the Paris Agreement aims to contribute to sustainable development and enhance adequate adaptation responses in the context of global warming. The paper also focuses on a special risk-oriented modelling and design-oriented perspective.

In general, assessing future climate change and the resulting impacts consists of continuously improving modelling approaches [3]. The latest consensus of climate change projections and their impacts is regularly put forward in the IPCC reports.

This also includes possible CCA activities that can be understood as the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities [4]. Within that process we present overviews on CCA and DRR, respectively, and the related frameworks and methods. Finally, we consider the links between the ESPREssO project with the specific PLACARD experience as two main studies of this contribution:

The PLAtform for Climate Adaptation and Risk reDuction (PLACARD) seeks to facilitate knowledge and dialogue between the Climate Change Action (CCA) and Disaster Risk Reduction (DRR) communities and continually develop a framework between these networks and stakeholders at the international, European, national and sub-national levels. The PLACARD program as coordination action brings together evidence-based research, stakeholders, and initiatives into such a comprehensive space for dialogue and consultation to facilitate policy-practice agendas and decision-making. PLACARD has been designed to contribute for better coordination, dissemination and communication of research and innovation activities in CCA and DRR, and increase the synergies between EU, Member State and international activities in these fields.

The aim of this structure is to provide and set the basis of a common understanding of such a concept of an integrative risk amendment beyond ESPREssO. In the following we now start with a general reflection of DRR activities.

2. Disaster risk reduction

The overall goal of DRR activities is to reduce the impacts caused by natural hazards through a culture of understanding and prevention. As such, DRR includes the systematic development and application of policies, strategies and practices to avoid (i.e. prevention) or limit (i.e. mitigation and preparedness) the adverse effects of hazards [14]. DRR initiatives have the potential to reduce the negative impact of hazards and can thereby lead to more sustainable development [4,15]. According to IPCC [16]; DRR can thus also be regarded as a policy goal or objective, and the strategic and instrumental measures employed for anticipating future disaster risk, reducing existing exposure, hazard, or vulnerability, and improving resilience. DRR has become a major topic of United Nations global policies since the late 1980s [17], leading into the establishment of the International Decade for Disaster Risk Reduction in 1990s [18]. Following the World Conference on Disaster Reduction, the Hyogo Framework for Action (HFA) was adopted in 2005.

This framework already called for multidisciplinary and future-oriented approaches to DRR when considering climate change [7]. Since approximately 2005, there has been a growing interest in concepts and definitions in DRR related fields [18,19] and in particular the concept of resilience. Since then, resilience has become a focal point for the post-2015 international agenda.

The current framework on DRR, the Sendai Framework for Disaster Reduction 2015–2030 (SFDRR) focuses on four priorities, i.e. enhanced understanding of risks, strengthened risk governance, and increased investment and better preparedness [20]. Thereby, it sets a clear path to resilient sustainable development [9]. As a global instrument for DRR, the SFDRR was adopted by the Third United Nations World Conference on Disaster Risk Reduction in 2015, continuing efforts of the Hyogo Framework for Action and identifies strategies for disaster risk reduction [8]. The SFDRR also presents guidance for the implementation of new and existing instruments, policies, programs, guidelines and standards to support risk reduction strategies in relation to four priority areas [8, 21].

At the same time, a shift took place from managing disasters to managing risk, as highlighted in the SFDRR, suggesting to set the basis and foster opportunities for increased coherence and mutual reinforcement across the post-2015 agendas and for this to be reflected in policies, institutions, goals, indicators and measurement systems for implementation." [8].

Methods applied in DRR activities cover a wide range of qualitatively or quantitatively approaches and cover areas such as risk assessment, prevention, preparedness, response and recovery [3]. The transfer of knowledge is a crucial aspect of DRR and best-practices, guidelines are frequently being reported from science as well as dedicated think tanks such as the Disaster Risk Management Knowledge Centre (DRMKC), an initiative of the European Commission to improve and deepen communication between policymakers and scientists in the field of disaster risk management. These activities should be embedded in an integrative risk management. Therefore, in the following we will characterize coherence issues between CCA and DRR.

3. CCA and DRR coherence issues

Similarities and Differences, Synergies and Barriers.

Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) can be found in parallel in many international political and legal frameworks, in government declarations and guidelines of states dealing with them, for example states that are trying to face DRR and CCA with operative guidelines: These include the Global Agenda 2030, the Sendai Disaster Risk Reduction Framework (SFDRR), the Sustainable Development Agenda 2030 (SDGs), the Addis Ababa Action Plans, the Paris Agreement on Climate Change, the New Urban Agenda and the Humanitarian Agenda. Taken as a whole, they provide a solid basis for addressing and managing disaster risks issues globally. The common message is that understanding the core issues of risk creation and propagation, exposure and vulnerability, hazard characteristics and their dynamic interactions is a sustainable development imperative of the world ([9]: 2). Therefore, we suggest a comprehensive approach.

3.1. A comprehensive approach

For the first time, this international landscape of agreements offers a comprehensive agenda for achieving the most important resilience goals, with approaches that are consistent with the complexity of the challenges overcoming the limits of traditional siloed approaches ([8]: 7). In this sense, understanding and using the existing links and synergies between the Paris Agreement, the Sendai Framework and the Sustainable Development Goals (SDGs) is a global priority for future research and innovation activities in the field of natural hazards.

The Sendai Framework aims above all at a paradigm shift from the management of "disasters" to the management of "risks", enabling a fundamental coherence and mutual strengthening of the agendas after 2015, which must be reflected in the policies, institutions, objectives, indicators and measurement systems for implementing the agendas ([8]: 10). Therefore, DRR and CCA can be interpreted as two overlapping communities of science and policies, which at the same time have similarities and differences, and whose increased coherence enables cooperation benefits for which however obstacles must be overcome. In the following we will describe and characterize similarities, differences, synergies and barriers.

3.2. Similarities

Both CCA and DRR aim to reduce the negative effects of weather extremes, reduce exposition, increase the resilience of particularly vulnerable people, and transfer and share risks. According to the IPCC [16]; they share goal of (1) understanding and reducing the impact of climate-related disasters and associated risks; and (2) promoting proactive, holistic and long-term approaches to risk management (Thomalla et al., 2006 according to Ref. [7]: 373).

CCA and DRR thus face similar challenges such as incomplete and uncertain knowledge bases, the interaction between many different actors and limited resources ([22]: 10). Both DRR and CCA are integrated into the main policies and strategies of the UN - mentioned above -and the EU, including the protection of civil and critical infrastructure, environmental protection, cohesion policy financial instruments, ESIF, cross-border health issues, agriculture, food security and integrated coastal management ([3]: 27).

3.3. Differences

CCA and DRR partly differ in their problem areas: besides hydrometeorological hazards, DRR also addresses geophysical hazards such as volcanic eruptions and earthquakes, while climate adaptation does not. CCA, on the other hand, considers long-term adaptation to changes in mean climate conditions (slow onset events), while the DRR is primarily interested in the extremes of weather and climate ([5]: 4). CCA and DRR have their origins in different communities of research and policy. They use similar but also different conceptual frameworks of risk management (DRM cycle vis-a-vis adaptation cycle) and they are implemented and financed in practice by different government agencies and organisations [23,24]. This leads to differences in the technical language used and in the project implementation principles and guidance. In particular, these institutional, financial and political barriers are conflicting with general cross-community, interdisciplinary and holistic cooperation [25]. These differences contribute to a 'silo' mentality resulting overall into separation and isolation of CCA and DRR communities ([16,25]; Howes et al., 2015; after [7]: 373; see also [5]: 5). This hinders the establishment of an integrated methodological and operational approach for DRR and CCA in a risk-oriented modelling (Fig. 2) and design-oriented perspective ([8]: 10).

