

Household-Level Coastal Adaptation and Its Drivers: A Systematic Case Study Review

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Evidence-based information on household-level adaptation is an important element of integrated management of vulnerable coastal regions. A growing number of empirical studies deal with household-level adaptation at the coast in different regions. This article provides a systematic review of these studies. We analyze studies according to how households in different parts of the world are currently adapting, or how they are intending to adapt, and identify explanatory factors for adaptation behavior and intention. We find that households implement a broad range of adaptation measures and that adaptation behavior is explained by individual factors such as socioeconomic and cognitive variables, experience, and perceived responsibilities. Nonpersonal characteristics have also been used to explain adaptation behavior and intention but have not been extensively investigated. Few studies employ qualitative research methods and use inductive approaches as well as models stemming from behavioral economics. Our findings suggest that coastal risk management policies should communicate the efficacy of household-level adaptation, in addition to information about flood risk, in order to encourage coastal households in their adaptation activities. In this context, we discuss the role of resources and responsibility of households for their adaptation behavior. We describe the lessons learnt and formulate a research agenda on household-level adaptation to coastal flood risk. In practice, coastal risk management policies should further promote individually driven adaptation by integrating it in adaptation strategies and processes.

KEY WORDS: Accommodation; climate change; coastal flooding; coasts; household-level adaptation

1. INTRODUCTION

Future coastal population will gradually become increasingly exposed as well as sensitive due to sea-level rise-related flooding and high population growth,^(1,2) compared to inland areas. Without adaptation, coastal residents will be frequently exposed

to flooding. Adaptation in terms of protection would first reduce the amount of people affected by flooding per year and second, decrease monetary costs significantly.⁽³⁾ However, building dikes and other forms of public capital intensive adaptation such as beach nourishment might exceed adaptive capacity in developing countries, for instance in Africa.⁽⁴⁾ Therefore, alternatives to protection, i.e., accommodation, which refers to the modification of existing structures; and retreat, which entails leaving the area under flood risk, can play a significant role in the future. Accommodation involves flood forecasts and warnings, insurance, installation of retention basins, land use changes, and enhancing the adaptive capacity of households in terms of the implementation of behavioral and structural measures.⁽⁵⁾ Furthermore, accommodation measures reduce any residual risk of

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flooding, also when other measures are in place, and thus are important complements to coastal risk management.

This study systematically reviews the existing literature on household-level adaptation to flooding caused by storm surges and tropical cyclones and its drivers. The investigation of adaptation implemented on the level of households is a particularly important exercise for a number of reasons. First, coastal residents are most at risk of flooding, compared to other actors.⁽⁶⁾ Second, many adaptation measures implemented by households can significantly reduce flood risk, particularly structural and building methods.^(7–9) Third, household-level adaptation is equally considered flexible and robust⁽¹⁰⁾ as well as a low-regret risk management strategy,⁽⁶⁾ which does not hinder the implementation of further adaptation pathways such as protection and retreat. Finally, it is often emphasized that the private sector has to undertake more responsibility for adaptation in the future, which is something that could be achievable through household-level adaptation.⁽¹¹⁾ However, there is a gap in knowledge about coastal flood risk adaptation behavior and its drivers and no systematic analysis of these factors has yet been undertaken.

We carry out a systematic review of the literature to fill this knowledge gap and address the following questions:

- (1) What are the predominant measures implemented and intended to be implemented by households to adapt to coastal flooding?
- (2) Which are the factors that drive adaptation behavior and intention to adapt?
- (3) Which models and theories explain flood adaptation behavior and behavioral intentions?

Following these questions, we discuss lessons learnt from the reviewed studies and compare these lessons to those identified in the complementary review of Bubeck *et al.* (2012) on household-level adaptation to river flooding. Finally, we synthesize our findings into an agenda for future research on household-level adaptation to coastal flood risk.

2. MATERIALS AND METHODS

2.1. Text Selection

We focus on household-level adaptation (or preparedness, which is the equivalent term used in

natural hazard research) to the impact of coastal flooding due to storm surges and tropical cyclones and include studies from the fields of natural hazard preparedness, disaster risk reduction, and climate change adaptation. We include studies that examine both long-term preparedness and short-term coping. Empirical studies about household-level adaptation to river flooding are not part of this review. For a review of these studies, see Bubeck *et al.*⁽¹²⁾ and for household-level adaptation to different types of climate change impacts see Malik and Smith.⁽¹³⁾ Furthermore, we focus on coastal flooding and do not consider other impacts of sea-level rise such as coastal erosion, saltwater intrusion, or wetland loss. Households are generally less able to adapt to such long-term impacts than to flooding, e.g., due to high costs and because of being these are usually addressed at higher levels of decision making.

By categorizing adaptation at the coast into protection, accommodation, and retreat,⁽¹⁴⁾ most household-level adaptation measures belong to the field of accommodation,⁽¹⁵⁾ except migration, which is part of coastal retreat. Most of the measures described seem to be geared toward decreasing vulnerability and enhancing adaptive capacity, whereas migration from the coast lowers the exposure to sea-level rise. Accordingly, most of the adaptation measures undertaken by coastal households are part of incremental adaptation, except migration which can be considered as a transformational form of adaptation.⁽¹⁶⁾ The household-level adaptation measures are listed in Table II.

For this literature review, we employed the ISI Web of knowledge database. The search procedure comprised four steps. In the first step, we used the following keywords in various combinations. The terms adapt*, mitigat*, prepared*, prevent*, protect*, and behavior* were used to specify the action. The terms household-level, house*, *owner, individual*, private, local, and citizen were used to specify the level at which adaptation takes place. Finally, for specifying the impact, the terms flood*, coast*, storm surge, cyclone, hurricane, and sea-level were used. To increase the number of relevant articles, we truncated the extent of terms by using superscript asterisks. For instance, adapt* was used to find adaptation, adapting, adaptive, etc. This process included reviewed literature published until December 2014.

In the second step of the search process, abstracts were checked regarding their relevance to the

defined scope. We excluded publications about different actions, societal levels, and impacts other than our research focus. This step also involved (1) an exclusion of studies on retreat and mobility as our focus was on coastal accommodation as defined above and (2) an exclusion of studies which focus on adaptation of working conditions such as the implementation of agricultural adaptation measures as the focus of this review is on the housing environment.

