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Potential Climate Risk Management in German Regions: Case Studies in Lusatia, inner part Spree Forest and Ahr Valley Region

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Abstract. The continuously more frequently threatening disasters are triggered mainly by climate change, next to further natural and cultural drivers. Continuously increasing global temperature and climate change represent current threats for rural and urban areas of the world, as well as Germany. Therefore, the high risks and spatially exposed situations of – in this research exclusively – terrestrial inhabitants for natural hazards are displayed next to dry land ecosystems, wetlands, and low mountain ranges with their cultural and natural landscapes.

The here supported regional perspective (embedded in a broader global research endeavour) includes a comparative assessment of three case studies from regions of Lusatia, the inner part lying Region of Spree Forest, the 2021 highly flood-affected Ahr Valley. This research analyzed the present CRM-implementation situation and its` behind risks behaviour within processing CRM. The result is a resume for an optimized, innovative and effective Climate Risk Management (CRM).

1 Introduction

The continuously more frequently threatening disasters are triggered mainly by climate change, next to further natural and cultural drivers. Continuously increasing global temperature and climate change represent current threats for rural and urban areas in worldwide and German regions such as Ahr Valley or Lusatia, which inhabits Spree Forest. Therefore, the high risks and spatially exposed situations of here so far more terrestrial inhabitants are displayed. The Intergovernmental Panel on Climate Change (2014) projected that European countries and regions suffer from droughts, degrading soil quality, floods, and pandemics. Also, the health crisis of the 2020 global COVID-19 pandemic underlined once more the importance of risk management while catapulting risk management into the centre globally, the same as regionally within the simultaneously threatening flood disaster in 2021 in Ahr Valley Region (compare (comp.) Figure (Fig. 1)). Within general global up to regional risk management, awareness raising and taking responsibility of actions in sorts of Climate Risk Management

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(CRM) – partially in case of IRI-CRM[1] (IRI - “International Research Institute for Climate Prediction”) – have to get standardized also within strengthening regions in a way of also supporting civil courage and decency peacefully, in order to minimize climate crisis impacts and readjust planetary health and simultaneously regional resilience. For instance, governance structures and adaptation combined mitigation measures have to be fully and newly approved within CRM.

Fig. 1. Lusatia Region (red colour) with inner part lying Spree Forest Region being distributed mainly in Germany with neighbouring Poland and Czech Republic, centred within European Countries and Ahr Valley Region (green colour) near to Belgium and Luxembourg (drawn by the author, changed after the drawing from Schütte, 2015 (CC BY-SA 3.0 DE); Reinstädtler, 2017c; 2018; comp. Reinstädtler, 2021a; b; 2022a; b)

Many regions in Germany (and worldwide) are suffering from more continuous vulnerability of coastal shoreline, river estuaries, coastal and terrestrial ecosystems next to, in this case, Ahr Valley floods (Reinstädtler, 2022a; 2022b; 2022c; 2023a; 2023b) and partially more continentally continuous drought disasters such as the hydrological droughts in Lusatia Region especially in the years of 2018 to 2020 (Creutzfeldt, B. et al., 2023, p. 12, 29-32). So, next to coastal regions, more continental regions are threatened by the ongoing climate crises as well, triggering many further crises, such as food (comp. Lee et al., 2007), water, economic, biodiversity or social crises.

[1] The CRM approach is partially understood in this research after the conceptual basis of the International Research Institute for Climate and Society (renamed from “International Research Institute for Climate Prediction”, IRI) (comp. Baethgen, 2010; Hansen et al., 2014; Barnston and Tippett, 2014).

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The regional perspective with a comparative assessment of three case studies from the three German regions of the eastern German part of Lusatia, the inner part lying Spree Forest and the western German part in Ahr Valley (comp. Fig. 1) in form of a resume for an optimized, innovative and effective CRM is the result. Therefore, this research approach is an independent, here summarized assessment of several before or still ongoing independent (and all non-funded) research projects: A comparative assessment of three case studies as European, partially more continental regions, is brought forward. So, a resume for an optimized CRM within most diversified regions' initial situations is the result. Within general (global up to regional) risk management, awareness raising and taking responsibility for actions in sorts of Climate Risk Management (CRM) have to be standardized in a way that also peacefully supports civil courage and decency in order to minimize necessities for climate crisis management and readjust planetary health. These are some of the most pending and not to be delayed homeworks for all governments, state, regional, and communal authorities and initiatives, institutions, civil society, and private businesses in worldwide regions, together, united, and peaceful. That means, for instance, governance structures (comp. Lemos et al., 2020) have to get fully newly approved within CRM and in its different and from each other dependent planning and governance levels. Up to that, Climate Change Adaptation (CCA) measures, which are integrated with climate risk management, have to urgently be combined with mitigation measures and more sustainable management in all sectoral and integrated fields in general. Especially alongside global warming, effects of Sea Level Rise (SLR) and further climate change impacts and pressures, the resulting vulnerability of in these case studies continentally lying terrestrial ecosystems and regionally perceived landscapes, are additional factors that need to be considered urgently to minimize risks and strengthen climate resilience throughout CRM. Also, many regions (worldwide), including the ones in these case studies, are suffering from more continuous drought disasters, so coastal regions, the same as continental regions, are threatened by the ongoing climate crises.

So, this study aims to review and analyze the overall CRM situation and how the affected regions of the case studies can benefit from this sort of management. Finding innovative incentives, approaches, and alternative solutions is one part of the depicted research for bringing, on the one hand, CRM as an approach to the forefront of implementation strategy for many regions worldwide. On the other hand, assessing CRM should enhance the possibility of safeguarding the many vulnerable people from the risks of ecosystems, heritage, cultural landscapes as well as land systems (due to the specific placed case studies). Main objectives of this study are the following: (a) Understanding the theoretical concept of CRM within different climate change impacts on the protection of terrestrial vulnerable land; (b) Analyzing the deficiencies and benefits of CRM; (c) Giving potential recommendations for the future development of CRM and climate risk reduction, adaptation and combined mitigation of the productive cultural and functioning natural landscapes in the case studies. This research analyzed the present CRM implementation situation and its risk behavior within processing CRM on regional level. Long-term planning for climate change risk reduction in the affected regions should be supported in order to spatially determine pending risks as well as action fields and locations for CRM.

2 Data and Methodology

The study, and so the three case studies and further urban or rural areas in German regions with their results, have been conducted based on primary and secondary data, while a literature review gave an added part on a secondary data basis. The case study results were based on an assessment of the general status quo, the partially differing case study objectives, and CRM-development perspectives in the three German regions of Lusatia, the inner part lying Spree Forest and Ahr Valley (comp. Fig. 1). The partially differing case study objectives, as well as different planning levels from the regional and communal levels in these regions, were not a hindering point in benchmark data collection: The data and information were conducted in a semi-structured way in order to keep flexibility in each region's main, further challenging status quo areas and needed scales and planning levels to be observed and to be determined, assessed, conducted and validated in case of summarizing CRM future development optimizations for German regions and also for worldwide regions. Deriving the regional perspective was partially processed through these primary and secondary data and up to that on an in-depth literature review on CRM in its global outreach and perception.

Following main case study objectives and focal points took part in the primary and secondary data acquiring, which, therefore, directed each status quo description and results for the CRM-development perspective:

1.) Lusatia Region:
- Lusatia Region and climate change needs (risks), measurements and strategies in a land and environmental systems model for a sustainable land and risk management with climate mitigation and Climate Change Adaptation (CCA) combined (Reinstädtler, 2011; Reinstädtler, 2013; Reinstädtler, 2014; Reinstädtler, 2017a; Reinstädtler, 2017b; Reinstädtler, 2017c; Reinstädtler, 2018; Reinstädtler, 2019; Reinstädtler, 2021a; Reinstädtler, 2021b; Reinstädtler, 2022 a; Reinstädtler, 2022 b);
- Lusatia Region and the potential of integrating Climate Smart Planning (CSP) and Integrated Drought and Water Management (IDWM) on a landscape scale and regional level through an innovative land approach for an optimized CRM (Reinstädtler, 2017c; 2018; 2019; 2021a; b; 2022 a; b);

2.) Spree Forest Region (inner part of Lusatia Region):
- Spree Forest Region and UNESCO MAB Reserve Spree Forest and climate change needs (risks), measurements and strategies in a land and environmental systems model for a sustainable land and risk management with climate mitigation and CCA combined (Reinstädtler, 2011; Reinstädtler, 2013; Reinstädtler, 2014; Reinstädtler, 2017b).
- Spree Forest Region and the potential of integrating Climate Smart Planning (CSP) and Integrated Drought and Water Management (IDWM) on a landscape scale and regional level through an innovative land approach for an optimized CRM (Reinstädtler, 2017c; 2018; 2019; 2021a; b; 2022 a; b);
- Climate change impacts and pressures versus livelihoods, heritage, and ecosystems in wetland areas focusing on Adaptation strategies

3.) Ahr Valley Region:
- Ahr Valley Region: Operationalization of an Innovative Theoretical Research Approach for Spatially Determining SDGs – Implementing Spree Forest and Lusatia Regions Land and Environmental Systems Model into the flood disaster-damaged Ahr Valley Region in Germany, thereby including rebuilding a

highly flood-damaged region and disaster-hit conflict landscape, spatially determining climate resilience (and in addition to that hope) (Reinstädtler, 2022a; 2022b);

- Ahr Valley Region: Chances and Challenges In Implementing Sustainable Development Goals in Disaster Risk Management and Post-Catastrophic Crisis Management – Case Study on the German Ahr Valley Region (Reinstädtler, 2022c);
- Transboundary systems provision for sustainable and resilient climate risk-, disaster risk- and crisis management in flood disaster-damaged Ahr Valley in Germany - Implementing Spree Forest and Lusatia Regions Land and Environmental Systems Model (Reinstädtler, 2023a, 2023b);
- Generally for German regions next to Ahr Valley: Investigative study about "Planning dimensions, prospects and potentials on water harvesting in Germany, and urban and regional investigations as well as water availability or sustainable urban water reuse" (Reinstädtler and Schmidt, 2015; Reinstädtler et al., 2017; 2021a; 2021b).
- Generally for worldwide regions next to Ahr Valley: Data assimilation in hydrological and hazardous forecasting (Reinstädtler et al., 2023).