3.4. Synergies

Enhanced CCA and DRR harmonization can bring benefits at all levels: minimize overlap and duplication in projects and programs [26] and, through studies on vulnerability and the concept of resilience, lead to a vision that ends the division between the two communities and promotes cooperation in achieving simultaneous and common goals (Kelman et al., 2015 according to ([7]: 373). CCA and DRR offer a range of complementary approaches to climate risk management, with the overarching goal of building resilient societies ([3]: 10). This will create an improved knowledge base that will benefit both policy areas; more effective and efficient policies and practices in both areas by exploiting synergies; stronger cooperation between scientific and policy makers and networks; more efficient use of human and financial resources ([3]: 17). Through the use of Climate Services, CCA can strengthen all phases of the DRM cycle, including through better informed climate risk and action assessments, sustainable investment in early warning systems and response measures ([2]: 30). The more recent focus on transformative processes ('transformative adaptation' and 'transformative resilience') creates further synergies between adaptation planning, development strategies, population protection and disaster risk reduction ([1,4]: 7).

3.5. Barriers/issues

Enhancing coherence between CCA and DRR policies and practices requires awareness-raising, resource mobilisation and action by public and private actors, preferably in the form of partnerships ([3]: 10). Institutional barriers are more than any other key challenges that hamper the process of successful cooperation between CCA and DRR ([27]: 7). In terms of methodology, however, the first step has been made: hazard mapping and risk assessment are areas in which the harmonization of DRR and CCA is at an advanced stage. The applied further development is now about high-quality and systematically collected data, cascade and spill-over effects and their modelling ([28]: 3139 [3]: 135f).

The promotion and implementation of a comprehensive learning culture and mutual understanding between all stakeholders dealing with DRR and CCA - especially where the two overlap - is crucial for overcoming institutional and cultural barriers and for building effective collaboration and communication between all relevant parties [29]. In order to establish a certain risk-oriented modelling and design-oriented perspective we present within the following section the priorities and practiced steps of two case studies.

4. Improving the coherence of CCA and DRR

4.1. Convergence of priorities and practical next steps in two studies

Many opportunities exist for synergies between CCA and DRR as described above. Some possibilities are being exploited by specific stakeholders or have been programmatically spelt out at EU and

Member State (MS) and at international level (e.g. Refs. [28]; ESPREssO 2018 [5], while others have yet to be developed. What are the ingredients and what are the important next steps to improve the coherence between CCA and DRR in the EU?

This section compares and analysis the degree of convergence of the results of two different research syntheses, both with intensive stakeholder involvement, at the EU and MS level: The ESPRESSO Vision Paper on future research strategies following the SFDRR and the EEA report "Climate change adaptation and disaster risk reduction in Europe: enhancing coherence of the knowledgebase, policies and practices" of the European Environment Agency [3] with the involvement of the European Environment Information and Observation Network (Eionet) - a partnership network of EEA's 39 member and cooperating countries. Both aimed to identify priorities and ways for how coherence of CCA and DRR can be built through knowledge sharing, collaboration and investments.

The recommendations of both reports can be structured along the six dimensions (see also Fig. 1):

Recommendations of EEA and ESPREssO – six central dimensions.

(1) Data needs
(2) Risk assessment
(3) Multi-stakeholder partnerships and programmatic approaches
(4) Role of human behaviour
(5) Role of finance/insurance
(6) Implementation and policy monitoring

These dimensions were ranked (1–4) according the priorities and concrete implementation plans attached to the different dimensions in the underlying studies (cp. Table 1 and the notes to tables).

Rankings are defined along the program priorities and the detailedness of the steps of implementation, i.e.:

4 = Priority mission with implementation elements considered.
3 = Stated mission.
2 = Important Challenge/Gap with detailed analysis.
1 = Stated Challenge/Gap without detailed analysis.
0 = Not included.

4.2. Data: agreement on higher quickly and systematic data collection

Data are an integral part of risk modelling and assessment in CCA and DRR. Loss data are collected at national and sub-national level (e.g. 'Länder' level in Germany) but increasingly also at EU level.

The Copernicus Earth Observation Program is such a European initiative providing information based on earth observation satellites and local observation data. Records at national and sub-national levels, however, are often fragmented and incomplete.