In the third step, commissioned reports and articles published in conference proceedings were excluded because these are generally not peer-reviewed and partially overlap with the peer-reviewed literature. Finally, the studies were filtered with regard to metadata variables, namely, the study area, the sample size, and the methodology applied.

2.2. Categorization of Adaptation Measures

Available literature indicates that a large variety of household-level adaptation options are undertaken and intended to be implemented. Here, we categorize adaptation options according to the widely applied distinction between nonstructural and structural adaptation, where nonstructural adaptation measures relate to the socioeconomic and institutional dimension, and structural adaptation measures involve the physical-tangible dimension (Table II). This typology is similar to the division into structural measures and nonstructural measures, which includes avoidance and emergency measures.^(7,17)

We also distinguish between actual and intended behavior. Actual behavior stands for adaptation measures that are already implemented, whereas behavior intention signifies the plan, willingness, or intention to undertake measures. Intention to adapt appears to be expressed more than actual behavior.⁽¹⁸⁾ It must be noted that behavioral intention does not necessarily lead to behavioral action,⁽¹⁹⁾ i.e., we cannot assume that intentions necessarily lead to the implementation of household-level adaptation measures.

2.3. Categorization of Explanatory Variables

A large variety of explanatory variables have been considered in the reviewed studies. We categorize these following Botzen *et al.*⁽²⁰⁾ who distinguish between the role of government, risk perception, experience and knowledge, geographical, and socioeconomic characteristics. We slightly adjusted the “risk

perception” category by renaming it “cognitive variables” in order to also account for variables such as perceived responsibility or perceived response efficacy. “Role of government” was extended to “situational variables” in the interest of integrating further nonspatial variables. The classification was further modified by dividing into the hypernyms personal and nonpersonal characteristics. Socioeconomic and cognitive variables as well as experience and knowledge are personal characteristics of the individual, whereas situational and geographical variables are nonpersonal factors, which all can have an effect on adaptation behavior. The five categories are listed in Table III.

2.4. Categorization of Methodological Approaches

We categorize methodological approaches into inductive and deductive ones. Inductive approaches are those that take a statistical model (i.e., a model without theoretical content, e.g., a regression model) and fit observational data to this model. Deductive approaches test hypotheses stemming from established models and theories against new observational data.

3. RESULTS

3.1. Studies Selected

Twenty-eight peer-reviewed studies on household-level adaptation to coastal flooding were identified. The articles have been published from 2008 onward, indicating that empirical research in this field is a recent topic. The majority of the reviewed studies use quantitative methodologies, whereas studies employing qualitative approaches were limited in number. The number of respondents in studies ranged from 35 to 3,030. Two-thirds of the reviewed studies investigate study areas in developed countries, whereas one-third explores household-level adaptation in study areas in developing countries. The studies analyzed in this review are listed in Table I.

A minority of the reviewed studies also consider coping with and reactions to flooding in addition to long-term preparedness, e.g.^(21–24) Although proactive adaptation to coastal flooding mainly implies preparation for the threat of damage caused by water, some studies also include wind damage, e.g.⁽²⁵⁾ Adaptation intention was reviewed in addition to adaptive behavior, e.g.^(17,20,26,27)

Table 1. Studies Considered

| Authors | Year | Study Area | Sample Size | Data Acquisition Method | Remarks | Models/Theories Used |
|--------------------------|-------|--|---|--|---|--|
| Baker | 2011 | United States: Florida | 1,200 | Telephone interviews based on questionnaire | Hurricane (wind and flood preparedness) | Probit model following past theoretical thoughts, e.g., Theory of Reasoned Action (Ajzen and Fishbein, 1980) or Model of Private Proactive Adaptation to Climate Change by Grothmann and Patt (2005) |
| Richard and Kazmierczak | 2011 | Great Britain: England and Wales | 961 | Telephone survey | Both river and coast | |
| Bočkarjova <i>et al.</i> | 2009 | Netherlands: four areas | 734 | Questionnaire survey | Delta (both river and coastal flooding) | Probit model |
| Botzen <i>et al.</i> | 2009 | Netherlands | 509 | Survey | Delta | Correlation analysis |
| Botzen <i>et al.</i> | 2013a | Netherlands | 473 | Online questionnaire survey | Delta | |
| Botzen <i>et al.</i> | 2013b | Netherlands: Rotterdam and adjacent municipalities | 1,250 | Internet survey with choice experiment | Delta | Choice experiment based on regulatory focus theory |
| Braun and Assheuer | 2011 | Bangladesh: Dhaka, six settlements | 625 (inclusion criterion: flood experience) | Questionnaire survey (after preparatory qualitative interviews) | Delta | |
| Chatterjee and Mozumder | 2014 | United States: Florida | 569 | Phone survey | Hurricane | Models based on random utility theory |
| Ge <i>et al.</i> | 2011 | United States: Florida | 599 | Quantitative survey | | Model based on Protective Action Decision Model (Lindell and Perry, 2004) |
| Harvatt <i>et al.</i> | 2011 | Great Britain: Aldeburgh, Barnstaple, and Truro | 35 (interviews) and 77 (surveys) | In-depth, face-to-face interview and structured questionnaire survey | | Individual Understanding and Response Framework drawing on the Social Amplification of Risk Framework |
| Harwitasari and van Ast | 2011 | Indonesia: Semarang | 60 | Observations, questionnaire survey, and semistructured interviews | | |
| Jabeen <i>et al.</i> | 2010 | Bangladesh: Dhaka and Korail | 35 | Qualitative survey | Delta | |
| Kellens <i>et al.</i> | 2012 | Belgium: Ostend | 313 | Online questionnaire survey | | Tested hypothesized relationships using path analysis |

(Continued)