Besides these, by the main request for regional optimization of effective CRM-operationalization settled studies, they were also screened on the future adaptability of more spatially and timely dense disasters while preventing crises situations. For information and data collection, as well as analysis combined with a number of standard approaches was used including review literature of external studies to get a broadened understanding of the general development situation of CRM. These secondary data inputs came from different publications of government agencies, NGO reports, and research organizations, the same as from running or closed-up (research) projects.

The primary data and information concerning the German-related case studies (Reinstädtler, 2011; 2013; 2014; 2017a; 2017b; 2017c; 2018; 2019; 2021a; 2021b; 2022a; 2022b; 2022c; 2023a; 2023b; Reinstädtler and Schmidt, 2015; Reinstädtler et al., 2017; 2021a; 2021b; 2023) invested in, are based on and were collected in a database on field level through observation on environmental media of landscape and water, partially within landscape scale and regional level for Lusatia Region and inner part Spree Forest Region, Ahr Valley Region, further urban or rural areas in German regions in general. Collected data and information were analyzed and visualized partially by using EXCEL, VISIO 32, Photoshop and ArcGIS 9.2 software in the case studies.

3 General Approaches to Climate Risk Management

The impact of global warming and climate change is also a threat to regions in countries such as Germany (comp. IPCC, 2007; IPCC, 2014; IPCC, 2018) and any other region worldwide being endangered more frequently by possible disasters. So, the impacts of climate change (and variability) show an increasing frequency and intensity in many regions worldwide, resulting in growing climate-related risks (IPCC 2018; 2019a; 2019b; 2019c) impacting our regions` civilization, natural and cultural heritage, landscapes and ecosystems or land and water systems. Risk, thereby, means the potential for unfavourable consequences with something of value at stake and with the occurrence and degree of an outcome in an uncertain state (GIZ, 2021, p. 15). Moreover, the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), and

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the (climate-related) hazard with the likelihood of its occurrence makes up a risk (GIZ, 2021, p. 15). Climate change is happening due to the emission of greenhouse gases, which are generated so far in more significant amounts by industrialized countries (IPCC, 2007; comp. Boden et al., 2017). The average global temperature already increased to at least 1.1°C, and climate change is promptly altering the risk profile of the planet (UNDRR, 2022b) while having regional-specific induced alterations. The strongest verifications from C3S (2023) are given to have crossed in the year 2023, 50% of days being more than 1.5°C warmer than the pre-industrial average, and two days were, for the first time, more than 2°C warmer in European regions. Because of the increased average global and European temperature, the magnitude, severity, and frequency of disasters are therefore enlarging. Up to that, extreme weather events have doubled throughout the last 20 years compared with the previous twenty years (UNDRR, 2022b).

The United Nations Office for Disaster Risk Reduction (UNDRR, formerly known as UNISDR), therefore, created the flagship initiative of the "Comprehensive Disaster and Climate Risk Management" (UNDRR, 2022a). This program is giving important financial incentives next to being aligned with Target E of the Sendai Framework for Disaster Risk Reduction (UNDRR, 2022a)(comp. Fig. 2). It targets to increase the number of countries having developed national or local disaster risk reduction strategies. In those strategies, the promotion of policy coherence with climate change, among others, is one of the defined principles (comp. UNDRR, 2021; UNDRR, 2022a, b). The flow chart of processing (comp. Fig. 2) includes in its first steps a risk information exchange, then guidance and technical resources check with its technical guidelines, methodologies and tools, and modular training (UNDRR, 2022b).

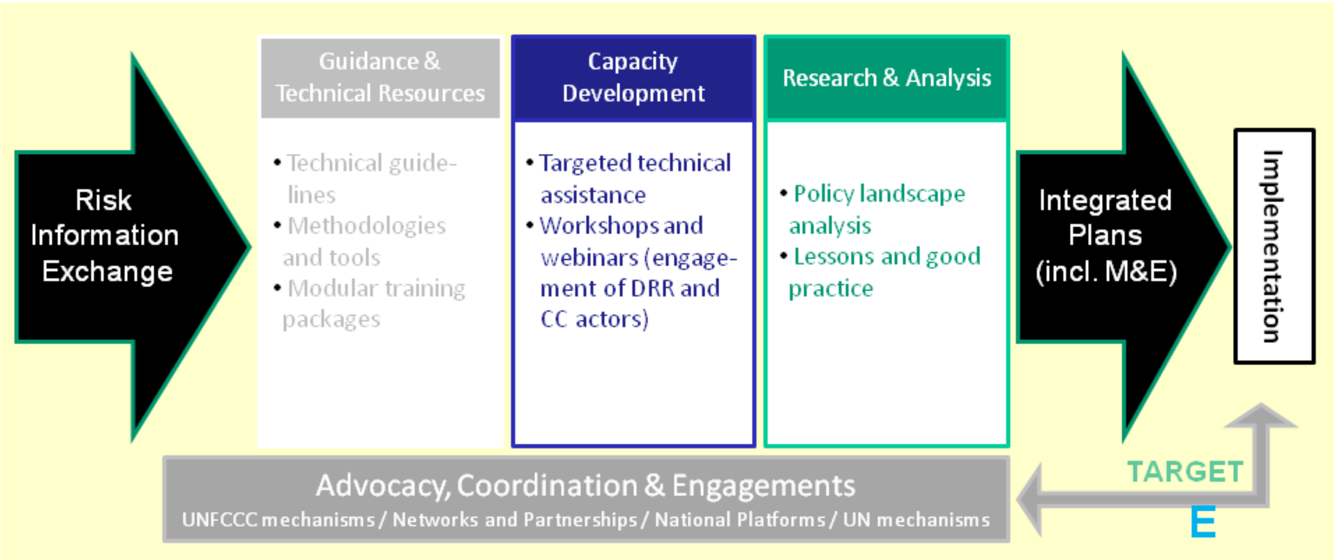

Fig. 2. General Concept of the UNDRR Comprehensive Disaster and Climate Risk Management (M&E means *Monitoring and Evaluation*; drawn by the author, slightly changed after UNDRR (2022b), Comprehensive Disaster and Climate Risk Management, p. 1)

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The next step is about capacity development with its targeted technical assistance, workshops, and webinars (engagement of Disaster Risk Reduction (DRR) and Climate Change (CC) actors) followed by research and analysis step with a policy landscape analysis, lessons, and good practice. The pre-last step includes integrated plans inclusive of *Monitoring and Evaluation* (M&E) closing up with the most important step of implementation (UNDRR, 2022b). All pillars of guidance and technical resources, capacity development, as well as research and analysis have to be strengthened through advocacy, coordination, and engagements with acknowledging UNFCCC mechanisms, general networks and partnerships, national platforms, or UN mechanisms (UNDRR, 2022b)(comp. Fig. 2).

In general perceived, CRM is a systemic framework in which all types of climate risks are fostered to anticipate, avoid and prevent as well as to absorb remaining impacts from extreme weather events (for instance heat waves, freezes, heavy downpours, avalanches, tornadoes, storm surges, hurricanes, tropical cyclones, floods, wildfires) or gradual, slow-onset changes (initially introduced at the Cancun Agreement, COP 16: increasing temperatures, desertification, loss of biodiversity, land and forest degradation, glacial retreat, ocean acidification, sea level rise, salinization). Risk management implements actions, plans, policies, or strategies for minimizing the likelihood and/or consequences of risks or reacting to consequences (GIZ, 2021, p. 15; comp. BMZ, 2017).

