A district level climate change vulnerability index for flood risks – concept, implementation and results for the city of Kiel

by

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Abstract

As adaptation actions by cities and communities in the face of climate change are becoming increasingly important, innovative and practical approaches for early identification and estimation of vulnerabilities on the local scale are crucial. Because this information only enables decision makers to prioritize future adaptation actions, to initiate additional detailed investigations if necessary, and to directly develop and implement specific adaptation measures. For cities, the exposure to flooding is high because of their spatial concentration of assets, people and economic activities. In the context of the current study, we therefore focus on the effects of climate change in regard to flooding, whereby a vulnerability index has been developed and applied that conceptually comprised of exposure, sensitivity (ability to evacuate and financial losses) and coping capacity. This index has been tested in fifteen municipal districts in the state capital of Kiel in northernmost Germany regarding their vulnerability against selected flood events. The used approach differs from previous vulnerability assessments carried out at the city and/or municipal district levels mainly due to the exclusive use of public and freely available data as well as the use of a ratio calculation for the relative comparison. As a result, our study provides detailed insights into climate change related risks, in order to identify the most vulnerable districts in a city, and highlights the reasons for their vulnerability.

Keywords: adaptation, cities, city planning, climate change, climate change impacts, coping capacity, exposure, flooding, heavy rain events, sensitivity, vulnerability.

JEL-Classification: H4, H11, H12, H41, Q51 Q54, Q58, R11, R50.

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1. Introduction

Impacts of climate change already affect regions, municipalities and cities worldwide, whereby future impacts are expected to increase (e.g. IPCC 2014; Revi et al. 2014; EEA 2012; IPCC 2007). Observational data for Germany for the period between 1881 to 2014 shows, for example, an increase in air temperature of approximately 1.3°C based on annual means (Kaspar and Mächel 2017). The greatest temperature changes (+1.5°C) occurred in the western German lowlands, the mountain chains west of the Rhine river and the lowlands in the upstream part of the Rhine during this period. On the other hand, the lowest temperature increase (Deutscher Wetterdienst 2016) is shown for the northeastern lowlands at + 0.9°C. The number of hot days – defined as days when the temperature reached 30°C at least once – also increased in Germany on average from three days a year to nine days a year. A shift in maximum temperatures toward more extremes can already be observed in Germany today (Deutschländer and Mächel 2017). At the same time, cold extremes became rarer and nine of the ten warmest years since 1881 occurred during the period from 1989 onwards – five of them since 2000 (Deutscher Wetterdienst 2016). In terms of annual precipitation, an average increase of approximately 10.2 % between 1881 and 2014 can be seen in Germany, compared to a long-term average from 1961-1990 (Kaspar and Mächel 2017). Regarding – in general spatially and temporally very differentiated – heavy precipitation events, for example, an increase in heavy winter precipitation can be observed mainly in the northwest and the southeast parts of Germany (Kunz et al. 2017).

Regional climate models predict additional changes for Germany in the future. Simulations from the regional climate model ensemble EURO-CORDEX[3] show a possible temperature increase between +1.2°C and +3.2°C by the end of the 21st century for the RCP[4] 4.5 scenario and between +3.2°C and +4.6°C for the RCP 8.5 scenario. However, due to the high temporal and spatial variability, no general statements can be made for precipitation. While the ensemble rather assumes an increase in precipitation sums for the winter, possible increases as well as decreases are seen in the summer months. Thereby it furthermore has to be considered, that also the precipitation patterns (intensities, distributions throughout the day) are changing (Jacob et al. 2017).

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[3] http://www.euro-cordex.net/.
[4] Representative Concentration Pathways (RCPs) are four greenhouse gas concentration trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014.

In addition to mitigation efforts, adaptation to climate impacts becomes increasingly important (GERICS/KfW 2015; IPCC 2014), whereby climate change does not only lead to new challenges but also opens up opportunities for businesses in different economic sectors as well as cities (Groth and Nuzum 2016; Groth et al. 2015; REGKLAM-Konsortium 2013; Hoffmann et al. 2011). With respect to adaptation in cities it has to be taken into account that possible measures can vary from place to place due to the geographical location, city structure, responsible institutions, number of inhabitants and the state of economic development. Therefore, successful adaptation measures have to be designed individually and specifically (Bender et al. 2017; Cortekar et al. 2016). To create and implement adaptation measures in cities, however, an awareness of potential weaknesses and/or identification and initial assessment of vulnerabilities is required (Birkmann 2013; Queste and Lauwe 2006).

The context of the current study focuses on the effects of climate change in regard to flooding, coastal flooding and urban flooding, whereby associated risks are usually defined as an interaction of the following influences: i) hazard (the probability of an event occurring), ii) exposure (extent of the impact on population and economic assets), and iii) sensitivity (society's ability to deal with the event) (e.g. Rose and Wilke 2015; Koks 2015; Oppenheimer et al. 2014; IPCC 2012; Kron 2005). While the understanding of hazards and exposure has improved in literature in recent years, specific knowledge concerning sensitivity is often regarded as one of the greatest challenges, e.g. in estimating flood risks (e.g. Koks et al. 2015; Mechler et al. 2014; Mechler and Bouwer 2014; Visser et al. 2014). In most studies the implementation of suitable management strategies, physical sensitivity of structures and goods as an indicator are taken into account (e.g. Koks et al. 2015; Filatova 2014; Jongman et al. 2014), but the sensitivity of the population is often missing. However, household adaptability is also of great importance for assessing vulnerability and the implementation of policy measures (Koks et al. 2015).

Vulnerability analyses at the urban and municipal district level are not new. The existing methods, however, are usually complex and were partially carried out based on comprehensive and expensive household surveys (e.g. Oppenheimer et al. 2014; Birkmann 2013; Bollin and Hidajat 2006). In order to develop and test a less time-consuming and more cost-effective approach, the method chosen here is based on data from official statistics and freely available data.