Table 1. Continued

| Authors | Year | Study Area | Sample Size | Data Acquisition Method | Remarks | Models/Theories Used |
|-------------------------|-------|--|---|---|---------------------------------------|---|
| Kievik and Gutteling | 2011 | Netherlands: four low-lying areas | 726 | 2 × 2 between subject experiment with online questionnaire (stimulus material + questions) Questionnaire survey | | Tested hypothesized model using two mediation models |
| Koerth <i>et al.</i> | 2013a | Denmark and Germany: North Sea coast | 257 | Questionnaire survey | | Model based on Protection Motivation Theory (Rogers 1975, 1983) |
| Koerth <i>et al.</i> | 2013b | Greece: Thessaloniki | 491 | Questionnaire survey | | |
| Kulpraneet | 2012 | Thailand: three coastal villages | 400 (inclusion criteria: income in last 6 months, under 80 years old, and permanently residence in last year) | Questionnaire survey | | |
| Linnekamp <i>et al.</i> | 2011 | (1) Suriname: Paramaribo; (2) Guyana: Georgetown | (1) 80; (2) 108 | Interviews | | |
| Lo | 2013 | Australia: Queensland | 501 | Telephone survey | Different types of flooding | Tested hypothesized model using path analysis |
| Molua | 2009 | Cameroon: Southwest province | 400 | Questionnaire survey | | Multinomial logistic regression model |
| Molua | 2012 | Cameroon: Southwest province | 400 | Questionnaire survey | | |
| Paul and Routray | 2011 | Bangladesh: Barisal | 331 | Interviews, focus group discussions, and questionnaire surveys | Cyclone (wind and flood preparedness) | |
| Poussin <i>et al.</i> | 2014 | France | 885 | Questionnaire survey | River and coastal flooding | Model based on Protection Motivation Theory (Rogers 1975, 1983) |
| Reiminger <i>et al.</i> | 2013 | United States: Texas | 3,030 | Face-to-face interview based on questionnaire | | Multivariable logistic regression models |
| Reynaud <i>et al.</i> | 2013 | Vietnam: 14 districts of Nghe An Province | 448 | Face-to-face interview based on questionnaire | Different types of flooding | Regression analysis |
| Soane <i>et al.</i> | 2010 | Great Britain | 2,109 (82.1% no flood protection) | Online questionnaire survey | Different types of flooding | |
| Terpstra | 2011 | Netherlands: Wadden Sea coast | 472 | Internet—and questionnaire surveys | | Tested hypothesized path model |
| Thurston <i>et al.</i> | 2008 | Great Britain: England | 1,131 (households and small businesses) | Telephone survey | Both river and coastal flooding | |

3.2. What are the Predominant Measures Implemented by Households to Adapt to Coastal Flooding?

3.2.1. *The Common Ways to Adapt*

Patterns regarding the implementation of and intention to implement specific adaptation measures, operationalized in multiple ways, were identified across studies. These involve mainly structural measures for preventing damage, elevation of furniture, objects, electric devices, and other items; using upper parts of the building;^(22,24,29) and using flood-proof building materials and items, e.g.^(22,29,30) Furthermore, houses in coastal areas were often elevated, for example, by stilts or raised floor levels, e.g.^(22–24,31,32) Although sandbags were found to offer modest protection,⁽³³⁾ a minority of households were found to keep sandbags ready, e.g.^(31,34), while many were willing to obtain some.⁽²⁰⁾ Apart from sandbags, other types of barriers were often kept in stock^(20,29) and were intended to be implemented in the future;⁽¹⁸⁾ however, such a decision also depended on the type of support, such as the reduction of insurance costs.⁽³⁵⁾ Up to one-third of households reported their houses to be elevated.^(22,23,31) In many regions, storm surge insurances were not available; however, many households intended to insure their properties^(18,28) and a majority had taken an insurance already,^(25,36) where insurances for coastal flooding were available. Proportions of households that implement or intend to implement further adaptation measures such as storing items, participating and communicating, as well as elevating valuables, have been compared and no conclusive evidence regarding preferred measures was identified. This could be due to the fact that the reviewed studies did not examine the same adaptation measures and that none of these studies needed to include all measures addressed in this review, thus suggesting that the implementation of those measures depends on local characteristics.

3.2.2. *Spatial Variations in Adaptation Behavior and Behavioral Intentions*

By comparing implementation of adaptation and intention to adapt in different locations, some spatial patterns emerge. In a case study conducted in Cameroon, a high proportion of the respondents reinforced their houses.⁽²⁹⁾ In Bangladesh, half of the respondents in the study of Paul and Routray⁽²⁴⁾

were living in buildings with special constructions and a similar proportion was using door barriers,⁽²⁰⁾ while many built their houses on stilts.⁽²³⁾ In a case study in Indonesia, many residents elevated their buildings or raised their floor level⁽¹⁵⁾; house elevation was also common in a case study in Vietnam⁽³²⁾ while in a study assessing adaptation behavior in Thailand, one-third of the respondents had renovated their house.⁽³⁰⁾ Specifically, Kulpraneet⁽³⁰⁾ found that coastal households spent money on capital expenditure related to the house (e.g., house renovation and building barriers) rather than on operating measures, (e.g., drinking water storage and medical supplies).

In contrast, in developed communities, the intention or willingness to undertake adaptation was repeatedly stated by many households, whereas the implementation of measures, particularly those classified as structural measures, was less common. A large proportion of Dutch residents were willing to purchase sandbags⁽²⁰⁾ and half of them were willing to purchase an elevated house if they would move in the future.⁽²⁷⁾ In a series of case studies conducted in Great Britain, residents often considered implementing measures such as constructing door guards or keeping sandbags ready,⁽¹⁸⁾ but fewer had implemented such measures already.⁽³⁴⁾ In Great Britain, residents often checked weather forecasts.⁽³⁷⁾ The majority of residents in a U.S. study stored equipment such as nonperishable food or battery-powered radios.⁽³⁸⁾ In two other U.S. American case studies, a majority of residents were willing to install shutters⁽³⁵⁾ and many residents would allow home inspections⁽²⁵⁾ in return for benefits such as reduction of insurance costs or property taxes. Similar to that, the decision of whether and how to adapt in the future strongly depended on the kind of future flood risk scenarios expected by households.⁽³⁹⁾ Households employing adaptation measures focused on the implementation of nonstructural adaptation measures as shown in studies carried out in Denmark and Germany.⁽³⁹⁾

Quantitative data and further information on adaptation measures are listed in Table II.