Further important research areas to be mentioned in correlation to CRM are Disaster Risk Reduction (DRR), climate change adaptation (CCA), -mitigation, and general resilience strengthening, being coupled in a sustainable development framework and depending on the time-scale being available for implementation. Up to that risk-awareness with acknowledging possible associated impacts, critical thresholds or even tipping points is the first step and an important option for getting into the second step of response with precautionary action. Different approaches to the response against challenges of climate change include the main two ones: reducing and steadying levels of heat-capturing greenhouse gases in the atmosphere, being called “mitigation” and adapting to the climate change already in prearrangement being called “adaptation” and having different forms of adaptation. Further, specific concepts such as the 17 Sustainable Development Goals (SDGs), known as the Agenda 2030, the extraordinarily important Sendai Framework for Disaster Risk Reduction 2015 – 2030 (UNDRR, 2022a), the Paris Agreement from 2015 and the New Urban Agenda from 2016, itself as a transmitter for implementing the SDGs and Paris Agreement on the local level (BMZ, 2019b). Up to that, the concept of CRM exists, and the International Research Institute for Climate and Society (IRI) seeks to manage the entire range of climate-related risks (Baethgen, 2010). Next to this further interesting IRI-CRM processing (please comp. later in subchapter 6.2) it is advantageous to also go ahead with further concepts such as with the GIZ’s ‘Deutsche Gesellschaft für internationale Zusammenarbeit’ (GIZ, German Association for International Cooperation) combined German Federal Ministry for Economic Cooperation and Development (BMZ) CRM framework and the implemented 6-step Climate Risk Assessment (CRA) methodology as a main component for the Global Programme on Risk Assessment and Management for Adaptation to Climate Change (Loss and Damage) (comp. BMZ, 2019a; b). The “Comprehensive Risk Management”-framework is based on (A.) Planning for resilience (also comp. Reinstädtler, 2011; 2013; 2017; 2018) and (B.) Implementation and monitoring for resilience with – for both parts – the strategies named in Figure 3 being essential (BMZ, 2019a): (1.) Climate change mitigation; (2.) CCA (including risk-transfer and transformative adaptation) (both also comp. Reinstädtler, 2011; 2013; 2017; 2018); (3.) Catastrophe reserve, risk management, and here added by the author CRM (including CRA) and Disaster Risk Management (DRM) in sorts of general risk management (4.) Transitional development assistance, aid/reconstruction, to which Reinstädtler (2017c; 2018) would have had added crisis management (CM)(BMZ, 2019a). The author suggests fostering CRM, DRM and catastrophe reserve while better preventing against areas of the fourth framework pillar (comp. fig. 3). So, figure 3 is slightly changed from the concept of "comprehensive risk management ", originally developed by the BMZ (2019a, p. 9) in cooperation with the GIZ.

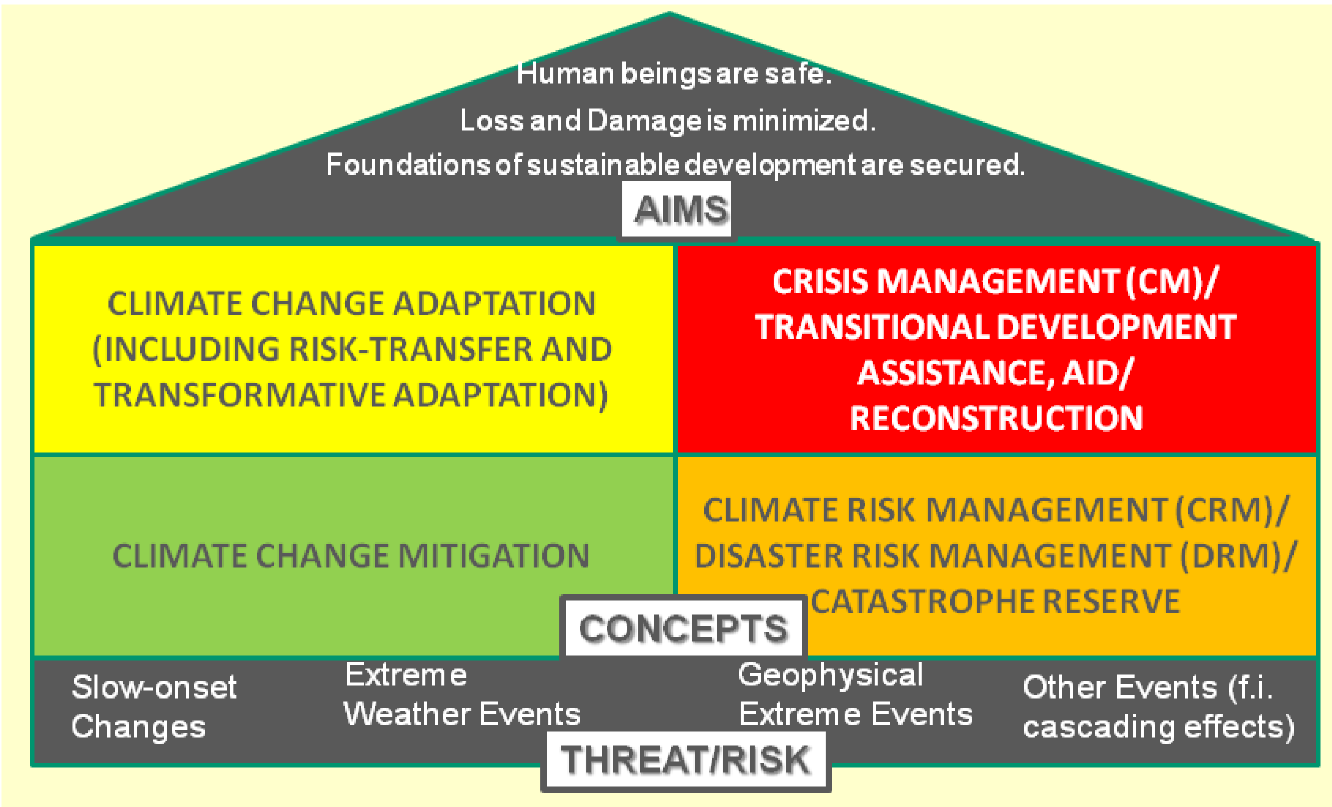

Fig. 3. Concepts around the comprehensive risk management (drawn by the author, slightly changed after BMZ (2019a), Umfassendes Risikomanagement: Der Ansatz der deutschen Entwicklungszusammenarbeit im Umgang mit Katastrophen- und Klimarisiken. In cooperation with the German Association for International Cooperation (GIZ) GmbH, Bonn, Germany, p. 9)

Within these strategies following risk management instruments are suggested by BMZ (2019a, p. 10) and GIZ to be involved in fulfilling the strategies on planning as well as implementation basis: risk assessments, capacity building, expansion of renewables, climate-resilient agriculture, decarbonization, risk-informed planning, and investment, climate-induced human

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mobility, preventive reconstruction, risk transfer, social protection, civil protection and early warning systems, Ecosystem-based Adaptation (EbA), sustainable natural resource management.

Moreover, throughout crisis management (CM), transition aid and reconstruction humanitarian aid can be bridged, with the superior aim of saving lives, for which CM, in general, should be prevented before occurring (also comp. Reinstädtler, 2017c; 2018, p. 92) with fulfilling the inbefore steps of the "Comprehensive Risk Management"-framework. In general, it is advantageous to prevent a need for a later risk or crisis management (comp. Wilhite et al. 2000, also comp. the usage of DPSIR-matrix in Reinstädtler, 2017c; 2018, p. 92) and is essential for economical, ecological, and social functioning regions in order to prevent unsustainable developments. In these regards, not to be forgotten is the fact of policy analyses on risk management and risk tolerances (comp. Kunreuther et al., 2013) under governmental guidance and in distribution to the different assessment, planning, and decision making levels.

To sum up, even different approaches to CRM exist, in general, a holistic and interdisciplinary but also structured, transparent, and to the specific scale and planning level adapted way of processing in the assessment phases are essential for an effective CRM general in global up to regional perception and implementation.

4 Regional Aspects of Climate Risk Management

The importance of acknowledging a locality or local area in the case of CRM and assessing on a local level is already standing among the 13 guiding principles in the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) (ADRC, 2015, p. 13–14; comp. Nohrstedt et al., 2022). SFDRR highlights "the centrality of the local level" (19i,f) (ADRC, 2015, p. 13–14), which, on the other hand, strengthens, in the same way, the implementation, assessment and general viewpoint of regional aspects within spatial planning combined CRM spheres. The fact that vulnerability varies temporally and spatially (Cutter and Finch 2008; comp. Birkmann et al., 2021, p.2) brings upon the general necessity of spatial observation. Also, the quantitative research of Birkmann et al. (2021) already verifies a strong regional dimension within core phenomena characterizing high vulnerability to climate change (for instance, access to basic infrastructure service, poverty, and state fragility). Therefore, not only the local or national planning level but for sure the further planning level, the regional one has its importance (comp. Polèse, 2007; Hall, 2009; van Leeuwen et al., 2009) while high levels of vulnerability can be found in regional clusters (Birkmann et al., 2021, p.2). The practice interface will be strengthened (Nohrstedt et al., 2022) through spatial determination on the local to regional level (comp. Reinstädtler, 2017c; 2018; 2021a; b; 2022 a; b). In general, regional aspects and regional spatial-cultural expressions and dimensions are "constructive motors" for regional innovation and unique selling points (Reinstädtler, 2005), which in the same way benefits further spatial related aspects and drivers in a region: In kind of climate risk or disaster risk management the regional observation is even the more essential in order to find the different characteristic abiotic and biotic media being some of the parameters to be worked within case of risk reduction.