The development of a vulnerability index for the city of Kiel is based on earlier work, such as the vulnerability assessment by Koks et al. (2015) for the city of Rotterdam as well as the development of an index for the city of Hamburg (Rose and Wilke 2015). Focusing on flood events, the exposure, vulnerability and coping capacity of inhabitants and businesses in fifteen municipal districts will be examined based on two flood types: storm surges and urban flooding after heavy rain events. The aim is to identify the respective relative vulnerability for the districts and thus to methodologically enhance existing approaches in order to address municipal decision makers and to lay the bases for subsequent adaptation measures to climate impacts. This supports both the development and provision of climate services (see also European Commission 2015) as well as a successful long-term adaptation to the impacts of climate change.

The paper is structured as follows: The methodical approach and the data used are described in chapter 2. The structure of the vulnerability index as well as partial core results on exposure, sensitivity and coping capacity for the municipal districts in Kiel are summarized and explained in chapter 3. The study concludes in chapter 4 with a comprehensive summary in which also the limitations of the approach as well as additional need for research are outlined.

2. Methodological approach and fundamental data

Our approach is applied to the city of Kiel. The capital city of the northernmost German state of Schleswig-Holstein has a population of about 240.000 inhabitants, and is located 90 kilometers north of Hamburg. Due to its location around the Kieler Förde – an approximately 17 km long inlet of the Baltic Sea, connecting the harbor of Kiel to the Baltic see – the city is a potentially hazardous area for flooding. Due to specificities regarding geographical location, structure, inhabitants and operational capability it is to be expected, that the vulnerability with respect to floods will substantially differ in the districts.

Numerous definitions and concepts are applied to the term “vulnerability” in literature.[5] Within the context of the current study, the definition outlined by the IPCC (2007) was used. According to this approach the following aspects were considered for the assessment: i) exposure, ii) sensitivity and iii) coping capacity.

For the present case in Kiel, a coastal flood level of 3.5 m above mean sea level is considered as external influence in order to examine how and to what extent people and goods are exposed. This scenario corresponds to the highest water level within the city of Kiel’s flood risk map (Landeshauptstadt Kiel 2017). The highest flood level in the Baltic Sea region – 3.43 m above mean sea level – was measured in the year 1872 in Travemünde (Ministerium für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein 2008).

Regarding sensitivity, the capacity for population evacuation as well as financial damage potentially caused by the event in question are analyzed, while possible financial damage is taken into consideration both for the general population and for businesses in the context of our study.

Finally, coping capacity is examined to discern what resources are available to reduce the consequences of the event. State transfer payments are used here, such as benefits within the German social system depending on financial needs (Social Code II (SGB II), housing benefits as well as old-age provision).

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[5] Thywissen (2006) lists thirty definitions. A comprehensive synthesis of previous studies, concepts and definitions in regard to risks and vulnerabilities can be found in Oppenheimer et al. (2014).

In principle, a large set of indicators[6] is fundamentally suitable to capture the content of the vulnerability assessment levels. But, suitable indicators differ with respect to the observation scale – global, regional or local. Overall, differentiated indicators must be used, which are constructive and meaningful to answer the respective question (Queste and Lauwe 2006).

In addition to these fundamental conceptual aspects of the vulnerability analysis, our approach is partly based on a study conducted by Rose and Wilke (2015) for the city of Hamburg. The requirement that only freely available data was used as indicators was primarily adopted and further developed. Based on seven districts, Rose and Wilke (2015) initially rank them for each indicator. Several indicators are summarized in the three areas – exposure, vulnerability and coping capacity – by calculating averages that in turn enter equally into the vulnerability index. Thus a ranking is provided (e.g. "Harburg" at number 1, "Eimsbüttel" at number 7 or "Wandsbek" at number 4). Inaccurate representation can, however, result because the actual differences between the city districts cannot be represented.

In order to overcome this deficit, methodological development has been carried out in the context of the present study by applying a ratio calculation. In this case, also the highest value of an indicator in the respective city districts is the starting point. However, the following values are set in relation to these highest values as a percentage. In the context of the index, high values above average are therefore regarded as negative. For example, a large number of workplaces in the manufacturing sector or a high number of motor vehicles must be viewed as critical because the potential for economic losses is high. Indicators whose high values are basically considered positive – for example, a large proportion of recreational areas means less paved surface – are converted accordingly so that in these cases a negative assessment is expressed with high values as well.

In each case, the highest value of all municipal districts corresponds to 100% and is automatically assigned the value of 10. The values of other districts always refer to this highest value. This allows for a more precise evaluation as a whole. Furthermore, especially individual values that

[6] According to Birkmann (2006, 57) an indicator is: "a variable which is an operational representation of a characteristic or quality of a system able to provide information regarding the susceptibility of a system to an impact of an albeit ill-defined event linked with a hazard or natural origin."

are particularly high or low above or below average, and deviations can be more precisely represented compared to using a simple ranking.

The basic data utilized in the study were taken from the following statistical reports published by the city of Kiel’s Office for the Economy:[7]

- Social and Structural Data 2013 from Municipal Districts of Kiel (Landeshauptstadt Kiel 2014)
- Population in the Municipal Districts of Kiel 2014 (Landeshauptstadt Kiel, 2015a)
- Quarterly Figures from the Municipal Districts of Kiel III / 2015 (Landeshauptstadt Kiel 2015b)
- Quarterly Figures from the Municipal Districts of Kiel IV / 2015 (Landeshauptstadt Kiel 2016)

In addition, data from the Statistics Yearbook 2015 (Statistisches Bundesamt 2015) was used as well as the interactive Flood Protection Map for the city of Kiel (2017) and the Riverine Flood Map for the state of Schleswig-Holstein (2014).