3.3. Which are the Factors that Drive Adaptation Behavior and Intention to Adapt?

The most widely used classes of variables were socioeconomic^(21,24) and cognitive variables.^(26,40) Socioeconomic variables were often combined with further variables to explain behavior, such

Table III. Categories and Examples of Investigated Explanatory Variables (Following Botzen *et al.* (2009), Modified)

| | Category of Explanatory Variables | Examples |
|-----------------------|-----------------------------------|---|
| Personal variables | Socioeconomic variables | Age, income, and ownership |
| | Cognitive variables | Risk perception, perceived efficacy, and perceived responsibility |
| | Experience and knowledge | Personal experience and awareness |
| Nonpersonal variables | Situational variables | Governmental assistance, social norms, and style of occupation |
| | Geographical variables | Distance to water and living in risk area |

as experience and knowledge,⁽¹⁸⁾ situational and geographical descriptors,⁽³⁸⁾ as well as cognitive variables.^(32,34,35,41) Both personal and nonpersonal variables were less frequently used to explain adaptation behavior.⁽²⁰⁾ Table IV lists all explanatory variables found in the studies and categorized as explained in Section 2.

3.3.1. *The Explanatory Power of Personal Characteristics for Adaptation Behavior*

Socioeconomic variables such as age, income, gender, family status, ownership, and other variables related to housing were found to have a strong impact on adaptation behavior. Age had a bidirectional effect on implementing adaptation measures. On the one hand, age enhanced the likelihood of implementing adaptation measures.^(21,24,38,41,42) On the other hand, age was found to be negatively correlated with adaptation behavior and intention in other cases.^(17,18) This is possibly due to higher levels of perceived severity and own responsibility in younger ages,⁽³⁴⁾ or because of the possibility that older individuals rate the benefits of household-level actions low when considering their residual lifespan.⁽³⁵⁾

Similarly, income has an ambiguous effect. It can affect adaptation behavior positively.^(21,24,38,42) This could be due to the fact that high expected costs of adaptation were a barrier to implementing measures.⁽⁴³⁾ In contrast to this finding, Linnekamp *et al.*⁽⁴⁴⁾ found that poorer households took more measures, including cost-intensive ones. Higher education in many cases increased the likelihood of undertaking adaptation measures.^(17,21,38,39) Gender⁽²⁴⁾ and marital status⁽²¹⁾ appeared to play a role in deciding to adapt. House or land ownership^(21,24,37,38) and insurance contracts⁽²⁵⁾ enhanced the likelihood of adaptation behavior. Living in single family houses⁽³⁸⁾ and living permanently in a house⁽⁴¹⁾ increased the likelihood of adaption

behavior, whereas the number of people in a household can either have a positive⁽²⁹⁾ or negative⁽²⁵⁾ effect.

Cognitive variables have also been extensively investigated. Perceived flood risk can influence adaptation behavior and intention positively.^(35,40,41) Adaptation behavior can be enhanced by the perception of high flood likelihood,^(20,27) which itself can be negatively related to trust in public measures.⁽²⁶⁾ Households were likely to adapt, if climate change effects were considered negative^(20,27) or if high severity was expected.^(34,39) People were willing to be informed, if they felt vulnerable,⁽²⁵⁾ or at higher risk than the average resident.⁽²⁷⁾ Accordingly, worry, hazard intrusiveness, and perceived dread were positively related to the expectation of participation in programs and adaptive behavior.^(26,35) However, perception of flood consequences affected preparedness slightly.⁽²⁶⁾ The expected flood damage could be positively related to emergency preparedness, whereas it limited the likelihood of implementing structural and avoidance measures.⁽¹⁷⁾ Similarly, flood risk perception enhanced the likelihood of collecting information, whereas it had a minor effect on the implementation of structural measures.⁽³¹⁾ When contrasted with risk perception, a household's own perception of being able to adapt was seen as an important explanatory factor for adaptation behavior and the intention to adapt.^(12,17,24,31) The assessed efficiency was seen to be important for adaptation decisions and intentions.^(40,41) Households adapted and intended to do so, if they felt they have the capacity to do so and if they felt own responsibility.^(17,34) Similarly, attributing responsibility to the government⁽²⁰⁾ and not feeling responsible⁽⁴³⁾ appeared to be negatively correlated with adaptation behavior and intention. High perceived costs can hinder the implementation of structural measures.⁽¹⁷⁾

Further personal variables such as flood experience, knowledge, and awareness can also affect