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The further dependence of different planning levels in spatial planning also has to be implemented within climate-smart planning (CSP) (Reinstädtler, 2011; 2013; 2017c; 2018; 2019), CCA, DRM for DRR, next to the transboundary planning necessities (Birkmann et al., 2021; Reinstädtler, 2023a; 2023b). A study by Tilleard and Ford (2016) (also comp. Birkmann et al., 2021) about an indicator and criteria-based evaluation framework for 42 transboundary basins in Europe, Middle-East and Africa results in a still low adaptive capacity in transboundary water basins. The reasons are partly insufficient financial or technical resources. Up to that, the development and governance conditions of these riparian transboundary influenced states are influencing the capacity for cooperation and adaptation across those transboundary river basins (comp. Birkmann et al., 2021). Therefore, transboundary global regions` interconnectedness is a further coordinative benchmarking option in quickening up CSP (comp. Reinstädtler, 2011; 2013; 2017c; 2018) and CRM (comp. Reinstädtler, 2023a; 2023b).

Next to the functioning planning and management "surrounding" and different planning levels to be involved, the sort of used concepts on the regional level are not to be underestimated: Both the in before described "General Concept of the UNDRR Comprehensive Disaster and Climate Risk Management" (including *monitoring and evaluation (*M&E*)* (comp. Fig. 2, UNDRR, 2022b, p. 1) and the "Concepts around the Comprehensive Risk Management "(comp. Fig. 3., BMZ 2019a, p. 9), including the instruments from mitigation, CCA, CRA, CRM, (or IRI-CRM,) DRM, or in worst case CM, are all concepts being able to be applied on regional level immediately. Up to that, in many cases most of the concepts are already implemented in different ways of implementation grades within regions and regional planning spheres.

The challenge of integrating and linking all the approaches named within the "Concepts around the Comprehensive Risk Management "in figure 3 (comp. BMZ 2019a, p. 9), such as DRR and CCA (Islam et al., 2020; Birkmann et al., 2021, p.2) will not be deepened over here – except highlighting the key challenge of gaining an effective linkage and integration between these approaches at conceptual, strategic and operational levels (Birkmann et al., 2021, p.2): practical barriers are the following three key areas, such as knowledge (data and information)(comp. Johnson et al,. 2020; Vogel and O'Brien, 2006); scales (spatial, temporal, and functional); and norms (legislative, cultural or behavioural) (Birkmann and von Teichman, 2010; comp. Birkmann et al., 2021, p.2). Potential solutions can be compared in Birkmann et al. (2021, p.2) and will be at least partially acknowledged in the constructive, solution-oriented part of this research.

5 Climate Risk Status Quo in German Regions

The climate in Germany is temperate generally without sustained periods of cold or heat, although being located mostly at latitudes north of the United States-Canadian border and therefore being closer to the Arctic Circle than to the equator. So far, some exceptions in the last years, especially naming heat summers of the year 2018 and further following ones, can be named (Sodoge et al., 2024). Warm westerly winds with a maritime climate are predominant in north-western and coastal Germany, whereas a continental climate dominates the inland centred uplands and the more mountainous climate in the south. A precipitation rate of 600 to 800 mm per year and a fairly uniform distribution of rainfall over the year so far is common in Germany (comp. Schuetze, 2013). The driest months are in February, with 49 mm, and October with 56 mm.

The monthly German average of 66 mm rainfall is exceeded in June and July by 85 and 78 mm rainfall (DWD, 2012). Germany has a decreased total renewable water resources per capita from an amount of 1,957 m^3/year in 1977 (World Data Atlas, 2019) to over an amount of 1,870 m^3/year (Schuetze, 2013) to 1,844 m^3/year in 2019 (World Data Atlas, 2019). There are regional exceptions and specifications for the named values, such as those named in the following, especially in some of the here depicted case studies.

In the case of climate risks combined drought and water stress, at least in Central Europe –including German regions –, exceptionally extreme droughts occurred in 2018, 2015, and 2003 while occurring quite often in recent years (Erfurt et al., 2019; Blauhut et al., 2015; 2016; Glaser and Kahle, 2020). Nevertheless, Germany as a whole is so far not affected by water stress except for occasional regional droughts (comp. Moss 2008, p. 135; Schuetze, 2013), such as areas in the vicinity of the city of Mainz or Frankfurt (Main) or Lusatia Region. Further, so far, especially eastern states of Thuringia, eastern Brandenburg, or Saxony-Anhalt are facing regionally affecting droughts. So, as for now, the newer federal states (of Eastern parts of Germany as a whole), with some exceptions of topological subspaces in Saxony and Thuringia, are endowed traditionally throughout distinct lower precipitation compared to the German average (comp. Moss, 2008, p. 135; Gerstengarbe et al., 2003, p. 36). Even most of the countries in Europe and Germany (comp. ECOM, 2010) overall do not suffer from water scarcity (Moss 2008, p. 135), extreme heat summers and multi-year droughts such as happened in 2018 to 2022 (Sodoge et al., 2024) are signals for possible tipping points in case of climatic changes and variability and therefore for a changing climate risk dependency also for German regions. Up to that, the average yearly rainfall might be possible to decline by 10% until 2080 due to climate change (Schuetze, 2013). Furthermore, flood risks caused by extreme precipitation will probably rise in all areas, particularly during the winter months (Schuetze, 2013). Up to that, during the summer months, mainly in the North Eastern and South Western regions of Germany, it was forecasted that higher temperatures and evapotranspiration, as well as declining precipitation, would lead to seasonal droughts (DWD et al., 2005), while even now showing up further diverse regional expositions.

Overall, it can be summarized, not only but also for German regions, that stable weather conditions with slower shifting, extremer weather events, such as floods or droughts, will lead to a higher percentage of extraordinary water-imbalanced situations (comp. Reinstädtler, 2017c; 2018). At the same time, those disastrous events themselves negatively affect the future water cycle or groundwater recharge rate next to others. Greater implications for an extended effect on enlarging climate risks are also standing behind regional overall systems stability.

5.1 Climate Risk Status Quo in Lusatia and the inner part Spree Forest Region

During the summer months, mainly in the North Eastern and South Western parts of Germany, it was already forecasted that higher temperatures and evapotranspiration, as well as declining precipitation, would lead to seasonal droughts (DWD et al., 2005), while even now showing up further diverse regional expositions: Lusatia Region in the Eastern part of Germany is predestined for regional droughts as being located in a water shortage area (comp. Vött, 2000; Balla and Kalettka, 2003;

Gerstengarbe et al., 2003, p. 27; Moss, 2008, p.127; MUGV, 2013; Reinstädtler, 2014; 2017c; 2018).

In this context, drought appearance, land degradation, and desertification processes are not to be under-evaluated in their impacts on landscape development its security (comp. in case of landscape security Reinstädtler et al., 2017), for the social security and the anthropocentric viewpoint on achieving economic values: it is getting evident that dryland degradation and competition over increasingly scarce resources can bring communities into conflict (Annan, 2006; comp. Reinstädtler et al., 2017). Drought is a temporary delimited appearance, which also can extend, for instance, in Lusatia in the form of a multi-year drought from the year 2018 up to 2020 and even 2022 (Creutzfeldt, B. et al., 2023, p. 12, 29-32; Sodoge et al., 2024) (with 2017 starting already a drier year and especially winter). However, also within short framed disruption, drought in its extent in the long row is able to create long lasting consequences: drought disasters – occurring more often at the same local extents – influence crop amount, soil consistency, and next to other environmental media degradation and cultural life (comp. Fig. 4; Reinstädtler et al., 2017).