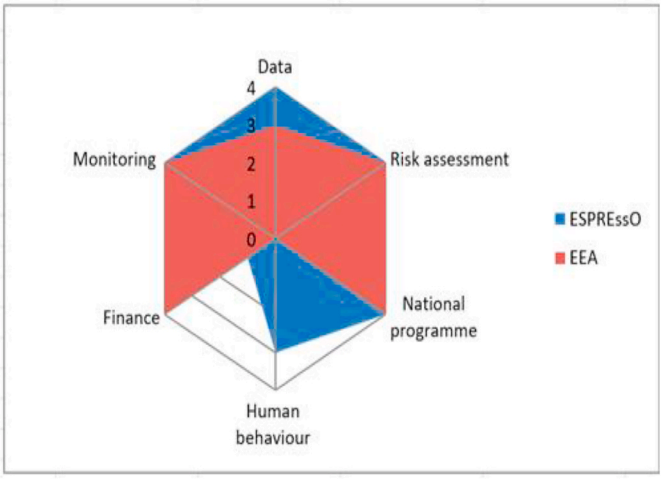

Fig. 1. Priorities for improving the coherence of CCA and DRR in the EU. Note to Fig. 1: EEA did not rank human behaviour as a stand-alone dimension.

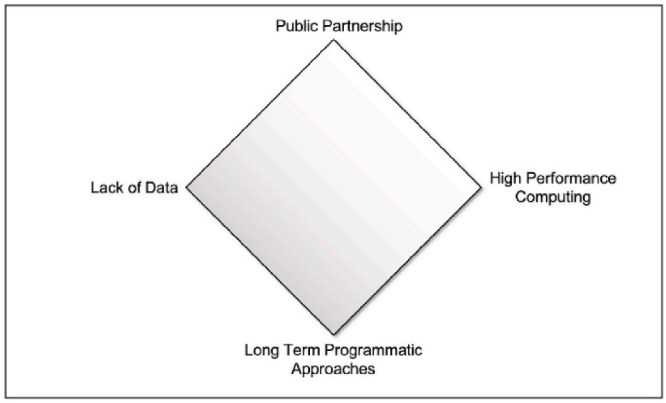

Fig. 2. Integrated methodological and operational approach.

As indicated in Table 1, at a high level of urgency, both studies agree that the systematic collection and availability of high-quality data is needed to improve hazard/impact simulation models to support long-term strategic planning ([28]: 3139 [3]: 135f [8]; 38f).

Further practical next steps suggested are (1) public-private cooperation to rationalize the use of existing data (2) advanced data mining techniques and (3) strengthening data services such as DRMKC and the COPERNICUS program.

The ESPREssO vision paper makes this need for improvement and action at all levels a mission in its report, which gives this need the highest priority (4) compared to a more general need (3) given to in the EEA report (see Fig. 1).

Regarding Fig. 1, it is important to mention that human behaviour was not considered within the EEA assessment:

5. Risk assessment: agreement to a comprehensive approach

To improve simulation-based risk and impact assessments, higher quality and systematically collected loss data are needed ([28]: 3139 [3]: 135f). Furthermore, the results of these modelling exercises need to be prepared in such a way that they can be used for further development, dissemination and evaluation in order to provide a real opportunity to translate risk knowledge from science into policy measures ([8]: 36).

Both studies agree on the objective of a comprehensive overall approach to risk and vulnerability assessment, supporting evidence-based and robust decision-making, and on guidelines for DRR and CCA ([3]: 11 [8]; 36). Both dedicate a specific section (Chapter 6.3., EEA 2018) or mission statement (Mission 1 [8]; to this need, which can be seen as the highest urgency for this dimension of need. Both studies agree that a more comprehensive risk governance approach based on long-term resilience strategies is needed. While there are many UN initiatives, such as SFDRR, the Paris Agreement, the New Urban Agenda, which promote the goal of resilience and the integration of DRR and CCA policies, their implementation, as well as the implementation of European policies, requires more cooperation and information exchange.

So far there are 'silos' between technical and political authorities at national and regional level, as explained above. To overcome these, multi-stakeholder partnerships such as DKKV (Germany) or AFCPN (France) are seen as useful ([8]: 41).

6. National programme: agreement active cooperation

Stock-taking carried out in these studies on the national "implementation gaps" of the Sendai framework show: Only a few Member

Table 1
Ranking of dimensions.