The following fifteen flood-prone municipal districts in Kiel were taken into consideration in the study:

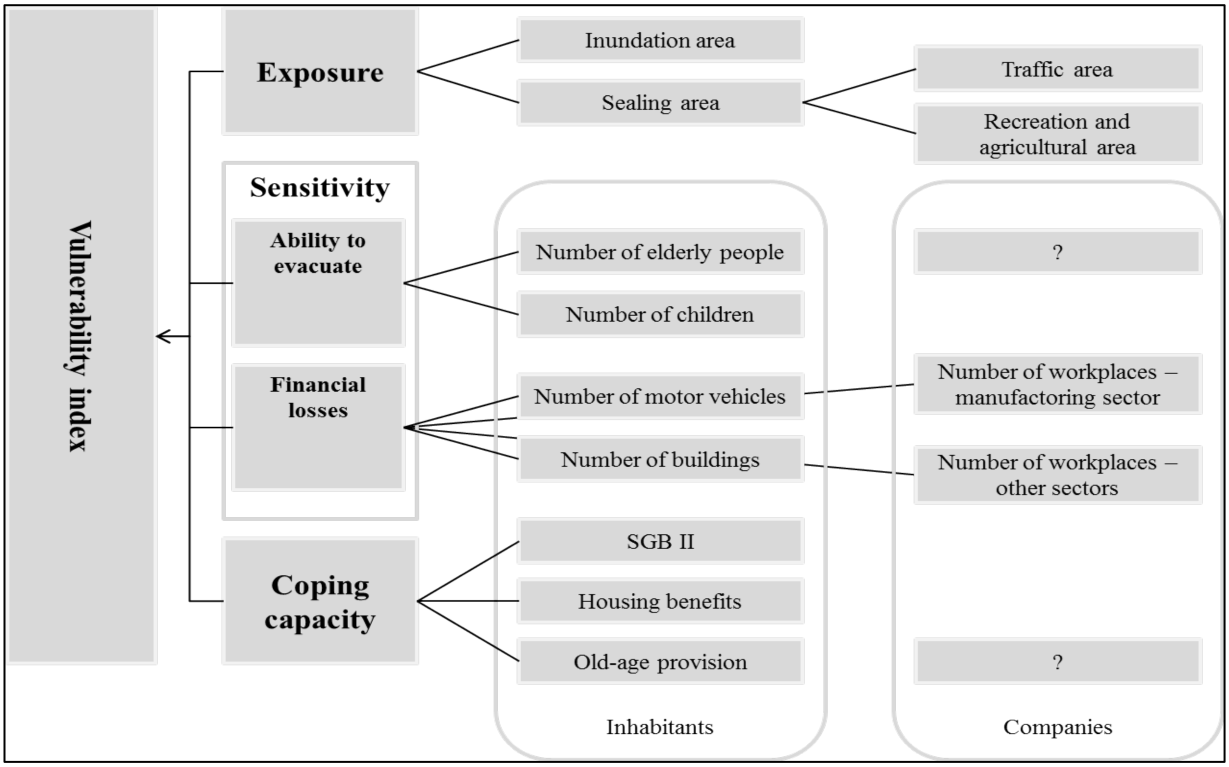
Altstadt	Damperhof	Düsternbrock	Ellerbek	Friedrichsort
Gaarden-Ost	Holtenau	Neumühlen/ Dietrichsdorf	Pries	Schilksee
Südfriedhof	Suchsdorf	Vorstadt	Wellingdorf	Wik

7 All reports and data used in this study are in German.

3. Vulnerability Index

The structure of the vulnerability index is illustrated in figure 1, with the components described below.