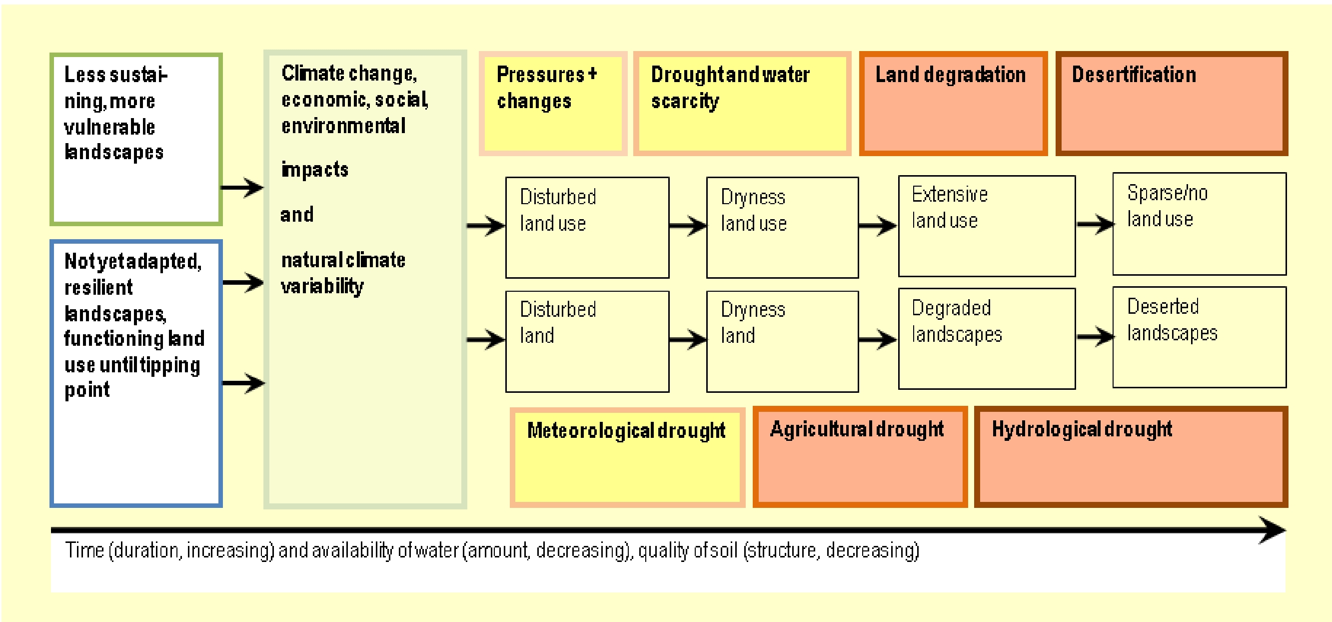

Fig. 4. Development chain of correlation between water availability and landscape sustaining and resilience grade (Source: drawn by the author (slightly changed after Reinstädtler et al., (2017), Drought Management for Landscape and Rural Security. Chapter 8. In: Eslamian, S. and Eslamian, F.A. (Eds.). Handbook of Drought and Water Scarcity. Vol. 2: Management of Drought and Water Scarcity. CRC Press, Taylor & Francis Group, Switzerland, USA., p. 200, Fig. 8.2; drawn after Reinstädtler, S. (2011), Sustaining landscapes – Landscape units for climate adaptive regional planning, in conference presentation and proceeding of abstracts of the international World Heritage Studies (WHS) – Alumni – Conference "World Heritage and Sustainable Development "from 16.–19.06.2011, IAWHP, Cottbus, Germany, p. 18, online-publication: http://www.iawhp.com/wp-content/uploads/2012/01/IAWHP2011_Book-Abtracts.pdf; Reinstädtler, S. (2013), Sustaining landscapes – Landscape units for climate adaptive regional planning, conference proceeding of the international World Heritage Studies (WHS) – Alumni – Conference "World Heritage and Sustainable Development "from

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16.–19.06.2011, IAWHP (International Association for World Heritage Professionals), Cottbus, Germany; Wilhite, D.A. et al., (2014), Weather and Climate Extremes, 3, 2014, pp. 4– 13; NDMC, (2013) Status of drought planning, USA; Accessed 24th July 2014, online available: http://drought.unl.edu/portals/0/docs/10StepProcess.pdf)

So, the damage to economic developments, especially to the food and agricultural sector, is negatively correlated to less environmental, economic, social, landscape, and rural (Reinstädtler et al., 2017) or urban security. Furthermore, next to drought, land degradation and desertification are important negative impacts to be defined in sorts of land, land use, and other environmental economic or cultural changes on land(scape) scale (Reinstädtler et al., 2017) also in Lusatia and inner part Spree Forest Region.

Figure 4 demonstrates the theoretical climatic scenario and possible changes in land use, landscapes, and agricultural crops in– in any region of the world and also possibly in Lusatia and Spree Forest – with unwatered land possible to develop drought appearance (comp. Reinstädtler et al., 2017, p. 200). The drought-prone area, such as also possible in some regions in Germany like Luatia, is put in correlation to the three different existing stages of drought: (1.) the meteorological drought, (2.) the agricultural drought, and (3.) the hydrological drought (Wilhite and Glantz, 1985; NDMC, 2013; Wilhite et al., 2014). The initial point is the less sustaining and more vulnerable landscape, and so less resilient landscape against drought. It is equalized to have less adapted land use. Land use and further culturally driven activities, climate change pressures, social, economic, or environmental impacts, and natural climate variability, as well as climatic, biotic, and abiotic conditions in general, are disturbing the landscapes and land use (comp. Wilhite and Glantz, 1985; NDMC, 2013; Wilhite et al., 2014).

Impacts have accelerated the open to wind erosion and soil totality bare during dry seasons in general (comp. Nicholson, 2000; Visser et al., 2003). A steady decrease of topsoil through erosion due to inadequate conservation practices initialize grounds for the reduction of vegetation cover; when the soil below topsoil is compressed, most of the rainfall water runs off to waterways (Folland et al., 1991; Fongwa and Gnauck, 2010). So, dryness and drought reduce vegetation cover (Reinstädtler et al., 2017) while going along with reduced water recycling (and monsoon circulation if the concerned region is lying in a monsoon area, which is so far not the case in Lusatia in Germany). Thus, continuous dryness, decline, land degradation, or even degraded landscapes and the predestination for an agricultural drought stage are possibly going forward into land use change and damage to agricultural crop production. The micro scale level scenarios' last stage is hydrological drought with desertification, in total deserted landscape and sparse, only irrigated or none landscape (comp. Fig. 4; Reinstädtler et al., 2017).

In perspectives of landscape development and sustaining or resilience grades of landscapes also, possibly in some parts of Lusatia as well as the inner part Spree Forest Region, (future) desertification is standing within the last step of defragmentation of functioning environmental media (Fig. 4). Drought in the beginning fragmentation period – while depending on extent and frequency – is leading into land degradation. The next stage is deserted land, as in this step of fulfillment, a nonsustaining landscape anymore with less existing environmental buffer (Fig. 4): thereby, desertification is hard to revert, but it can be prevented (Annan, 2006) or mitigated. So, Lusatia and inside Spree Forest Region has still the chance to implement strong CRM measurements in order to avert most negative scenarios. Right to the statement of Smith (1776, p. 44) was already stated more than two hundred years ago and has included an even most actual point of fulfillment necessity in sorts of climate risk prevention: “nothing is more useful than water; but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any value in use; but a very great quantity of other goods may frequently be had in exchange for it. “

5.2 General Climate Risk Status Quo in Ahr Valley Region

Flood risks caused by extreme precipitation will not only presumably rise in all areas in Germany, particularly during the winter months (Schuetze, 2013), but is not excluding further seasons as shown by the tremendously endangering flood disaster from mainly 12th to 17th up to 25th July in summer 2021 starting in United Kingdom and affecting that time vast regions and countries of Europe such as devastating Belgium, Luxembourg, France, Germany, Austria, Czech Republic, Romania, Croatia, Italy, the Netherlands, and Switzerland (and up to that on 15th to 20th July in Romania; 24th July again in Belgium and on 25th July in Friesland, Netherlands and again in London, United Kingdom) (comp. Reinstädtler, 2023a; b): especially the by a 5B depression caused extreme precipitation and resulting floods from 14th to 15th July 2021 in Ahr Valley in Rhineland-Palatinate (RLP, comp. Reinstädtler, 2022a; b; c; 2023a; b) and also in North Rhine-Westphalia (NRW) due to a (in this region) two days lasting storm complex with heavy (record) rain falls showed up consequence of more than 180 fatalities in the greater area (in NRW and RLP) and 134 facilities with up to that two still missing people in Ahr Valley alone (Vorogushyn et al., 2024; after DKKV, 2022), greatest destruction and therefore losses in excess of €30 billion (Bento et al. 2024) to even €35- 40 billion (Vorogushyn et al., 2024; after Szöni et al., 2022).

Extreme flash floods and river floods in the tributaries and main channel of the river Ahr, the same as of Erft (NRW), were showing that following two days of heavy rainfall with an accumulated volume of more than 150 mm (Bento et al. 2024), could not be defended or compensated while having greater deficiencies being confronted within case of CRM and CM (Zander et al., 2023). In the case of the Ahr Valley, after the extreme flash and riverine flood, strongly needed DRR (and in the first instance CM), disaster resilience, and building back better (BBB) are approaches not to be underestimated and also having shown challenges, the same as chances in Ahr Valley Region (Birkmann et al., 2023). The overall vulnerability and strong necessities for building up disaster and climate resilience in case of climate risks and in the future stronger needed CRM can be therefore also verified next to balancing short-term urgency recovery (CM, actual loss recovery) versus mid- to long-term planning (climate and disaster resilience, BBB, SDGs, CRM, DRM, mitigation, CCA, CSP) (comp. Birkmann et al., 2023; BMZ (2019a); Reinstädtler, 2017c; 2018; GIZ, 2013).

In the case of climate change-induced disaster and especially flood risk management, there is already a higher at least geomorphologic, topographic while land use-induced exposition and therefore predestination of future risks being coupled to and interacting with climate risks and its necessary to be further strengthened management on the one hand and practical fulfillment – f.i. within intensities and return periods of disasters in historical backgrounds – underestimations, on the other hand (Thieken et al., 2021; Roggenkamp and Herget, 2014; Bürger et al., 2006; Sudhaus et al., 2008a; 2008b; after Kahle et al., 2022).