Table IV. Explanatory Variables of Observed Adaptation and Adaptation Intention

| | | Studies | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|---|------------------------|-------------|--------------------------------|--------------------------|----------------------|-----------------------|-----------------------|---------------------------|--------------------------------|------------------|-----------------------|--------------------------------|----------------------|-----------------------|-----------------------------|-----------------------|-----------------------|-------------------|-------------------------|-----------|---------------|---------------|-------------------------|-----------------------|-------------------------|-----------------------|---------------------|-----------------|------------------------|---|
| | | Explanatory variables* | Baker(2011) | Bichard and Kazmierczak (2011) | Bočkarjova et al. (2009) | Botzen et al. (2009) | Botzen et al. (2013a) | Botzen et al. (2013b) | Braun and Assheuer (2011) | Chatterjee and Mozumder (2014) | Ge et al. (2011) | Harvati et al. (2011) | Harwitasari and van Ast (2011) | Jabeen et al. (2010) | Keilens et al. (2012) | Kievik and Gutteling (2011) | Koerth et al. (2013a) | Koerth et al. (2013b) | Kulpraneet (2012) | Linnekamp et al. (2011) | Lo (2013) | Molina (2009) | Molina (2012) | Paul and Routray (2011) | Poussin et al. (2014) | Reininger et al. (2013) | Reynaud et al. (2013) | Soane et al. (2010) | Terpstra (2011) | Thurston et al. (2008) | |
| Personal variables | Socio-economic | Age | •+ | ○ | ○ | | | | | | ○- | | | | • | | | | | | | •+ | | • | •+ | •+ | | | | | |
| | | Income | •+ | | | | | | | | | | | | | | | | | / | | | •+ | | • | •+ | •+ | | | | |
| | | Gender | | | ○ | | | | | | | | | | | | | | | | | | | •+ | | • | • | | | | |
| | | Marital status | | | | | | | | | | | | | | | | | | | | | | •+ | | • | • | | | | |
| | | Children | •- | | | | | | | | | | | | | | | | | | | | | •+ | | • | • | | | | |
| | | Education | •+ | | | ○+ | | | | | ○- | | | / | | | | | •+ | | | | | •+ | | • | • | | / | | |
| | | Unemployment | | | | | | | | | | | | | | | | | | | | | | •+ | | • | • | | | | |
| | Ownership | • | | | | | | | | | | | / | | | | | | | | | | •+ | | • | • | | / | | | |
| | Household size | • | | | | | | | | ○- | | | | | | | | | | | | | •+ | | • | • | •- | | | | |
| | Cognitive | Perceived risk | | | | | ○+ | | | | | ○ | | | | | ○ | | | | | | | | | | | | | / | |
| Perceived severity | | | | / | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Perceived likelihood | | | | | | ○+ | | | | | | | | | | | | | | | | | | | | | | | ○+ | | |
| Perceived damage | | | | | | | | | | | | | | | | | | | | | | | | | • | • | | | ○+ | | |
| Experience and knowledge | Perception of cc effects as negative | | | | ○ | ○ | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Perceived relationship of flood risk and climate change | | | | ○ | + | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Low perceived personal vulnerability | | | / | ○- | | | | ○- | | | | | | | | | •- | | | | | | | | | • | +/ | | | |
| | Worry | | | / | | | | | | ○ | | | | | | | | | | | | | | | | | | | | / | |
| | Hazard intrusiveness | | | | | | | | | ○ | | | | | | | | | | | | | | | | | | | | ○ | |
| | Perceived dread | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | |
| | Perceived rewards of living at coast | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Perceived self-efficacy | | | | | | | | | | | | | | | | | | | | | | | | • | + | | | | | |
| | Perceived efficacy of behaviour | | | | | | | | | | | | | | | | | | | | | | | | • | + | | | | | |
| | Perceived capacity | | | | | | | | | | | / | | | | | | | | | | | | | • | + | | | | | |
| | Prevention motivation | | | | | | | ○+ | | | | | | | | | | | | | | | | | | | | | | | |
| | Perceived costs | | | | | | | | | | | | | | | | | | | | | | | | | • | - | | | | |
| | Adaptation appraisal | | | | | | | | | | | | | | | | | | • | | | | | | | | | | | | |
| | Feeling of own responsibility | | | | | | | | | | | | / | | | | | | | | | | | | | | | | | | |
| | Trust in government | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | / |
| | Civic trust | | | | | | | | | | | | | | | | | | | | | | | | | | • | + | | | |
| | Government responsibility perceived | | | | | ○- | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Perceived fairness | | | | | | | | | | | | | | | | | | | | | | | | | | • | + | | | |
| | Reliance on dike | | | | | | | | | | | | | | | | | | | | | | | | | | • | + | | | |
| | Experience (Perceived) knowledge | | | | | ○- | | | | | ○ | ○ | | | | | | • | • | | | | | | | • | | | | | / |
| Experience | | | | | | | | | | + | | | | | | | + | • | | | | | | | • | | | | | | |
| Past damage | | | | | | | | | | + | | | | | | | | • | | | | | | | | • | | | | | |
| Awareness | | | ○ | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Government compensation | | | | | ○- | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Incentive from insurers | | | | | | | | | | | | | | | | | | | | | | | | | • | + | + | + | | | |

(Continued)

with empirical methods.^(17,18,35) Ge *et al.*⁽³⁵⁾ proposed a model to find explanatory variables for adaptation intention based on the Protective Action Decision Model (PADM), which was developed to explain protective behavior of individuals against environmental hazards by Lindell and Perry.⁽⁴⁵⁾ Bichard and Kazmierczak⁽¹⁸⁾ used a probit model to study behavioral intention following the assumptions of the Theory of Reasoned Action (TRA) by Ajzen and Fishbein⁽⁴⁶⁾ and of the Model of Private Proactive Adaptation to Climate Change (MPPACC) by Grothmann and Patt.⁽⁴⁷⁾ PADM assumes hazard preparations to be related to both hazard-related variables (e.g., as perceived efficacy to undertake measures) and resource-related attitudes (e.g., cost and time) and describes a process of decision making. TRA proposes that intention is related to attitudes and subjective norms, whereas MPPACC integrates both cognitive and socioeconomic variables to explain implementation of adaptation measures. The regression analyses used by Poussin *et al.*⁽¹⁷⁾, Koerth *et al.*,⁽³¹⁾ and Reynaud *et al.*⁽³²⁾ followed the Protection Motivation Theory (PMT) by Rogers,^(48,49) supplemented by further variables such as socioeconomic characteristics. The theories used are influenced by social psychology, integrating cognitive variables to explain behavior and behavioral intentions; the MPPACC is further influenced by behavioral economics. Also the Regulatory Focus Theory used by Botzen *et al.*⁽²⁸⁾ for choice experiments is a well-established theory in the field of psychology, which includes explanatory variables that are consistent with those originating from behavioral economics such as the expected damage compensation.

3.4.2. Studies Using Inductive Approaches

Fewer studies have proposed models based on empirical findings and statistical analysis. Botzen *et al.*⁽²⁰⁾ present a probit model to explain the willingness-to-pay for insurance. Similarly, a model explaining a range of adaptation behaviors was proposed by Molua⁽²¹⁾ who also used regression analysis. The inductive approaches used in these studies can be regarded as an extension to the above-mentioned deductive approaches. They consider economic aspects of the decision to adapt, assuming that individuals adapt to minimize potential costs and that adaptation behavior can be further encouraged by premiums or compensations, while the

above-mentioned studies use models with a focus on cognitive explanatory variables.