Figure 1: Structure of the vulnerability index

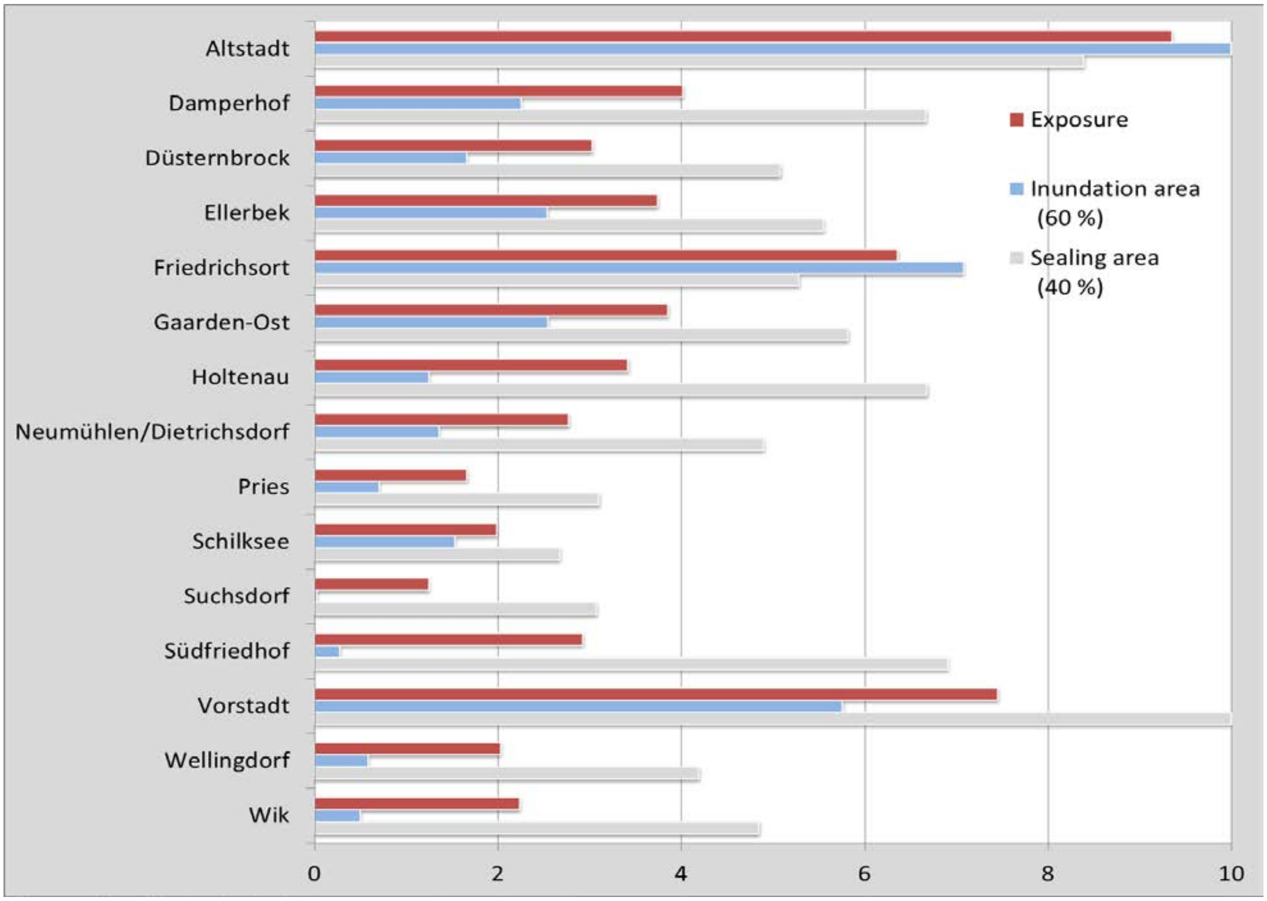


3.1 Exposure

In terms of exposure, the extent to which the districts are affected by a flood event is examined. Based on the available data and according to Birkmann et al. (2013) as well as Rose and Wilke (2015), the relative portion of flooded area in relation to the district area is used as an indicator. An interactive flood map and its measurement tool are used to determine the respective flooded area at 3.5 m above mean sea level. As figure 2 shows, "Altstadt" is by far the most severely affected district in regard to flooding from storm surges, followed by the districts "Vorstadt" and "Friedrichsort". The districts "Südfriedhof", "Wik" and "Wellingdorf" are the least affected here.

River floods are not taken into consideration because relevant areas are not expected to be flooded at HQ200 – this means with a probability of once in 200 years (Schleswig-Holstein Riverine Flood Map 2014).

Figure 2: Exposure



Flooding can also happen after heavy rain events. Unfortunately, there is no corresponding data available for the city of Kiel on the district level. With respect to urban flooding, however, the degree of soil sealing is of great relevance because this is the limiting factor for rainwater infiltration (UBA 2011). Therefore, the degree of surface sealing is used here as an indirect indicator. For this purpose, the transport, recreation and agricultural areas are taken into account (Landeshauptstadt Kiel 2014: 28)[8] and their fraction of the total district area is determined.[9] The evaluation of the results show the highest degree of sealing at the districts "Vorstadt" and "Altstadt" this means the highest exposure, while sealing in the districts "Suchsdorf", "Pries" and "Schilksee" is relatively low (figure 2).

[8] Buildings and open spaces were not included in the calculation, as they are not listed in detail in the sources available.

[9] In determining the base area of the district area, the respective water surface was subtracted.

Due to its slightly lower relevance for the city of Kiel as well as the more difficult and unsecure estimation of the relevant share of surface sealing, it is taken into consideration within the entire exposure index as an indicator at 40 %, while the storm flood exposure contributes at 60 %.

In summary, the results in figure 2 show that “Altstadt” and “Vorstadt” districts have the highest relative exposure regarding storm flood events due to the high area potentially at risk during flooding (the highest level 10 for “Altstadt”) as well as due to high sealing (the highest level 10 for “Vorstadt”). The overall exposure index for both districts however does not reach 10, because it is detremined by the mean values of the indundance area as well as the sealing area. Districts with the relatively lowest level of exposure are “Suchsdorf”, “Pries”, “Schilksee”, “Wellingsdorf” and “Wik”. In “Wik”, “Südfriedhof” and “Pries”, this is mainly caused by low soil sealing.

3.2 Sensitivity

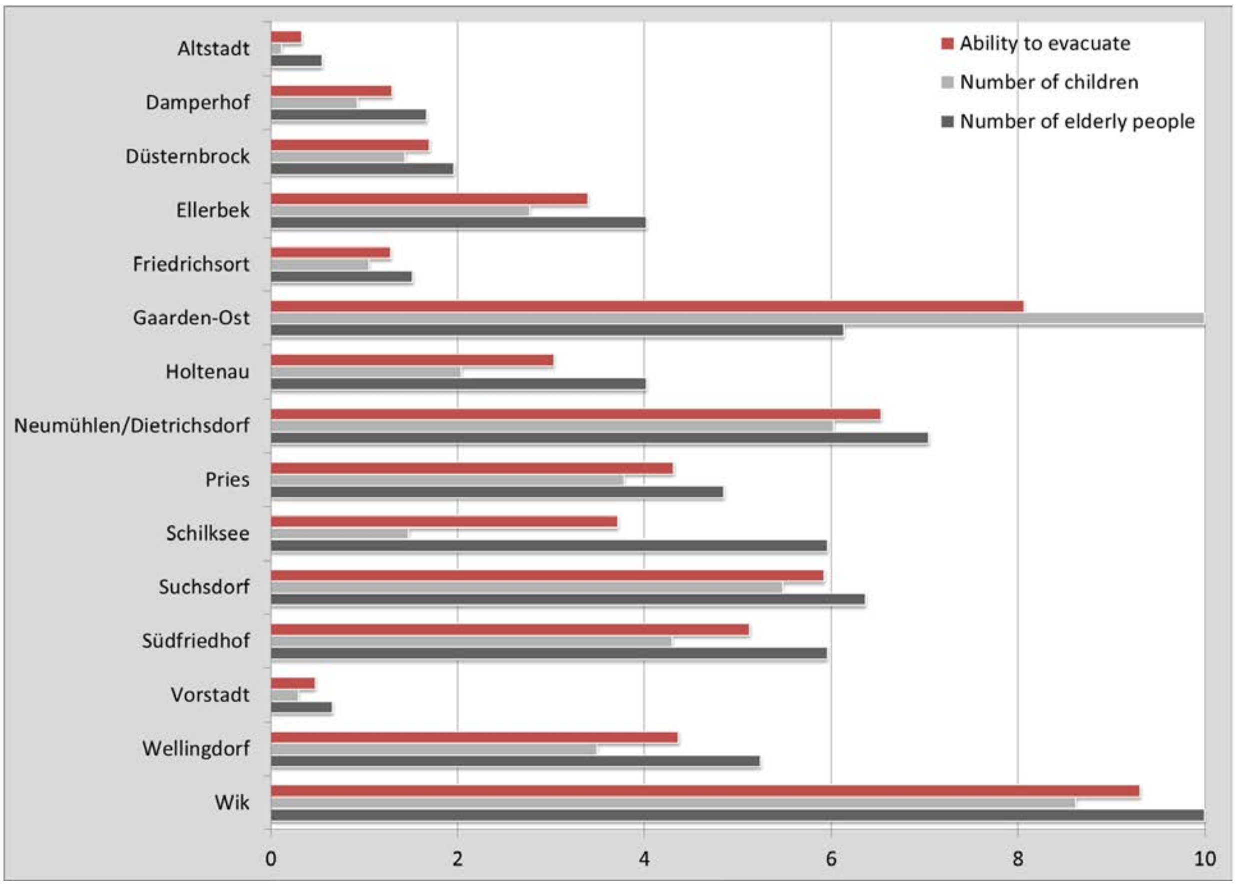
For analyzing sensitivity, an approach is chosen which is based on the concept from Rose and Wilke (2015) where capacity to evacuate and economic losses (affecting the general population and businesses) are incorporated separately into the vulnerability index. Furthermore, social sensitivity (the ability to evacuate) and economic sensitivity (the potential for economic losses to businesses) are combined equally to a sensitivity index that is incorporated into the overall vulnerability index. Financial losses affecting the inhabitants are integrated into the exposure as an indirect impact factor for the vulnerability. Compared to this approach the method chosen here assigns a higher weighting to the capacity to evacuate – and according to Birkmann et al. (2011) – the protection of the general population.