6. Climate Risk Management and Development Perspectives in German Regions

CRM in Germany and its regions is often understood to be co-adjusted by CCA, also shortly called adaptation. In this constellation, many methods and tools for CRM and adapting to climate change exist, such as those already assessed by the Climate Service Center in Germany (comp. Bowyer et al., 2014). Both CRM and CCA are already necessary, such as in case of water-related targets like floods or droughts: Shortly summarize, the main challenges having to be taken in German regions are in case of CRM to secure against the river and urban floods, the same as coastal floods (but not in the case study regions), and wildfires, with all of them having a high level of hazard risk (ThinkHazard, 2020). However, Germany, in general, is not considered a water-poor country, and naturally induced water-scarce situations are given so far mainly to north-eastern parts of Germany, such as regions of Lusatia or Uckermark (comp. Reinstädtler et al., 2017). Moreover, one of the past long-time hot and dry climatic conditions, especially in summers from 2018 on, was showing to have many more areas being already at some point of risk, such as different city areas like Mainz or Frankfurt (Main) or further rural landscapes, in such exposed and enduring climatic circumstances happening that time in the form of (multi-year) drought and, or heat waves. Thereby, German-wide water scarcity has a 20% chance depending on the region, so droughts will occur in the coming 10 years and specific situations about drinking water proliferation should be taken into account; wildfire chances are greater than 50% of encountering weather that could support a significant wildfire through drought that is likely to result in both life and property loss in any given year; and the hazard of extreme heat has a 25% chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years (ThinkHazard, 2020). It means further on, potentially damaging and life-threatening coastal floods are expected to occur at least once in the next 10 years (excluding this research's case study areas); also, potentially damaging urban and river floods are expected to flood cities and beside areas at least once in the next 10 years (ThinkHazard, 2020).

In the case of German regional CRM development, so far, cyclone (also known as hurricane or typhoon) hazard has no available data, and tsunami hazard is classified as having a very low hazard risk in north-western, oceanic-influenced areas of Germany (ThinkHazard, 2020): so there is less than a 2% chance of a potentially-damaging tsunami occurring in the next 50 years and excluding this research's case study regions. Next to possible droughts, heat waves, or wildfires, hazards such as floods or tornados (the last tornado before submission of this work on 01.07.2024 with approx. 140 km/h wind speed in Cottbus-Sielow, Lusatia, Brandenburg) occur in Germany, and in the last decade more frequently than before. As in the case of rural but also urban landscapes, next to food security and life quality, greater challenges of insecurities are to be recorded worldwide (comp. Petrosillo et al., 2008; Reinstädtler et al., 2017), a stronger need for well-applied CRM, DRM, and CM is getting obvious for Germany as well (comp. DWD et al., 2005).

The medium level of hazard risk includes, in greater parts of German regions, earthquakes, landslides, and volcanoes, next to already named water scarcity and extreme heat (ThinkHazard, 2020): for landslides, it can be summarized for further application in CRM that Germany has (depending on its region) terrain slope, geology, rainfall patterns, soil, land cover, and (potentially) earthquakes that make localized landslides an infrequent hazard phenomenon; earthquake themselves have a 10% chance of potentially-damaging through shaking in German regions in the next 50 years; for volcanic eruption, the selected area within the federal states of North Rhine-Westphalia, Rhineland-Palatinate, Saarland, and Hesse is located at less than 50 km from a volcano for which a potentially damaging eruption has been recorded in the past 10,000 years and that future damaging eruptions are possible.

Protecting and restoring for a sustaining future of landscapes has to not only begin with – by example of an hydrologic hazard – the first appearance of drought inland areas but before when signalizing to be a drought-endangered area, so called preventive or risk management (Wilhite et al., 2014) and not only crisis management (Reinstädtler et al., 2017). A further challenge for CRM next to many potentials and recommended assets might be the so far not entirely adjusted responsibility on the different planning, implementation, and decision making levels from communal and regional over state and national or even international level and their legal implications. In the case of DRR up to CM, for instance, the different terminologies are "disaster control" (in German: Katastrophenschutz), "civil protection" (in German: Zivilschutz), and the "protection of the population" (in German: Bevölkerungsschutz). Their distribution of tasks is divided up between different governance levels (Abad et al., 2018; comp. Eckstein, 2009): In Germany, "civil protection" is strictly understood as part of national defense policies, for which the federation is responsible, whereas "disaster control" is under the responsibility of the federal states (Bundesländer), and "protection of the population" is the official term of both ones (Eckstein, 2009), being not defined to any specific administrative level (Abad et al., 2018). Nevertheless, an interlinkage of "civil protection" and "disaster control" is – under certain conditions – possible (Abad et al., 2018).

Nevertheless, potential recommendations for the future development of CRM in any planning level or responsibility order are coupled to exactly the greater acceptance of prevention in general, but especially on regional level. Also, strengthening climate resilience and sustainable development (comp. Brundtland, 1987) might be better initiated sustainably together with climate risk reduction, adaptation, and combined mitigation (CSP) within productive cultural and functioning natural landscapes. So, a landscape scale combined with a regional level are suggestions next to worldwide regions benchmarking and exchange (comp. Reinstädtler, 2011; Reinstädtler, 2013; Reinstädtler, 2017a; Reinstädtler, 2017b; Reinstädtler, 2017c; Reinstädtler, 2018; Reinstädtler, 2019; Reinstädtler, 2021a; Reinstädtler, 2021b; Reinstädtler, 2022a; Reinstädtler, 2022b; Reinstädtler, 2022c; Reinstädtler et al. 2017) in order to better implant CRM, not only for German regions, but for many further countries regions.

6.1 CRM-Development Perspectives in Lusatia and the inner part Spree Forest Region

As drought (land degradation and desertification) is also climate-related driven, especially and therefore, for Germany, the iterative risk management as part of a more qualitative processing of risk governance (IPCC 2014; Power, 2007; Renn, 2008) and uncertainty processed decision making is of greater interest for bringing forward drought management purposes: iterative risk management comprises an ongoing process of assessment, action, reassessment, and response (Kambhu et al., 2007; IRGC, 2010) that will proceed, especially in case of many climate-related decisions, for decades if not longer (IPCC 2014; after US National Research Council, 2011; comp. Reinstädtler et al., 2017). More important, it also supports research, pro-active implementation, and action of best practice planning and management options on drought and water management combined with landscape, spatial, and land use planning aspects (comp. Reinstädtler et al., 2017). Also included in risk management, DRM and CRM should be the well known steps of drought management. Moreover, proper planning procedures have to be structured. For example, the 10-step drought planning processes of Wilhite (et al., 2014) are to be affiliated: (1.) Determine a drought task force or committee; (2.) Schedule purposes and objectives of the drought mitigation plan; (3.) Find stakeholder input and resolve conflicts; (4.) Make an inventory of resources and ascertain groups at risk; (5.) Set up and write the drought mitigation plan; (6.) Realize research needs and fill up institutional gaps; (7.) Integrate science and policy; (8.) Publicize the drought mitigation plan, build awareness and consensus; (9.) Develop education programs; (10.) Evaluate and revise drought mitigation plans (NDMC, 2013; Wilhite et al., 2014; comp. Reinstädtler et al., 2017). Not only in the case of a drought mitigation plan might these steps be advantageous, but also for CRM itself is combined with the well known procedures (comp. Fig. 3, 2). And not to be forgotten should be the advancements of capacity building against drought, for its management (Islam et al., 2017) and in the same way for CRM.

Coming to the overall summary for Lusatia and the inner part Spree Forest Region and the ongoing greater transformation processes on various aspects, capacity still needs to be generated, especially in the fields of disaster management, water resource management, forestry, and agriculture. For climate change impact analysis and risk measures, understanding and activity role of the theoretical concept of CRM within different climate change impacts, as well as the protection of terrestrial vulnerable land, are well understood in general. Deficiencies, especially in the correlation of DRM, could have been found in the case of transparency. Benefits within CRM were found in the case of activity grade and the overall civil society response. In order to even better strengthen regional adaptation capacity on CRM and connect the collaboration between civil society, NGOs, official instances, and other institutions concerned, the following processing way could be followed (comp. Fig. 5): Four steps should guide to build up regional up to combined federated state and national capacity on climate change adaption in order to mainstream and implement into CRM-processing (comp. Fig. 5) (Ayers et al., 2014, p. 297; Huq and Ayers, 2008). Therefore, prevention and protection against risks are not only but also essential for Lusatia and Spree Forest Region, ranging from forecasting and early warning to building codes, climate protection, and land-use zoning (comp. Bouwer et al., 2022). Being composed of a linear chronology of (1.) awareness and scientific capacity-building, (2.) training of key stakeholders and targeted information, the framework is followed up by (3.) pilot studies in order to (4.) inform policy-makers (comp. Fig. 5) the concept originally was developed for a better implementation of CCA on national capacity building level (Ayers et al., 2014; after Huq and Ayers, 2008). Also, generating incentives to incorporate lessons learned into policy and planning is part of the framework (Lebel et al., 2012), but in these case studies taken for CRM to the regional level, for which the approximate necessary time frame is so far not yet verified in total.