	Data	Risk Assmt	National programme partnerships/national programmatic approaches	Human behaviour	Finance	Monitoring (including implementing)
ESPREssO	4	4	4	3	1	4
EEA	3	4	4	0	4	4

States have detailed action plans to implement the Sendai objectives, for example through programmatic approaches such as the German "Strategic Alliance of Authorities", which is a strategic alliance of authorities in Germany. Beyond Germany, there are other initiatives, like the EU Aid Volunteers or the EU Civil Protection Mechanism, which are acting on a transnational level (see https://ec.europa.eu/echo/what/humanitarian-aid/disaster_preparedness_en). According to the EEA, these programmatic approaches, which are initiated from top to bottom and implemented from bottom to top, can lead to effective CCA and DRR integration ([3]: 116; for further examples see Ref. [30]: 117ff).

Both studies combine the goal of strong public participation and active cooperation between sub-national, national and transnational institutions (both public and private) to increase the leverage of political engagement ([8]: 41) with long-term national programmatic approaches. And both dedicate a specific section (Chapter 6.5., EEA 2018) or a mission statement (Mission 3 [8]; to this need, which can be regarded here as the highest urgency for this dimension of the need.

7. Monitoring: institutional and operational gaps

Both studies jointly note that institutional and operational gaps hamper the coordinated implementation of DRR and CCA measures in Europe. From the perspective of the ESPREssO project, interdisciplinary research on organizational barriers, like issues regarding the policy environment, complex interactions and feedback loops that impede the practical integration of DRR and CCA measures could help. Another useful step "could be the establishment of specialized agencies at national and sub-national level to avoid duplication and competition for resources and administrative inefficiencies ([8]: 42). Overcoming the "implementation gap" in DRR and CCA is s a mission statement of this assessment with a very high need level (Mission 4, [8]. Monitoring and evaluation is considered similarly important in EEA (2018) to close the 'implementation gap' in Europe. Despite these commonalities, the EEA still sees a significant need for research before integrated monitoring and evaluation of policies can be conducted - beyond the "silos" of CCA and DRR. It devotes an entire section to this need, which can be considered a "high-level need" in this risk and vulnerability assessment [30].

8. Role of human behaviour: quantitative and qualitative analytics

A significant difference between the two studies concerns the role of human behaviour in risk management. The ESPREssO Vision Paper recognizes that disaster prevention, management and response are strongly influenced by human behaviour, like panic or fear situations. It is therefore important for the authorities to know the psychological requirements and stressors in order to raise awareness and deal better with the situation before, during and after an event. Quantitative and qualitative analyses of vulnerable and diverse groups, knowledge transfer, innovative information tools, analyses of the impact of a crisis are therefore necessary. A mission statement for studies on human behaviour and disaster risk (Mission 5 [8], indicates a high priority for this dimension, while the EEA [3] does not focus on this dimension.

9. Finance: instruments and institutions

Disaster financing comprises a variety of instruments designed to achieve different objectives and to achieve different outcomes. A strategy based on a diversified pool of complementary financial instruments and institutions is higher ranked in the EEA (2018) needs assessment in terms of managing and responding to a variety of environmental and human risks. For example, since insurance provides personal protection that also reflects the insured's prevention behaviour against the risk, comprehensive agricultural multi-risk management is classified as best practice in the EEA (2018).

The "great potential for external contributions from private actors, including the insurance sector" is shared by the ESPREssO study ([8]: 21), but is neither investigated nor classified as a mission statement. The EEA [3] devotes a high urgency dimension to this issue in a separate section (Chap. 6.7.).

Comparing the rankings of EEA (2018) with the ESPREssO project ranking (see Fig. 1) shows a very high degree of convergence, but a relevant divergence in the assessment of the role of human behaviour and the consideration of financing, especially from private sources such as insurance. The importance of private funding is partly due to the design of the EEA process - a relatively weak representation of scientists combined with a strong participation of national (environmental) authorities from the Eionet in the review process of the study, who strongly oriented themselves to Sendai's implementation problems from the standpoint of the authorities. Eionet stakeholders rather emphasised the budgetary constraints for fulfilling the new and additional reporting obligations of the SFDRR.