3.2.1 Sensitivity – ability to evacuate

The health risks caused by urban flooding are particularly high for elderly people, disabled and children. This is accompanied by the capacity to evacuate, which is crucial in regard to protecting the population as well as in the context of demographic development (Birkmann et al. 2013; Birkmann et al. 2011; Hajat et al. 2005). Based on data pertaining to elderly people as well as families with children, an evacuation capability indicator is developed that addresses the sensitivity of potential affected persons and in turn provides information on possible needs during rescue work.

Using the city of Kiel as an example, the absolute number of people of sixty-five years or older as well as the absolute number of children younger than ten were determined for each district (Landeshauptstadt Kiel 2015a). The use of a relative number – for example, the number of elderly people in relation to the urban population – would not have any significance in regard to estimating the potential future need for aid workers. If, for example, the ratios in the districts of “Vorstadt” and “Pries” would be equally high, it could not be inferred that the number of elderly people – and thus the potential need for aid workers – is much higher in “Pries” than in “Vorstadt”.

Figure 3: Sensitivity – ability to evacuate



In order to provide a comprehensive assessment of the evacuation capacity, the mean value was formed from the two values (figure 3). Overall, the sensitivity of “Wik” and “Gaarden-Ost”, due to a relatively low level of evacuation capacity, is highest – due to the high number of elderly people and children. On the other hand, the ability to evacuate, especially in the districts “Altstadt” and “Vorstadt”, is high.

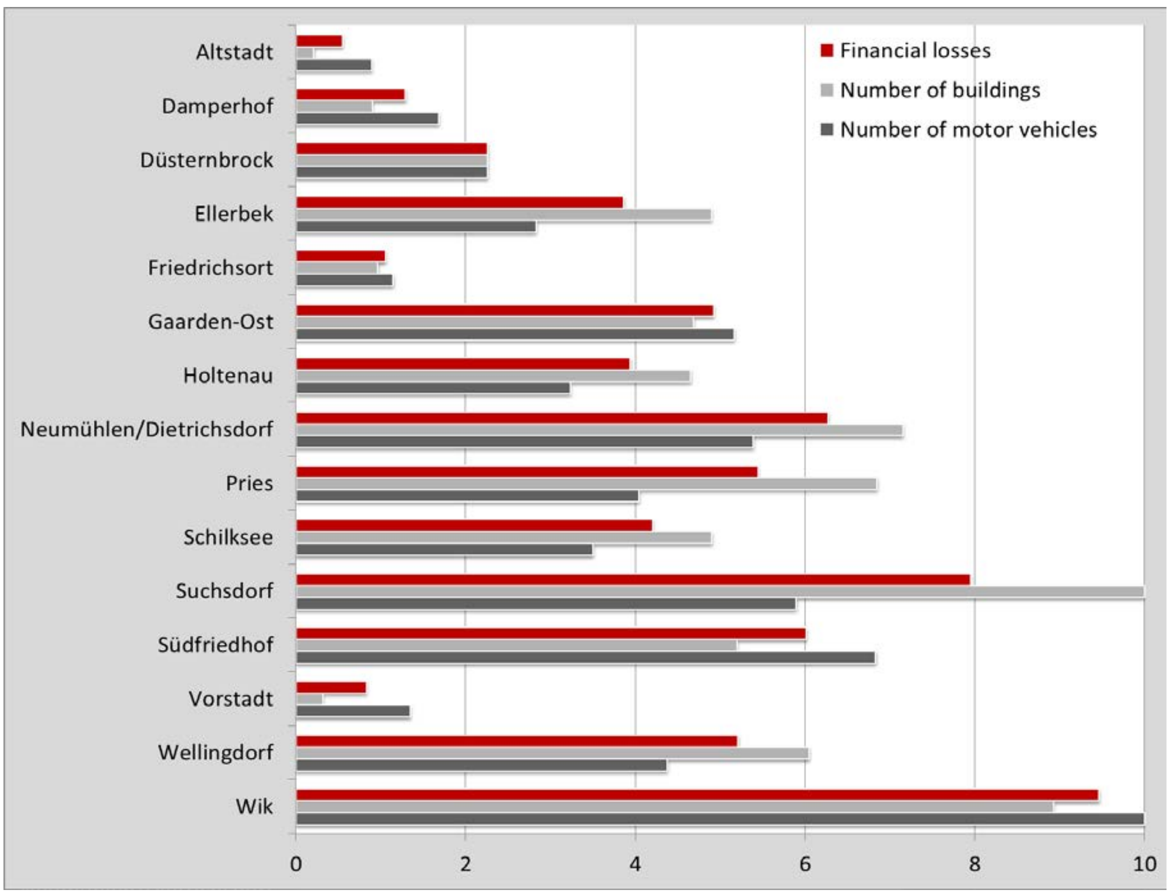
3.2.2 Sensitivity – financial losses

In addition to the ability to evacuate, the potential financial losses are also directly included in the vulnerability index. The value is composed of the mean value of the indices for financial losses of inhabitants and of businesses.

Financial losses for inhabitants

Financial damage to the general population is measured according to Rose and Wilke (2015) based on registered motor vehicles as well as the number of existing residential buildings (Landeshauptstadt Kiel 2014). However, the possible financial losses affecting the general population is taken into account as a separate value in the total index and thus has an indirect effect on the overall result.