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Many challenges remain, highlighting the need for the most possible transparency within actions taken by all actors, including the government (Huq and Rabbani, 2011). However, the equally important and further general step for the (regional) government is about acknowledging the short- and medium-term of climate change as a development issue while not seeing it exclusively as an environmental issue for the long term (Huq, 2001). Up to that installing a pro-active learning mechanism informs policies and action while developing over time (Huq and Rabbani, 2011). At the same time, appropriate scientific and strategic planning initiatives have to be developed and kept in view (Huq, 2001), such as within the described four steps in building (national and) regional capacity on climate change adaption while mainstreaming and implementing into CRM-processing agencies (comp. Ayers et al., 2014; after Huq and Ayers, 2008). The same essential is the regional developmental planning level and landscape scale for planning for climate change in general (Reinstädtler, 2011; Reinstädtler, 2013), but also in specific for German regions such as Lusatia and inner part of Spree Forest: some of the challenges such as the watershed problems of the Spree River have always to be tackled on a regional scale and cross-state cooperation in the concerned region(s).

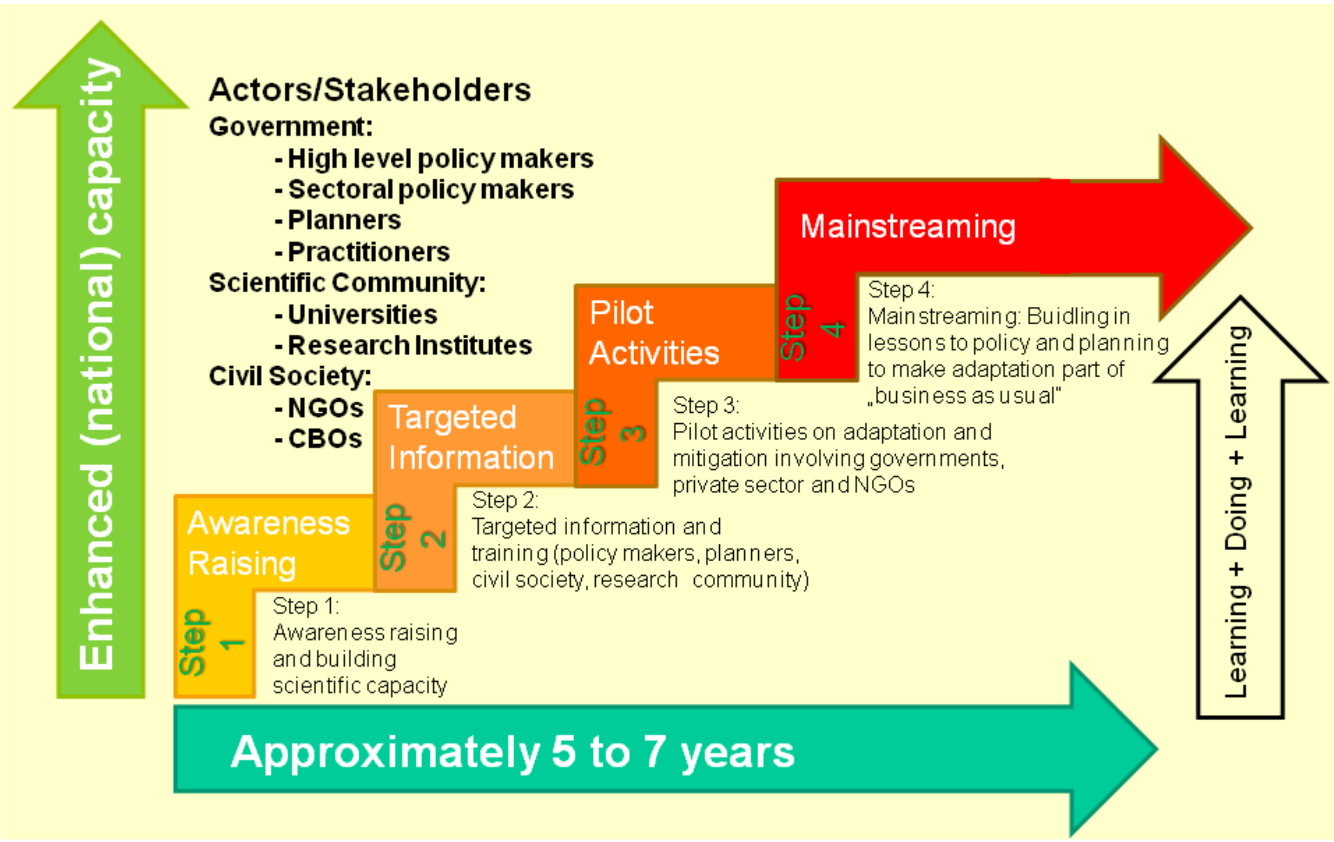

Fig. 5. Four steps to building (national up to) regional capacity on climate change adaption for mainstreaming and implementing into CRM-processing (drawn by the author, slightly changed after Ayers et al., 2014, Mainstreaming climate change adaptation into development: a case study of Bangladesh. Wiley Interdisciplinary Reviews: Climate Change, 5(1), p. 297; after Huq and Ayers, 2008)

Overall, climate change is still a new challenge humanity is facing together with an uncertain future. As not all of the answers yet exist and complex causes–and–effect relations in adapting to climate change (Reinstädtler 2013; after Roggema 2009), a learning-by-doing mindset must abide by the main model for next time (comp. Huq and Rabbani, 2011) in order to strengthen climate resilience through CRM and climate risk reduction, adaptation and combined mitigation.

6.2 CRM-Development Perspectives in Ahr Valley Region

The for Lusatia and inner part Spree Forest Region research objectives, as well as methods, suggested four steps to building regional capacity on climate change adaption for mainstreaming and implementing into CRM-processing (comp. Ayers et al., 2014; Huq and Ayers, 2008) might still be complicated to adjust even it would be a greater added value for stabilizing at least more resilient and sustainable structures: the still enduring phase and greater pressures of rebuilt and (rapid) recovery strongest destructions especially in the private sector is less releasing capacities to bring forward mainstreaming or mid- to long-termed sustainable and resilient planning processes (comp. Birkmann et al., 2023). One of the “classical chances” next to the further by Reinstädtler (2017c; 2018; 2022a; 2022b; 2022c; 2023a; 2023b) in case of developmental transition-topics suggested to be implemented land use and environmental systems model of CA(LU)²WA-application might be more promising to be successfully overtaken in the status quo in case of Ahr Valley Region: The International Research Institute for Climate and Society (IRI)-concept of CRM seeks managing the entire range of climate-related risks, which is based on following four main pillars (Baethgen, 2010):

1. Process of identifying vulnerabilities and potential opportunities due to climate variability and/or change for a given water, agriculture, or health system (Baethgen, 2010).
2. Quantifying uncertainties in “climate information”: uncertainties should be reduced in using that information (Baethgen, 2010; comp. Johnson et al. 2020). Climate aspects of these vulnerabilities, challenges, and opportunities, such as expected recurrence, predictability, and possible long-term changes, have to be better understood.
3. Processing technologies and practices have to be identified. Those selected should optimize results in normal or favorable years (Baethgen, 2010).
4. Detecting interventions, institutional arrangements, and best practices that help reduce exposure to climate vulnerabilities and facilitate the opportunistic exploitation of favorable climate conditions (Baethgen, 2010).

A few common features characterize the IRI approach to CRM (comp. Goddard et al., 2014; Baethgen, 2010; Hansen et al., 2007; Hellmuth et al., 2007), which might help activate first CRM implementations within recovery situations in Ahr Valley Region: It admits climatic uncertainty as a significant challenge; it further targets to quantify and, where possible, to minimize decision-makers uncertainties. Managing climate risk frequently comprises a portfolio of interventions containing, for instance, climate-informed technologies, which minimizes vulnerability to climate variability. Also, climate-informed policy as well as market-based interventions, are included, which convey risk from vulnerable populations. Climate information plays a prominent role in IRI’s work on CRM and consists of historical observations, forecasts at a range of

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relevant lead times, and monitoring of current conditions (Hansen et al., 2014). IRI's concept of CRM focuses on the full range of variability, targeting to protect against the impacts of adverse extremes. Also, opportunities in years or seasons when climatic conditions are favourable should be actively focused on (Hansen et al., 2014; comp. Barnston and Tippett, 2014).

Moving forward, and coming back to the importance of involving stakeholders, it is getting further obvious that engagement and capacity building are required across the community of stakeholders through participatory governance (comp. Lemos et al., 2020) in order to understand the full range of climate-related risks (Arribas et al., 2022): In that constellation, the assessment of compounding and systemic risks should be enabled and in the same time should be a priority. While general participatory processes are already implanted successfully, also ambitions and the process of defining the appropriate scope of a CRA/CRM in the Ahr Valley Region require community, stakeholders, and participatory governance (comp. Arribas et al., 2022). An operant integration of individual risk assessments demands standards for interoperability, which, in turn, requires fundamentals and governance processes involving producers, users of CRA/CRM, data regulators, and providers (comp. Arribas et al., 2022). So, one further "puzzle piece" of participatory governance in all these implementation processes is essential, such as be seen also in Figure 5 and its building up of regional capacity on climate change adaption for mainstreaming and implementing into CRM-processing.