The strong focus on private funding in EEA (2018) was also influenced by the initial involvement of the insurance industry in the kickoff. The needs ranking of the ESPREssO project was much more based on a strong and interdisciplinary scientific analysis with a comparatively less influential consultation of national and EU stakeholders in workshops. This potential for 'process bias' suggests that synthesis processes for the coherence of CCA and DRR should be continued in different settings and further developed towards a comprehensive multi-stakeholder/multi-community process as it is enshrined in the governance structure of SFDRR (cp [31].

10. ESPREssO compared to EEA

In order to provide an actual analysis, we compare the results of the ESPREssO project with general EEA in the following sense:

The coherence of the EEA is leading to a comparison between ESPREssO and EEA and provides the basis for the following five "missions".

Mission 1: Better data for a resilient future.
Mission 2: Improved risk and impact assessments.
Mission 3: Risk governance and partnership.
Mission 4: Overcome the implementation gap in DDR and CCA.
Mission 5: Human behaviour and disaster risk.

This will be characterized in detail by the following analysis.

	ESPREssO (Vision Paper)	EEA [28]
Data needs	Data is not only collected on the national and sub-national levels, but also on the EU level. · **Goal**: support long-term strategic planning, feeding hazard/impact	Records can be fragmented and incomplete. Therefore, more high quality and systematically collected data is needed to further model of cascade and spill-over effects ([28]: 3139 [3],: 135f).

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	ESPREssO (Vision Paper)	EEA [28]
	simulation models · **Need:** integrate different datasets, "innovative methods and tools for advanced data collection and analysis methods" ([8]: 38), public-private cooperation "to streamline the use of already existing data" ([8]: 39), advanced data-mining techniques · Call for implementation of improved services ([8]: 39) · Focus on DRM cycle **Mission 1: Better data for a resilient future**	**Goal**: knowledge of climate change impacts and the assessment of (multiple) vulnerabilities and disaster risks can be crucial to identify trends and risks. · **Need**: improvements in new models, availability of high-resolution datasets, high-performance computing ([3]: 11) · Quantitative impact assessment models important for climate risks ([3]: 11)
Risk assessment	To reduce the impact of disasters, it is important to understand and quantify physical and economic impacts of hazards. **Simulation-based risk** and impact assessments provide an opportunity to transfer risk knowledge from science into politic actions. · Key elements of assessments: hazard, exposure, and vulnerability · **Need**: "Multi-risk assessments and all hazards approaches […] need to be strengthened" ([8]: 36) · Goal: improve high-level assessments and identify priorities by using big data and satellite/remote sensing information **Mission 2: Improved risk and impact assessments**	Although hazard mapping and risk assessment is an area where integration of DRR and CCA is well advanced and recognised as a priority area, there is still scope for improvement as records can be fragmented and incomplete. Therefore, more high quality and systematically collected data is needed to further model **of cascade and spill-over effects** ([28]: 3139 [3],: 135f). · **Goal**: "Comprehensive, multi-hazard risk and vulnerability assessment frameworks can support evidence-based and robust decision-making, and guide policies in DRR and CCA ([3]: 11) Chap. 6.3 Improved monitoring and risk assessment
Multi-stakeholder partnerships and programmatic approaches	There is a need for a more **comprehensive risk governance** approach with more long-term resilience strategies. · **Need**: "strong public participation and active collaboration among sub-national, national and transnational bodies (both public and private) […] to boost the leverage of political commitment" ([8]: 41), strong partnerships **Mission 3: Risk Governance and partnership**	There are many international frameworks and agreements focusing on DRR and CCA, such as the Sendai Framework for Disaster Risk Reduction [20], the Paris Agreement on Climate Change [12], the World Humanitarian Summit or Urban Habitat. The EU has played an important role in preparing these frameworks and has further integrated DRR and CCA into EU policies and strategies as well ([3]: 29). These developments fostered a proposed reform of the EU Civil Protection Mechanism, knowledge sharing as well as the development of