Figure 4: Sensitivity – financial losses for inhabitants

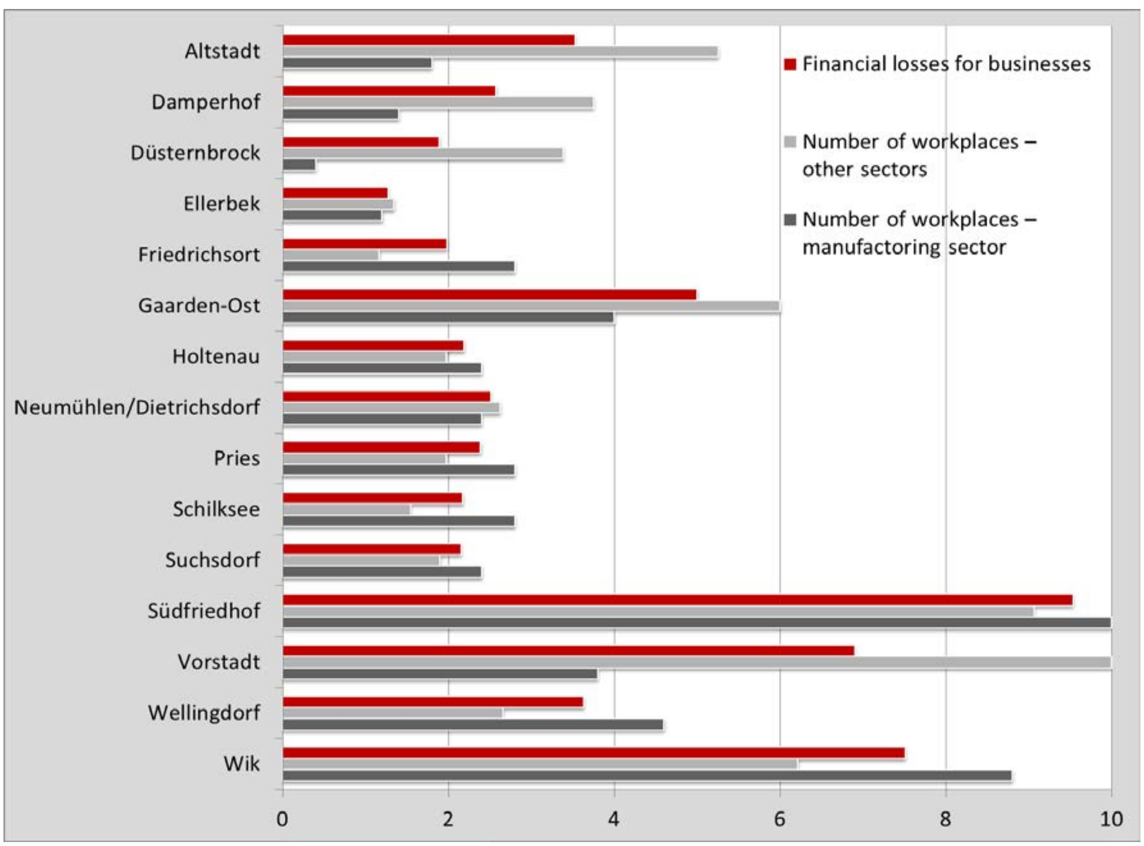


The highest number of motor vehicles is registered in the district “Wik”, while “Suchsdorf” has the highest number of existing residences. Thus, both districts form the starting points for the ratio calculations. Overall, the highest financial losses for inhabitants are expected in the districts "Wik", "Suchsdorf" and "Neumühlen/Dietrichsdorf". The least damage potentials are in the districts "Altstadt", "Vorstadt", "Friedrichsort" and "Damperhof" (figure 4).

Financial losses for businesses

The number of workplaces according to economic sectors is used in order to incorporate financial losses for businesses (Landeshauptstadt Kiel 2014). The fixed assets and thus the potential damage may vary depending on the sector. Based on gross investments in tangible assets in 2013 (Statistisches Bandesamt 2015), potential financial losses are estimated by economic sectors. The manufacturing sector accounted for approximately half of the total investment and thus was the sector with the highest investment. Therefore, the associated number of workplaces has a 50 % impact on the interim result, while the workplaces in other sectors also contribute 50 %. As a result, the financial losses to be expected are highest for companies in the districts "Südfriedhof", "Vorstadt" and "Wik", and lowest in the districts "Ellerbek", "Friedrichsort" and "Schilksee" (figure 5).