3.4.3 . Explaining Adaptation Intention

Terpstra⁽²⁶⁾ built a path model of causal effects on preparedness intention, which he tested with empirical data from three studies. According to this model, both trust in public protection and emotions related to personal experience with flooding negatively influence the perceived likelihood of flooding and the emotions are also negatively related to the perceived dread. Further, the perceived likelihood and perceived dread are positively influencing preparedness intention. In a study exploring explanatory factors of the implementation of (additional) adaptation measures using PMT, Poussin *et al.*⁽¹⁷⁾ found the number of implemented structural adaptation measures to be negatively related to the intention of implementing additional structural measures. They also found the implementation of both avoidance and emergency measures increases the intention to acquire more in the future. Furthermore, the analysis showed that perceived self-efficacy and perceived response-efficacy increase the intention to take adaptation measures. Ge *et al.*⁽³⁵⁾ explored variables that influence the expectation of participation in direct or indirect hazard mitigation incentives such as discounts for material expenses or lower insurance premiums. They found risk perception and hazard intrusiveness to have a major effect on the expectation of participation. Bichard and Kazmierczak⁽¹⁸⁾ used variables to explain the intention to receive flood-protection measures in the future by principal component analysis and found awareness of climate change and awareness of flood risk, as well as lower age to have a significant positive effect. Also in the framework of intention, Botzen *et al.*⁽²⁰⁾ used a probit model to explain willingness to buy sandbags. They found that willingness is significantly reduced by an assumption of governmental responsibility and compensation, and significantly increased by risk perception in different dimensions, knowledge and experience with evacuation, and significantly influenced by geographical characteristics; whereas socioeconomic variables are not significantly related to the willingness to buy sandbags. The willingness to pay for flood insurance can be explained to a large extent by a choice model proposed by Botzen *et al.*⁽²⁸⁾; risk communication, the type of motivation for the decision to purchase flood insurance, as well as insurance characteristics such as the duration of

the insurance contract are related to insurance demand. Models developed following the random utility theory explore households, which intend to allow a home inspection mainly because they are insured, have experienced flooding, and feel vulnerable.⁽²⁵⁾

3.4.4. Explaining Adaptation Behavior

With regard to actual adaptation behavior, Molua⁽²¹⁾ used a multinomial logistic regression model to explain different adaptation behaviors such as homestead reinforcement and disaster plans from empirical data. He found that the implementation of most queried adaptation measures is significantly influenced by socioeconomic variables. Also Baker,⁽³⁸⁾ who worked with a framework explaining the number of hurricane preparations by using the explained variables as a preparedness index, found socioeconomic variables such as ownership and income being significantly related to preparedness. This may be due to the influence of socioeconomic characteristics on adaptation behavior which is mediated through further variables as tested in a hypothesized model with path analysis by Kellens *et al.*,⁽⁴¹⁾ they found that risk perception and perceived risk knowledge were mediators between individual variables and information-seeking behavior. However, social norms can mediate insurance purchase and risk perception as described in a path analysis following a hypothesized model developed by Lo.⁽³⁶⁾ Information-seeking behavior could be a mediator between risk perception and perceived efficacy on the one hand and intention to take protective measures on the other hand, as proposed by Kievik and Gutteling⁽⁴⁰⁾ in two mediation models. Accordingly, high perceived efficacy of adaptation was found to enhance adaptation behavior significantly in models tested by Kellens *et al.*,⁽⁴¹⁾ Poussin *et al.*,⁽¹⁷⁾ and Koerth *et al.*⁽³¹⁾ Botzen *et al.*⁽²⁷⁾ found that individuals were more likely to invest in elevating their buildings if adaptation is framed as eliminating flood risk. Poussin *et al.*⁽¹⁷⁾ further found the implementation of structural and avoidance measures to be negatively related to the perception of flood damage and households to be more likely to implement emergency preparedness measures when anticipating high flood damage; in general, perceived costs decrease the likelihood of adaptation.⁽¹⁷⁾ By using both qualitative and quantitative data, Harvatt *et al.*⁽³⁷⁾ propose the Individual Understanding and Response Framework that suggests that people understand a hazard according to experience and individual understanding.

4. DISCUSSION

4.1. Consistent Findings across Studies

A number of explanatory variables consistently appear to be relevant across diverse studies for explaining adaptation behavior and intention. Explanatory variables related to the perception of flood risk significantly influence both adaptation behavior and behavioral intentions in a positive way, with the exception of the perception of damage. Similarly, variables associated with coping appraisal are in all cases significantly and positively related both to actual behavior and intentions, except from the variable perceived costs. With regard to perceived responsibilities, the adaptation actions of households are hindered by the perception of governmental responsibility, whereas the implementation of measures increases with trust, perceived fairness, and reliance. Experience with flooding significantly increases the likelihood of household-level adaptation and adaptation intention according to all relevant studies. The effect of socioeconomic drivers is rather heterogeneous across studies. Only age was consistently found to be positively related to adaptation behavior. The smaller the distance to the water, the more likely households are to adapt or intend to adapt.

The proportion of households collecting information (3–96%), storing items (2–87%), participating and communicating (11–53%), elevating valuables (8–43%) or houses (7–54%), and using flood-proof materials and items (1–69%) and those using permanent or removable barriers (2–53%) is very heterogeneous. With regard to adaptation intention, the intention to use flood-proof materials and items (20–72%) and the intention to use permanent and removable barriers (29–70%) is also pronounced differently between study sites. In general, the comparability of households implementing specific measures is limited by the use of different sampling strategies.

4.2. Comparison to the Review of Bubeck *et al.* (2012)

Comparing our results on coastal flooding to the review of Bubeck *et al.* (2012)⁽¹²⁾ who focused on river flooding, we find two things. First, similarly to the results of Bubeck *et al.* (2012),⁽¹²⁾ most studies make coping appraisal operational as a single variable, although in accordance with PMT, this should include several aspects such as perceived self-efficacy, perceived efficacy of behavior, and

perceived costs. This is particularly unfortunate because the individual aspects of coping appraisal affect behavior and intention in different directions. Perceived self-efficacy and perceived efficacy of the behavior have a positive effect on adaptation behavior and behavioral intentions, whereas the perceived costs inhibit the implementation of adaptation measures. Second, also in accordance with Bubeck *et al.* (2012), we find that the perception of responsibilities interacts with adaptation behavior. Specifically, we find that cognitive and situational variables standing for a shared responsibility for adaptation such as civic trust, perceived fairness, and incentives from insurers foster adaptation behavior. On the other hand, explanatory variables representing the government being responsible for adaptation, such as perceived government responsibility and government compensation, hamper adaptation intentions.