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	ESPREssO (Vision Paper)	EEA [28]
		national adaptation strategies and plans ([28]: 3138). According to EEA, these programmatic approaches initiated from top-down and executed from bottom-up "can deliver effective CCA and DRR integration" ([3]: 116; for further examples, see Ref. [30]: 117ff). Chap. 6.5 Long term national programmatic approaches
Implementation and Policy Monitoring	There are institutional, operational and research gaps hindering the implementation of DRR and CCA measures in Europe. An uncoordinated implementation process is often the consequence. · **Need**: investigation of integrating DRR and CCA measures, funding allocation mechanisms, knowledge sharing processes, legal instruments and operative measures · "[…] need of an improved collaboration and integration between CCA and DRR fields to overcome the implementation gap in resilience investments" ([8]: 42) **Mission 4: Overcoming the implementation gap in DRR and CCA**	**Knowledge platforms** provide a great opportunity for greater engagement and networking. Adding CCA and DRR in the design process of nature-based solutions would add to understand the multipurpose nature of these solutions, help to leverage funding, and facilitate connecting different communities working on joint solutions CCA and DRR share a number of characteristics which can make monitoring and evaluating policies and measures challenging including long timescales Chap. 6.8: Monitoring and evaluation to improve policy implementation and adaptive management)
Human behaviour and disaster risk	Disaster preparedness, management and response are strongly influenced by human behaviour. Analyses of human behaviour, however, often focus on specific events or specific behaviour. It is important for public authorities to know the psychological demands and stressors in order to raise awareness and better handle the situation before, during and after an event occurs. · **Need: quantitative and qualitative analysis of vulnerable and diverse groups, transfer of knowledge, innovative information tools, analysis of effects following a crisis** **Mission 5: Human behaviour and disaster risk**	No focus in this study
Finance/Insurance	· Funding instruments like ESF, CAP and ERDF for DRR and CCA ([8]:	Disaster financing embraces a variety of instruments that are

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	ESPREssO (Vision Paper)	EEA [28]
	42) · Non-structural investments are needed, and should be addressed […]. The perceived large potential for external contributions by private stakeholders, including insurance sector, public-private partnerships, volunteer groups, is still not adequately investigated" ([8]: 21f) Not named as mission, individual references in the text, e.g. from	intended for and capable of achieving different outcomes. A strategy that builds upon a diversified pool of mutually complementing financial tools and institutions is better equipped to cope with and respond to a variety of environmental and human-induced risks. Insurance offers individual protection against the risk of losses caused by various natural hazard. For example, comprehensive agricultural multi-risk management schemes could be supported through common market programs … Chap. 6.7 Risk and adaptation financing

This comparison may strengthen the importance of the five missions.

There are not many simulation models which try to consider all this aspects in one holistic framework. Before we conclude we would like to mention that the so called TEM model Krabs [32] intends to support such a detailed comparison via a simulation based approach. Originally, the TEM model was developed to simulate different Technologies, CO_2-Emissions and the impact of financial Means. In Krabs [32] the foundation of the three dimensions are elaborated and described. The TEM model considers on one site "the lack of data" on the other site it stands for a scalable approach towards "high performance computing" insights in that context. The cooperative treatment and the control theoretic approach reflects the fact of public partnerships as well as long term planning initiatives. Therefore, it can be seen as thought experiment for a suitable process-oriented approach which supports co-design and co-development of appropriate climate services within an integrated operational approach:

The figure demonstrates the relationship between these four key aspects. Finally, the detailed comparison and analysis in that chapter may lead as summary towards an improved holistic understanding of DRR and CCA in the sense of Zuccaro ([8]: 39).

11. Conclusions

The contribution ([8]: 10) stresses the fact that the establishment of an integrated methodological and operational approach for DRR and CCA in a risk-oriented modelling and design-oriented perspective is a central task for the future. This can be also seen as a summary of the present paper.

The reflection ESPREssO Vision Paper on future research strategies following the SFRDRR 2015–2030 and the EEA report "Climate change adaptation and disaster risk reduction in EUROPE: enhancing coherence of the knowledgebase, policies and practices" act on this, demonstrate this in a specific way.

The three dimensions elaborated and characterized by this article together with the service-oriented perspective lead to a special methodological and operational approach where -in the spirit of the ESPREssO vision paper-all levels are considered. The TEM model is not a unique solution and its role should not be exaggerated at this point but it stands for an example that such a chain of thought in the sense of a service-oriented approach by Zuccaro could be realistic and reasonable in the future. Via such integrated approaches policy measures ([8]: 36) could be developed and optimized in a service-oriented way.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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