Figure 5: Sensitivity – financial losses for businesses



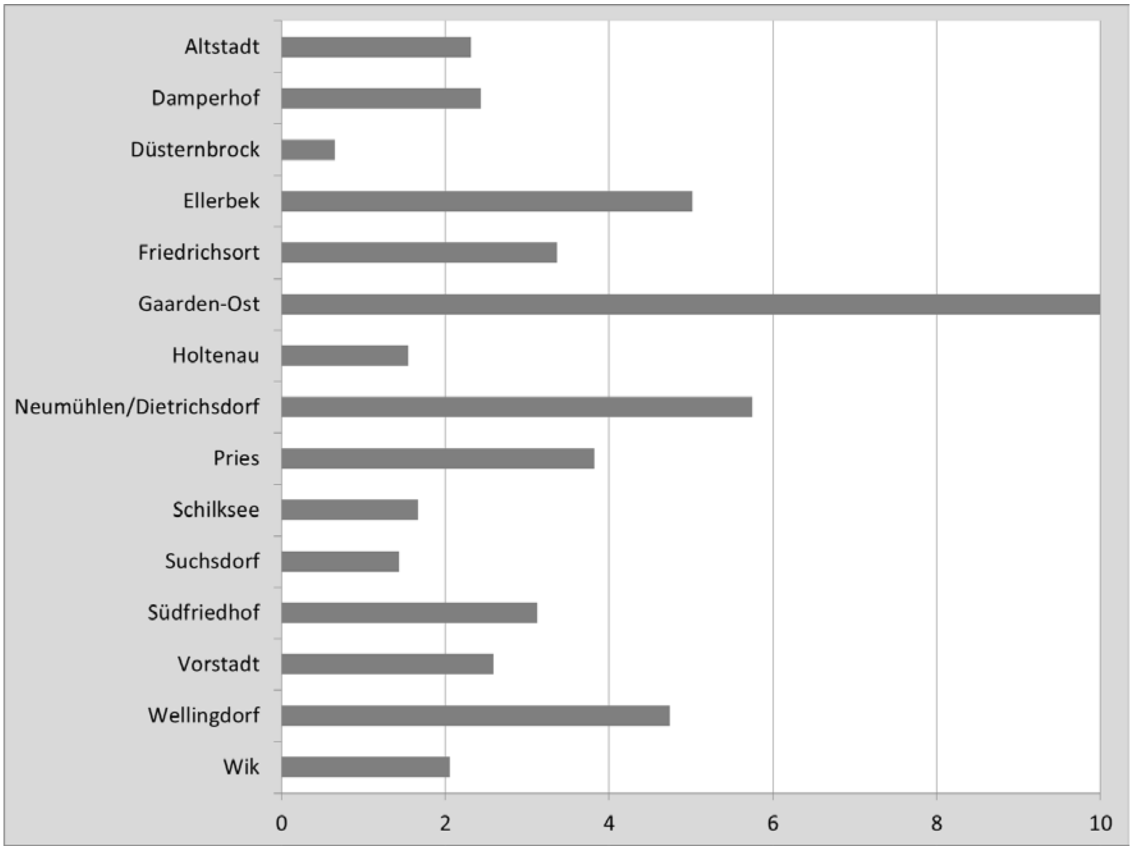
3.3 Coping capacity

The coping capacity is taken into account as the third component of the vulnerability analysis. It can be utilized to determine possible means of dealing with the consequences of flood events. It is assumed that more financial resources will be available in connection with higher coping capacity.[10] Due to limited data availability, the financial possibilities are included in the analysis indirectly through incorporating social welfare data. Payments of (i) housing benefits, (ii) benefits under the Social Code II (SGB II), and (iii) old-age provision are used as indicators (Landeshauptstadt Kiel 2016; 2015b; 2014).

While housing benefits are also paid to home owners depending on the rent index, benefits under SGB II are the last resort in the social security system. The third group of payments (benefits for pensions and/or disability is exclusively for individuals incapable of working or individuals of retirement age. This last category is summarized here as old-age provision. According to social legislation, all three benefit groups are granted with regard to income and wealth assessments and cannot be drawn simultaneously so that they address different entitlement groups. The statistical data for the city of Kiel are set in relation to the district population for the respective absolute numbers of the social benefits claims, whereby the values of the three independently-drawn benefit groups are added. Altogether, almost 50 % of the population in the district “Gaarden-Ost” and approximately 6.5 % in the district “Düsternbrock” receive one of the three benefits. The coping capacity is derived from these numbers, which is lowest in the districts of “Gaarden-Ost”, “Neumühlen/Dietrichsdorf”, “Ellerbek” and “Wellingdorf”. On the other hand, the coping capacity is highest in the districts “Düsternbrook”, “Suchsdorf”, “Holtenau” and “Schilksee” (figure 6).

[10] Birkmann et al. (2011) determine the coping capacity, for example, based on potential insurance protection as well as on previous experience with flood events. However, there were no corresponding data available for this study.

Figure 6: Coping capacity



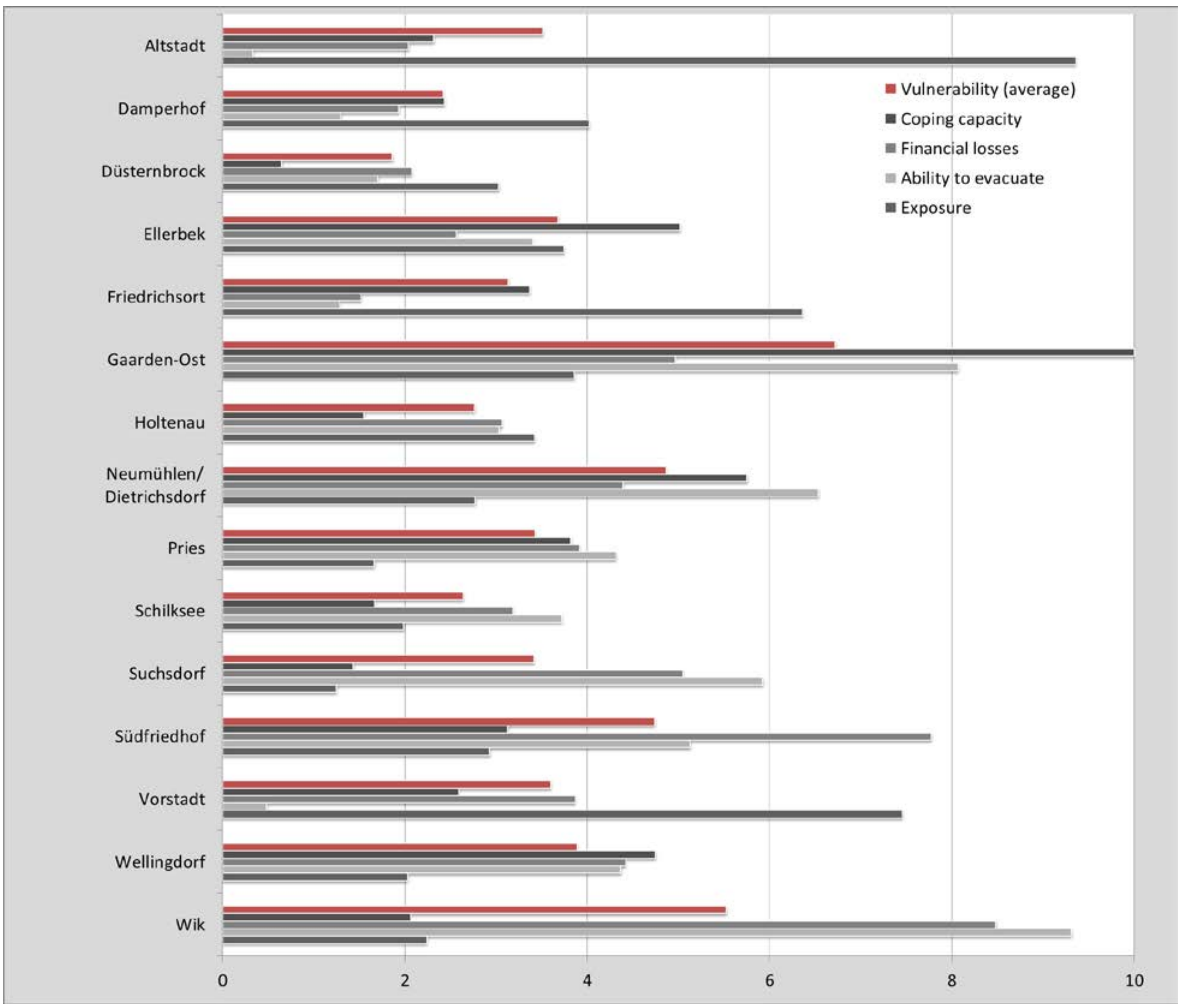
A comparison of the summarized index for coping capacity with the single indices of the basic data leads to the result that the benefits according to SGB II are strongly in line with the total coping capacity. This result is important for future assessment of coping capacity as part of a possible reapplication of the approach insofar as it is to be expected that the statistics for the benefit receipt under the SGB II will be more readily available. Thus, for simplification, they could very likely be used as the only data basis.