4.3. The Role of Economic Variables in Household-Level Adaptation

This review enables a geographic comparison of household-level adaptation in study areas in different countries. One finding of this review is the particular expression of implementing structural measures in the study areas in developing countries. This may be unexpected as adaptive capacity in terms of available resources is limited in developing contexts. Households with little capital available could instead consider alternatives to prevent flood damage, e.g., storing food or strengthening social capital,⁽⁶⁾ and thereby enhance their resilience. Apparently, these households use other resources for the development of adaptation than monetary assets, which can be regarded as part of their adaptive capacity. However, this may be due to the fact that governmental adaptations in the form of compensations, insurance provision, and coastal defenses are often not available in developing countries and therefore households may need to take structural adaptation measures to be physically protected and to protect their physical resources. It must be noted that the different sampling strategies, for example, the proportion of flood-prone households versus those facing low flood risk, do not allow for a spatial comparison. However, the reviewed studies define flood-prone households by being located in relevant areas, independent of their particular vulnerability.

Another significant finding is that the economic situation of an individual household may affect the decision to implement adaptation measures. Income

has indeed been found to be positively related to adaptation,^(24,38) but adaptation behavior seems not to be necessarily restricted to high-income households. Local architecture and traditional building styles, e.g., buildings on stilts, are also realized by households with moderate income.⁽⁴⁴⁾ This ambiguous effect can be explained on the one hand by small budget constraints of high income households, which are able to invest in adaptation measures; and on the other hand a far smaller need of high income households to act proactively as potential flood damages could be also paid reactively.

Both findings suggest important factors apart from the economic state of a household, but these factors have not been explored in the reviewed studies. One set of factors only examined by very few of these studies includes institutional arrangements, which are recognized as important determinants of behavior. For example, social norms can influence the expectations and behavior of others⁽³⁶⁾ and social capitals such as the trust between households and the perceived fairness⁽⁴¹⁾ have a significant impact on adaptation behavior. Furthermore, characteristics such as local knowledge may play an important role for household-level adaptation decisions.⁽⁵⁰⁾ Local knowledge, i.e., knowledge about traditional practices to protect from flood damage in a region, was also rarely addressed as an explanatory variable of adaptation behavior in the reviewed studies (except the study of Botzen *et al.*⁽²⁰⁾).

4.4. Sharing Responsibility and Supporting Households within Risk Management Frameworks

The results also suggest that encouraging shared responsibility may motivate individuals and stimulate a common strategy for adaptation as well as a joint way to respond to climate change. Feeling individual responsibility enhances the probability of getting prepared^(34,37,51) and the intention to adapt is higher, if households do not externalize responsibility for adaptation to the government.⁽²⁰⁾ Households are also more likely to adapt, if they are prevention-motivated⁽²⁸⁾ and if incentives from the municipality, insurers, and others are available.⁽¹⁷⁾ Risk communication approaches particularly those individuals who feel an own responsibility to maintain the existing situation.⁽²⁸⁾ The responsibility can be shared not only between public and private citizens, but also within the population as preparedness is more likely if households perceive fairness

and civic trust.⁽⁴¹⁾ Thus, to support household-level adaptation, a message has to mainly include a partnership in responsibility.⁽⁵²⁾ Following this approach, a management strategy of shared responsibility increases the probability of household-level adaptation and household-level adaptation generates a feeling of shared responsibility, thus producing a positive feedback.

A possible way to promote such strategies would be to subsidize household-level adaptation^(27,53) or provide insurance incentives.^(17,27) Adaptation intention appears to be highest, if insurance costs would be reduced, in comparison to other support measures.⁽³⁵⁾ An alternative could be the provisioning of noncash rewards for implementing adaptation measures,⁽¹⁸⁾ such as complementary vouchers. On the contrary, the expectation to receive post-flood compensations might hamper proactive adaptation behavior.⁽²⁰⁾

4.5. Encouraging Adaptation Behavior Effectively in Flood Risk Communication

Our results indicate that risk communication instruments should not only address risk perception (e.g., by informing households on return periods and potential damage of flooding), but also provide information on the feasibility and efficacy of potential adaptation measures. Furthermore, it is essential to make adaptation relevant to the households.⁽⁵⁸⁾ A risk communication instrument could, for example, indicate that “storing sandbags is a viable measure to protect from the threat of flood damage.” Traditionally, risk perception in coastal areas is seen as a crucial element to be addressed in risk communication as it affects preparedness behavior at the coast.^(25,41) Bubeck *et al.*⁽¹²⁾ showed that risk perception as a key driver of adaptation behavior is often the main focus of studies on household-level adaptation to river flooding although recent empirical studies indicate that other factors may be able to explain the actual implementation of adaptation measures. For example, factors such as coping appraisal and experience can function as mediators between risk perception and adaptation behavior. In many empirical studies in similar contexts, perception of the protective behavior has been found to be one of the most important factors leading to protective behavior.^(54,55) The findings of the present literature review, with the exception of the study of Reynaud *et al.*,⁽³²⁾ indicate that perception of coping

is more important in explaining flood preparedness than risk perception.^(17,31,41) However, this relationship appears to be less strong in coastal areas than in areas prone to river flooding, especially in the case of the implementation of nonstructural measures.⁽¹⁷⁾ The weak relationship between risk perception and adaptation behavior can be either explained by the fact that the implementation of measures can decrease risk perception,⁽¹⁷⁾ or by mediating factors between risk perception and adaptive behavior.⁽³⁶⁾

In order to improve risk communication instruments, a better understanding of the factors that drive private adaptation is essential. Household-level adaptation to coastal flooding depends on a wide range of explanatory variables. However, the reviewed studies have used different subsets of variables, which impedes comparison. For example, personal variables in relation to nonpersonal variables were more often investigated to explain household-level adaptation in the reviewed studies. Personal variables such as individual characteristics of people are particularly difficult to address in generalized frameworks of risk communication instruments. Risk communication instruments addressing specific audiences are therefore an efficient way to reach individuals.⁽⁵⁸⁾

Finally, since adaptation is based on experience and local knowledge,^(12,50) we must emphasize the importance of local knowledge in developing and processing risk communication strategies. It integrates potentially affected people in a participatory way, strengthens a feeling of responsibility, and thus contributes to risk sharing and a reduction of social vulnerability. To promote this positive aspect further, communication could also appeal to positive emotions resulting from flood experience such as solidarity and care.⁽²⁶⁾

