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Implementation and adaptation of a macro-scale method to assess and monitor direct economic losses caused by natural hazards

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ABSTRACT

As one of the 195 member countries of the United Nations, Germany signed the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR). Among other targets, the SFDRR aims at reducing direct economic losses caused by natural hazards by 2030. The United Nations Office for Disaster Risk Reduction (UNISDR) has hence proposed a methodology for estimating direct economic losses per event and country, based on experiences from developing countries. Since its usability in industrialized countries is unknown, this study presents the first implementation and validation of this approach in Germany. The methodology was tested for the three costliest natural hazard types in Germany, i.e. floods, wind and hail storms, considering 12 case studies between 1984 and 2016. Although the event-specific input data requirements are restricted to the number of damaged or destroyed units per sector, incomplete event documentations did not allow a full validation of all sectors necessary to describe the total direct economic loss. New modules (cars, forestry, paved roads, housing contents and overall costs of urban infrastructure) were developed to better adapt this methodology to German conditions. Whereas the original UNISDR methodology both over- and underestimates the losses of the tested events by a wide margin, the adapted methodology is able to calculate losses accounting well for all event types except for flash floods. Hence, this approach serves as a good starting point for macro-scale loss estimations. By implementing this approach into damage and event documentation and reporting standards, a consistent monitoring of the SFDRR could be achieved.

1. Introduction

Globally, economic losses caused by natural hazards have been reaching an average of US$ 250 billion to US$ 300 billion each year and are estimated to exceed US$ 300 billion per year in the future [51]. Between 1995 and 2015, 71% of all economic losses were caused by weather extremes [9]. By signing the Sendai Framework for Disaster Risk Reduction 2015–2030 (short: SFDRR or Sendai Framework), all member states of the United Nations agreed on a new framework aimed at reducing the impacts of such hazardous events within the next 15 years [49]. The Sendai Framework contains seven global targets, of which target C (reducing direct disaster economic loss in relation to global gross domestic product (GDP) by 2030) is the most important for the development of indicators to monitor progress and achievements in reducing economic losses caused by natural hazards. Although all countries agree on reporting losses, most are currently not able to quantify and thus report losses on the national or even local scale in a consistent and comprehensive manner. Since there is no agreed-upon methodology for quantifying (economic) losses consistently in space and time, any progress in monitoring improvements in disaster risk reduction as required by the Sendai Framework is hindered.

Therefore, the Open-ended Intergovernmental Expert Working Group on Indicators and Terminology Related to Disaster Risk Reduction (OEIWG) discussed a methodology for estimating direct economic losses from hazardous events in order to measure achievements towards target C of the Sendai Framework. Hence, the United Nations Office for Disaster Risk Reduction (UNISDR) recently proposed a methodology based on the work published in the Global Assessment Report on Disaster Risk Reduction 2015 [50,51] which is a simplified and adapted version of the ECLAC methodology (The United Nations Economic Commission for Latin America and the Caribbean) [48], for estimating direct economic losses from hazardous events [50,52,53]. The basic idea of the UNISDR method is that first the physical damage is documented, which is followed by a standardized procedure to derive rough, but reasonable and consistent estimates of financial losses. In this way, the approach differs substantially from other proposals for consistent damage reporting that focus on human indicators and direct economic damage, while neglecting physical damage [24,8]. Although

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the methodology has been tested with datasets from 82 countries [50], it is unclear whether this simplified approach is applicable to industrialized countries. Therefore, this study tests the approach for assessing costs of natural hazards in Germany and validates the existing method for an industrialized country for the first time.

Accounting for all the impacts and costs of natural hazards is complicated for many reasons [12]. While direct damage to buildings and assets can be monetized easily because such goods are traded on the market [29], indirect economic costs of damaging events, e.g., along production chains, are difficult to measure and can often only be assessed by models [21,30]. Moreover, many losses caused by natural hazards are intangible and thus difficult to monetize or even count. This includes health effects, for example, but also damage to cultural heritage or the environment [30]. Furthermore, damaging events might have both direct and indirect benefits, for example donations, relief funds or other (financial) support provided to affected regions, which should be crosschecked with the costs [12]. Finally, losses might differ and depend on the spatial and temporal scales of the assessment, for example the property (asset), local, regional, national or international scales as defined by [10], as well as on the overall context of the analysis. For example, direct costs are commonly estimated on the basis of repair work and other replacement costs. For cost-benefit analyses, however, such costs have to be reduced due to the improvement that the damaged structures underwent during reconstruction, while taxes have to be excluded [29]. The true costs of natural hazards are hence difficult to determine, not to mention further potential biases that might occur during loss data collection, such as hazard, temporal or geographic biases [14].

Due to this complexity, there is currently a clear focus on accounting for the primary effects of damaging events by using economic and/or human indicators [24,8]. While human indicators such as the number of people killed, injured or evacuated can be determined fairly reliably shortly after the event, a reliable estimate of the direct costs of an event can often only be made after several years when all repair work and compensation payments have been completed. Therefore, the proposal by UNISDR to use reported physical damage as a basis for consistent cost estimations is appealing since it overcomes some of the difficulties mentioned above.