Data that allows conclusions to be drawn regarding business coping capacity are not available for this specific approach in the city of Kiel. Therefore this aspect is not considered here.

3.4 Overall result – the vulnerability index

The four sub-indicators for exposure, sensitivity and coping capacity are merged and – weighted equally – form the comprehensive overall vulnerability index, which is shown in figure 7. For example, a high number of workplaces or motor vehicles within a district are assumed to be negative regarding the specific vulnerability, since the potential economic damage – or financial loss – is very high. Indicators where a high number would generally be positive – like a high proportion of recreational area and thus fewer surface sealing areas or a higher amount of financial resources – are converted accordingly. The highest value thus corresponds to 100 % and is automatically assigned the value 10 in the scale. The percentage and scale values of the other districts therefore always refer to the highest value. In other words, a relatively high number in the four indicators as well as the overall vulnerability index shows a relatively high vulnerability for a specific district – a relatively high exposure, a relatively high sensitivity or a relatively low coping capacity – compared to other districts in the city of Kiel.

Figure 7: District level climate change vulnerability regarding flood risks in the city of Kiel



As a result, the differences between the vulnerabilities of individual districts arise notably – as a whole, as well as in regard to the four different partial aspects of the vulnerability analysis (figure 7). Above all, to consider different influencing factors and their relevance for the vulnerability assessment allows an initial analysis of basic relationships. For example, the vulnerabilities of "Vorstadt", "Altstadt" and "Friedrichsort" are relatively low, despite their relatively high exposure. The districts "Gaarden-Ost", "Wik", "Neumühlen/Dietrichsdorf" and "Südfriedhof" are particularly vulnerable, while "Düsternbrock" shows the lowest vulnerability. The district "Gaarden-Ost", for example, is characterized on the one hand by a relatively low exposure. On the other hand, the vulnerability of this district is highest due to low coping capacity and a limited ability to evacuate. The relatively high vulnerability of the districts "Wik" and "Südfriedhof" in turn is mainly due to high potential financial losses. The lowest ability to evacuation can be seen in "Wik". In the district "Neumühlen/Dietrichsdorf", which is also regarded as relatively vulnerable, negative effects can be expected in all other areas except for a moderate exposure.

4. Conclusion

Urban governments play a key role in climate change adaptation, as it depends on local assessments and the integration of adaptation actions into local investments, policies, and regulatory frameworks. Therefore, a scientific evidence base on local risk and vulnerability assessments, information and data is essential for appropriate work. Our study provides insights into climate change related risks, by the development and application of a district level climate change vulnerability index, which comprises all three main factors of vulnerability. It is an approach to identify the most vulnerable areas in a city, and to highlight the reasons for their vulnerability.

By the development and application of the vulnerability index for the city of Kiel, relevant detailed information is provided on flood risk vulnerability of municipal districts. This especially enables local decision makers to prioritize future adaptation strategies, to initiate further in-depth investigations if necessary, and to directly develop and implement adaptation measures. As a limitation, however, within the context of the analysis carried out, neither the structural substance of buildings nor existing technical flood protection measures could be taken into account.

Regarding the methodological development by using a calculation of ratios, our approach has proven to be both practical and useful. Because climate change impacts for cities and communities are individual with respect to local environmental and other framework conditions, a more comprehensive prototypical development of the approach presented here should be applied to other cities and impacts – for example, to increasing temperature, accelerating heat stress or urban heat islands.

With regard to the use of freely available data, this approach has proven to be effective and practical. Also to be taken into account, however, is that the information base for state capitals such as Kiel or Hamburg in regard to the quantity and quality is very good. However, the free and comprehensive availability of data will likely decrease for smaller cities and municipalities. Additional methods of data collection must therefore be applied for such cases.

Further research is needed, for example, on how flood events caused by rivers can be integrated based on expanding and new data sources. Furthermore, the partial aspect of sealed soils could only be derived indirectly in our study, which leads to restrictions on the indicator validity with regard to exposure. Further analyses are also needed as to what extent the degree of sealing in urban areas can be determined more easily and more precisely, and what data are required for this task. In this case also the morphology/topography as well as the size of catchment areas, the presence of temporary emergency waterways, and the condition of drainage systems, including the clogging level of road gullies and gullies, could also play an important role and should be taken into account. This has also to be considered for possibly extending the approach to other impacts of climate change.

Other important points that should be taken into account are possible changes in the vulnerability assessment caused by future demographic development, changes in social composition and age structures in the districts, which can have a particular effect on the ability to evacuate and the coping capacity as well as on expected financial losses.

In conclusion, supplementary validation by means of practical assessment of the results derived with local decision-makers is necessary in order to examine the significance of the vulnerability assessment for administrative practice. Through the dialogue it will be also possible to determine the possible compatibility and consideration within the framework of existing methods and decision-making processes, also implementing a regular vulnerability assessment and evaluation.

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