7. Concluding Remarks and Recommendations

Specific objectives of this study were, to understand the theoretical concept of CRM within different climate change impacts while protecting especially terrestrial vulnerable land on regional level. Most beneficial was the interrelation of having included different approaches from the perspective of highly industrialized and highly threatened flooded Ahr Valley and wildfire-concerned and water-scarce Lusatia and inner part Spree Forest region. A further objective of this study was to give potential entrance points and recommendations for the future development of CRM and climate risk reduction, adaptation, and combined mitigation of the productive cultural and functioning natural landscapes of the assessed and mainly both hydrological threatened regions while strengthening climate resilience. Even the most diverse or different demands exist, also similarities in benefits as well as challenges or future potentials within the different CRM processing of the three case studies' regions could have been found. Nevertheless, the development – if still necessary to provide adapted forms – of common principles, approaches, and appropriate standards (within regulatory or technical reasons) should be fostered to enable comparison and interoperability of data and methodologies in general. Thereby, regulators, research bodies, and the private sector all have a task to fulfill in the development of common principles, approaches and standards in CRM on regional level. So, existing CRM also guarantees implementing expertise, users' needs, and capabilities. In the case of CRM, it is crucial to enable an integration of CRAs while perceiving the required field of application.

A common, interoperable outcome, for instance, is that vulnerability, sensitivity, and resilience are the three most important terms to be implemented within CRM. In sequence to many German regional (up to state and national) cases, it would mean

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to have a valuable contribution to fostering a regional up to (at least) national plan for CRM (flood, drought or other such as IDWM) disaster management and adaptation in order to overcome vulnerability while acknowledging sensitivity in exactly that region and in addition to that possibly strengthening resilience.

Further important terms are scope, data, and transparency, which are three key conditions in making current CRAs as a basis of CRM appropriate to operatively assess the true exposure of the environment, businesses, and society to climate-related risk. Within that, again, the comparability, interoperability of data, and methodologies of diverse and different risk assessments should be given through named principles, approaches and appropriate standards. Further recommendations were identified within interconnected critical paths for improvement and, therefore, could lead to the way forward to a more sustainable CRM in the case studies and up to that in worldwide regions:

- Broaden the application of existing and newly originating technology and science to facilitate better use of geospatial data and dealing with uncertainties in case of spatial determination: The GIS-, Remote Sensing (RS)-techniques (comp. Lein, 2014), next to scalable and rapid data processing capabilities (provided by machine learning and cloud computing) should be wider and frequently used in CRM within the step of CRA and its data analysis, visualization, mapping, planning, and modeling for future climate-risk forecasting and effective management measures (comp. Islam et al., 2022).
- Especially RS analysis (comp. Lein, 2014) has to be done for further validation of, in case of drought risks, the selected drought-vulnerable areas by – for example, such as available – MODIS (MODerate-resolution Imaging Spectroradiometer)[2] satellite image or similar sensors like the Advanced Very-High Resolution Radiometer, called ENVISAT-MERIS (MODIS, 2014; Saha et al., 2013).
- Global, national, state, and regional (up to communal) collection of information for drought and combined degradation and desertification (UNEP, 1997; Reinstädtler et al., 2017; Reinstädtler et al., 2023), and also for any other especially for these cases hydrologic catastrophic and climate risks.
- Open (data and information) access for universities, institutions, ministries, schools, libraries, and international conferences (UNEP, 1997; Reinstädtler et al., 2017).
- Further always actualised and for all stakeholders open accessed available collection of climate model simulations like already completed for the IPCC's 2013 climate report and further reports.

[2] is a payload scientific instrument launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands ranging at varying spatial resolutions. Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere. Also highly processed products such as vegetation indices are available over MODIS ("Landscapetoolbox", MODIS, 2014)(MCST Web: http://mcst.gsfc.nasa.gov/ ("MODIS Terra Satellite Images"). ucar.edu (National Center for Atmospheric Research: Earth Observatory Laboratory). Retrieved 2011-01-07. (Landscape Toolbox Wiki: http://wiki.landscapetoolbox.org/doku.php/remote_sensor_types:modis).

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- Monitoring, forecasting and warning systems should be a self-evident part of CRM while getting more transparent to local people.
- In general a combination of adaptation and mitigation measures together with CRM, DRM, and, in case of possibly to be strongly avoided (while applying precautionary principle) necessity, the CM.
- Community participation, local adaptation and mitigation strategy, awareness education, and applied research on CRM and its systems should always be incorporated in all planning levels` development agendas and within the implementation of participatory governance practices to enable the capable participation of multiple stakeholders: Local settlers, habitants and further stakeholder would be equal partners in the CRM development, e.g., for more secure settlement and livelihoods by incorporating Indigenous knowledge, skills, and capacities in the different regions. Up to that, governance should facilitate appropriate scoping and accomplish the empowering environment, being demanded to operate difficult and critical decisions around CRAs and CRM.
- In correlation with participation always, regional up to national governments are also playing a vital role in global climate negotiation processes by raising their voice for the specific area concerned (for example, with LDCs) and in this correlation for active implementation of CRM. Their respective role is also given by Civil Society Organizations (CSOs)/Non-Government Organizations (NGOs), private sectors, and development partners in order to deal with climate change and climate risks.
- In regards to Government policy analyses on risk management and risk tolerances (comp. Kunreuther et al., 2013) are further essential endeavours in getting strengthened CRM.
- Expedite capacity building to empower knowledge generation, innovation, and proliferation: A practical alternative should be to promote and strongly support local, regional, state, and national level programs and initiatives (such as the World Climate Research Programme Lighthouse Activities, Task Force on Climate-related Financial Disclosures) on CRM to enable societies to become resilient to negative impacts of climate change.
- In the case of knowledge generation and knowledge-sharing a further important part is also trust: trust and knowledge-sharing are vital to capacitate an efficient and fast assessment being demanded to manage systemic risks. The examples of international efforts to combat the COVID pandemic have demonstrated the importance of trust and knowledge-sharing while fostering governance processes. Increasing resilience or negative and improper "trading-out of climate risk" might be positive or negative amplitudes. The optimizing one of increasing resilience and, at the same time, enhancing climate justice is supported through rapidly mounting capacity and engagement of all stakeholders, which means including the most vulnerable: It is about influencing, implementing, and maintaining end-to-end CRAs. On the contrary, knowledge asymmetries or inadequate governance processes between users and providers can create improper "trading-out of climate risk" (Arribas et al., 2022).

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- Also, risk assessment for better climate risk preparedness has to be implemented by giving some checklist with YES - or NO - requests to communities for risk assessment regarding cases of severe risks and prevention or action needs (comp. in constellations of drought WSDA, 2006; Reinstädtler et al., 2017).
- Evaluation of own facility for fire risk, establishing fire breaks, reducing fuel loads, and other appropriate measures.
- Existence of regional (, state, and national) programs that may be available to address the economic impacts of hazards such as drought and further hazards regarding climate risks.
- Within examples of many diverse national governmental activities to address the impact of climate change and climate risks, a number of policy and institutional initiatives were adopted that are relevant for any country to be "a Must-Have": the National Adaptation Programmes of Action (NAPA), a possibly called Climate Change Strategy and Action Plan, the establishment of a Climate Change Unit, the foundation of a Climate Trust Fund, and high-level committees with specific functions to empower adaptation actions (comp. Huq and Rabbani, 2011) while being always and urgently directly coupled to state and especially regional governance and without complex-cause-communication transferral barriers.
- In general, especially in any regional governing instance, NGOs and social organizations such as CSOs need to bring up their contributions to develop methodology mechanisms, policy-making, validation tools, impact assessment indicators and instruments for CRM and general protection against climate risks and crises with including management at the regional and micro level (comp. Islam, 2010; Islam, 2021).

There are many options for still optimizing CRM, especially in combination with landscape scaled and regional levelled mitigation and adaptation to climate change, DRM, and CM. Within the assessment part of CRA, data assimilation and accuracy, also coupled with GIS and RS, in general, plays a crucial role, the same as proper community participation, governance, and knowledge transfer with global, national, state, regional open (data and information) access, trustworthy processing are important areas to raise interest within CRM optimization. However, at the same time, scientists and practitioners in the case study- and worldwide regions already contribute to perfect CRM through multifarious innovative ideas while fostering capacity building to empower knowledge generation, further innovation and proliferation. Well-balancing minimization of uncertainty and maximizing flexibility while profoundly stabilizing the architecture of CRM frameworks against climate risk vulnerability, binding (regional) sensitivity for strengthening climate resilience might be access points for optimized scope, data, and transparency in CRM processing. Also, sustainability science endeavours and requests on sustainable CRM structures could be gaining ones (comp. Reinstädtler et al., 2023).

Appendices: --

Code availability: --

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Interactive computing environment: --

Sample availability: --

Video supplement:--

Supplement link: the link to the supplement will be included by Copernicus, if applicable.

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