In many European countries, including Germany, collection of damage and loss data is weak, and approaches differ considerably between countries [11]. Therefore, the European Commission established a working group on disaster loss data at its Joint Research Center with the goal to propose a consistent methodology that allows data sharing across Europe and supports international efforts such as SFDRR [8]. While some countries increased their efforts in data collection when implementing the European Floods Directive (2007/60/EC), loss data in Germany are still scarce and heterogeneous (as illustrated by [45], for the flood of 2013), although Germany has suffered heavily from damaging events in recent decades [15–19]. Since 2002, Germany has applied five times for financial help at the European Solidarity Fund (i.e. for the floods in 2002, 2010, 2013 and 2016 and after a storm in 2007), receiving more than € 1 billion for the 2002, 2013 and 2016 (regional) floods and the storm "Kyrill". An analysis of the EM-DAT loss database reveals that losses caused by wind storms, river and flash floods as well as hail storms (for some regions in Germany) occur regularly [25]. Insurance claims gathered by the Association of German Insurers (GDV) also underline the relevance of natural hazards in Germany, calling for a more consistent approach to loss recording. Therefore, representative natural hazards such as wind and hail storms as well as floods (flash floods and river floods) were considered in this paper for the validation of the proposed monitoring approach. The chosen hazards are of significant importance regarding their magnitude and resulting economic losses. Since most events occur on a regional scale, not only the national, but also the state scale is considered.

Since the UNISDR method was developed according to standards from developing countries, the application implies an adaptation to German conditions and further development. The question can finally be answered: (how) can the UNISDR method be applied to estimate reasonable direct economic losses from natural hazards in Germany?

2. Material and methods

The UNISDR method [50,52,53] follows the basic idea that primarily physical damage should be recorded. The conversion of physically damaged or destroyed units into economic losses is then achieved by assuming average unit sizes, unit replacement costs and typical damage ratios. By this, the consistency of estimating economic losses is assumed to be improved. Very recently, a new edition of the method [53] was published, replacing the draft version from 2017 [52], mainly with extensions considering the agriculture, public and urban infrastructure sectors. We carried out our study on the basis of the 2015 approach and discuss our suggestions regarding the extensions from the 2018 final version.

The approach [50] considers the total economic loss as the sum of direct economic losses in the sectors of agriculture (C2), industry (C3), commerce (C4), housing (damaged, C5 and destroyed, C6), and public infrastructure (C7–as the sum of health (D2), education facilities (D3) and roads (D4)).

$$\textit{\textbf{direct economic loss C1}} = \textbf{\textit{C2}} + \textbf{\textit{C3}} + \textbf{\textit{C4}} + \textbf{\textit{C5}} + \textbf{\textit{C6}} + \textbf{\textit{C7}} \tag{1}$$

with $C7 = D2 + D3 + D4$

In a minimum version,[1] the loss of each sector C3, C4, C5, C6, D2, D3 is calculated according to

$$\textit{\textbf{direct loss}} = \textbf{\textit{N}} \cdot \textbf{\textit{s}} \cdot \textbf{\textit{c}} \cdot \textbf{\textit{d}} \tag{2}$$

With

- Average size of the units (s) in m^2,
- Reconstruction costs in EUR per m^2 (c)
- Average damage ratio (d), for C6: d = 1

as well as the event-specific variable number of damaged or destroyed units (N), which is the only variable necessary from the event documentation.

In the sectors industry (C3), commerce (C4) and housing (C5), as well as health (D2) and educational facilities (D3), the number N refers to the number of damaged buildings or premises (or destroyed residential buildings in C6). However, for the agriculture sector (C2), the damaged agriculturally used area in ha, the average yield per ha and the price per ton yield are considered. Additionally, the number of four-legged livestock is considered by their average weight and average yielded price per weight unit.

With regard to roads (D4) [50], proposed distinguishing paved and unpaved roads. This definition was adapted to road categories and costs relevant in Germany. Details are described in Section 3.1.

To ensure a consistent estimation, it should be noted that the reconstruction costs c are changing in time and hence have to be scaled to a common reference year or to the year of the event – depending on the use of the loss estimates. Commonly, price indices are used for this purpose. Finally, the damage ratio might change not only per sector, but also per hazard type and intensity. Therefore, we firstly tested the recommended defaults according to [50] and later adapted and refined the model to German conditions by using additional data sources and expert knowledge and by accounting for sector- and hazard-specific characteristics.

The UNISDR method was implemented in Excel. For automatization of data processing, a VBA code was developed. A module-based calculation for each sector was implemented, allowing the user to integrate new modules or sectors easily [33].

[1] The minimum version implies one average size per sector only; in extended versions, the average size of structure per sector can be differentiated into several types.