4.6. Methods Applied in Empirical Research

This literature review shows a variety of research approaches and methodologies applied, consistent with the literature review of empirical findings on flood risk perception and communication of Kellens *et al.*⁽⁵⁹⁾ In terms of research methods employed in the reviewed empirical studies, most have employed quantitative approaches, i.e., surveys with closed response formats. Studies using qualitative approaches employing interviews, focus group analysis, and participant observations, or qualitative content analysis were less often used (Table I). Among the articles reviewed here, only Jabeen *et al.*⁽²²⁾ use a

solely qualitative approach. Our results suggest that qualitative research could complement quantitative research, especially to find unknown explanatory factors or those, which are difficult to measure by using quantitative approaches, such as social norms and traditions. Therefore, mixed-method approaches, which combine the advantages of both quantitative and qualitative methods, can significantly improve the information about how individuals deal with increased risk of flooding due to climate change.^(57,58)

Generally, research methodologies were presented clearly and comprehensively in the articles that we analyzed. We could thus not confirm Bird,⁽⁵⁶⁾ who criticizes that although questionnaire surveys are very popular in research about perception of natural hazards and risk mitigation, information on the methodology applied, such as the response format or the sampling technique of the survey, are often not specified.

Deductive approaches are more common than inductive approaches. The theories used in the reviewed studies using deductive approaches mainly originate from the field of psychology. The reviewed studies using inductive approaches are limited in number. The only two studies investigating a theory in the field of behavioral economics use a choice experiment to explain the willingness to pay for flood insurance⁽²⁷⁾ and a survey based on the random utility theory to explore allowing inspection of the building,⁽²⁵⁾ whereas the implementation of structural, high-effort measures has not yet been investigated by reviewed studies that use methods from the field of economics. However, the results of these studies show that the economic aspects are important drivers or barriers for adaptation behavior. Research on household-level adaptation using inductive approaches would benefit from integrating both psychological and economic explanatory variables.

4.7 An Agenda for Future Research about Household-Level Adaptation to Coastal Flooding

Our findings suggest that one important topic of future research would entail carrying out carefully designed comparative case studies. For example, the comparability of the findings of the reviewed studies is limited due to the diversity of the household-level adaptation actions. The explained variables in the reviewed studies cover a very wide range, from the willingness to implement measures to the actual implementation of those measures, in terms of deci-

sion making; and from informing oneself to building barriers, in terms of behavior. To gain deeper insights into the adaptation behavior of coastal households, there is a need to investigate similar/common adaptation measures across case studies, in order to enable comparisons of adaptation behavior and adaptation intentions.

The present review shows that empirical studies increasingly test the effects of explanatory variables on adaptation behavior other than risk perception. These include cognitive variables such as coping appraisal variables and different types of perceived responsibilities, or economic variables. Further empirical research needs to investigate those explanatory factors in order to enable a comparison of drivers.

Further empirical research should also investigate the way responsibilities for adaptation are framed and communicated, also with regard to risk communication. Both this review and previous efforts show that perceived responsibilities are important determinants of adaptation behavior of coastal households. In detail, positive and outcome-oriented framing of a shared responsibility has a clear positive impact on adaptation behavior.

Last, further knowledge on household-level adaptation in areas such as delta regions or islands is required as in those regions other types of adaptation on higher levels of decision making, such as public protection, are more difficult to implement and the integration of household-level adaptation in risk management is more urgent. Empirical studies on household-level adaptation in coastal areas as defined within the present review may also be related to data on retreat, which could be seen as a form of transformational adaptation,⁽⁶⁰⁾ because both depend on decisions of individuals.

5. CONCLUSIONS

We have presented a systematic review of studies that attempt to explain household-level adaptation to coastal flood risk. Studies were analyzed in terms of the implemented and intended measures; the range of explanatory variables; and models and theories used for explaining adaptation behavior. Further, the significance of different explanatory factors has been assessed.

The reviewed studies demonstrate that many coastal households adapt in a proactive way or intend to do so in the future, often despite the lack of state support. A wide variety of adaptation measures are available, ranging from everyday actions,

such as getting informed about risks, to costly and time-consuming activities such as the modification of the housing environment (e.g., changes in the construction of buildings). However, the percentage of households implementing or intending to implement measures varies widely across studies and study sites, which suggests that household-level adaptation behavior in coastal areas strongly depends on the local context.

Our results also show that there are, to some extent, counter-intuitive differences in adaptation behavior between developing and developed countries. Respondents in study areas of developing countries often apply high-effort, structural measures despite the lack of financial means, whereas in study areas in developed countries nonstructural measures as well as the intention to adapt appear to be more pronounced. Furthermore, in developed countries, adaptation behavior appears to be hampered by trust in governmental action, which is consistent with the findings of the literature review of Kellens *et al.* (2013). One explanation for this difference in adaptation behavior could be the (non-)existence of public measures, such as dikes, in developing countries. Households thus have to adapt in the absence of state protection. Another reason could be that generally in developed countries, more public effort is made to communicate the state of affairs of protection.

In terms of policy recommendations, our findings suggest that solely targeting risk perception in coastal risk communication (i.e., raising awareness of the threat) is not necessarily sufficient for motivating households to take action, which is also consistent with the results of literature review of Bubeck *et al.* (2012). The reasons for adaptation decisions are more complex and appear to stem from both personal variables (such as socioeconomic and cognitive variables or experience and knowledge) and nonpersonal variables (such as situational and geographical characteristics). Communication instruments should thus emphasize the importance of household-level adaptation as an easy-to-realize and common way to respond to climate change-related impacts in coastal regions. Governments may further encourage and support households in their adaptation activities by providing tangible help, for example by offering state subsidies for preventive measures.

ACKNOWLEDGMENTS

Jana Koerth and Athanasios T. Vafeidis have been supported by the Cluster of Excellence 80

“The Future Ocean.” “The Future Ocean” is funded within the framework of the “Excellence Initiative by the Deutsche Forschungsgemeinschaft (DFG) on behalf of the German federal and state governments. Jochen Hinkel and A.T. Vafeidis have received funding from the European Union’s Seventh Programme for Research, Technological Development and Demonstration under Grant Agreement No 603396 (RISES-AM project) and from European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No 642018 (GREEN-WIN project). We would also like to thank Horst Sterr and the two anonymous reviewers for their valuable comments, which have helped in improving the article.

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