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Drivers of migration intentions in coastal Vietnam under increased flood risk from sea level rise

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Abstract

Elevated flood risk due to sea level rise is expected to increase migration from coastal areas. This presents an enormous policy challenge given the hundreds of millions of people living in low-lying coastal areas globally. Despite its relevance, little empirical research has been done on what drives coastal residents to migrate or stay under increased flood risk. This study aims to improve the knowledge base on this topic by collecting and analyzing unique survey data of flood-prone coastal residents in Central Vietnam. To explain permanent migration intentions under increased flood risk, we present respondents with realistic scenarios of more frequent severe flooding and utilize a theoretical framework that incorporates flood risk indicators as well as key indicators of sustainable livelihoods. Results indicate that flood risk could play a major role in future migration behavior; permanent migration intentions strongly increase under the scenarios of increased flood risk. Several individual characteristics also play an important role in the migration decision. Regression analyses reveal that respondents who implemented *in situ* flood adaptation, and thereby reduced their flood risk, are less inclined to migrate. Past experiences during flooding such as evacuation or the reception of help from community members or the government are also strong predictors of migration intentions. Of the sustainable livelihood indicators, social capital plays the most important role, where a larger social network inside (outside) the place of residence is negatively (positively) related to migration intentions. We draw lessons from these insights for policymakers aiming to anticipate the challenge of sea level rise-induced migration.

Keywords Migration · Adaptation · Sea-level rise · Flooding · Sustainable livelihoods · Household survey

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1 Introduction

Climate change-induced sea level rise (SLR) will affect coastal habitats and populations through more frequent and extreme flooding, permanent inundation, coastal and riverbank erosion, and soil and water salinization (IPCC 2021). These SLR-related hazards threaten coastal livelihoods by decreasing agricultural yields, contaminating fresh water supplies, damaging homes and critical infrastructure, and compromising human health and safety (Myers 2017; Wrathall et al. 2019). It is likely that during this century more than one billion people globally will inhabit the low-elevation coastal zone and be potentially at risk of SLR impacts (Neumann et al. 2015).

Although global projections of SLR-induced migration suggest the migration of potentially tens of millions of people this century alone (Lincke & Hinkel 2021), the relationship between SLR-related hazards and migration is not as straightforward as it may seem. People can decide to move away from SLR risk well before they are absolutely forced to do so, or can stay put even under seemingly dire conditions (Hauer et al. 2020; Laurice Jamero et al. 2017). It has been widely documented that the relationship between environmental risk and migration is not linear and people's migration decisions are therefore expected to depend on many more factors, including economic, social, political, and demographic factors, characteristics, and preferences of the individual or household, and obstacles and facilitators such as government policies (Abu et al. 2014; Adger et al. 2021; Black et al. 2011; Hauer et al. 2020). Specifically, theoretical and empirical work in the mainstream migration literature often emphasizes how migration depends on the life course of people, wealth and income, social networks, macroeconomic factors, and maintaining viable livelihoods (Mallick et al. 2020; Massey et al. 1994; Wingens et al. 2011). This coincides with the development of multiple theoretical approaches in migration research with some focusing on specific aspects such as neoclassical theory, social network theory, and structural approaches (Haug 2008; McLeman 2014), and others incorporating a broader and more pluralistic view of migration such as the new economics of labor migration (NELM) theory and the sustainable livelihoods approach which have been found to often be better aligned with the complex reality of migration (de Haas 2010; Kniveton et al. 2008). Empirical research shows that environmental risk can spur migration in certain contexts but often is not the main driver, although this can change in the future under climate change (Adger et al. 2021; Hunter et al. 2015; McLeman 2014).

A small but growing literature has investigated empirically how SLR-related hazards impact migration, with most focusing on flooding and few on salinization and erosion (see e.g. Chen & Mueller 2018; Codjoe et al. 2017; Duijndam et al. 2022). Salinization and erosion risk are positively associated with migration in the few studies assessing this, while findings for flooding are more ambiguous (Duijndam et al. 2022). A limitation of present empirical research on the relationship between SLR-related hazards and migration is that it is mainly focused on historical analogues of hazard events or on current risk and perceptions (Duijndam et al. 2022). However, under future SLR the dynamics of these hazards will change considerably, thus their impact on migration may also change. For instance, more frequent and severe flooding could trigger migration thresholds unobserved in the recent past (Hauer et al. 2020). In addition to reactive migration, increased coastal risk may also drive anticipatory migration. Knowledge about this is pivotal to successfully anticipate SLR-induced migration and to adopt appropriate policies to manage migration (Wrathall et al. 2019).

This study adds to the current stock of scholarly knowledge by analyzing survey data on permanent migration intentions of flood-prone coastal residents in Central Vietnam at present as well as under hypothetical scenarios of increased flood risk, based on model expectations of flood risk under SLR (Kirezci et al. 2020; Vitousek et al. 2017). SLR is expected to strongly increase (compound) coastal flooding in frequency and intensity because a higher sea level means that the water level is closer to the flood stage and that there is more water available to contribute to flooding during (typhoon) storm surge and high tides and waves (Kirezci et al. 2020; Moftakhari et al. 2017; Vitousek et al. 2017). In the coming decade(s), a 10-cm increase in SLR is expected to already double the frequency of coastal flooding at a given depth in many coastal areas around the world, including Vietnam (Vitousek et al. 2017), and what today are 100-year floods are expected to become 10-year floods by as early as 2050 (Moftakhari et al. 2017). In tandem with the effects of SLR, climate change-induced changes in storm patterns and associated extreme precipitation are expected to further exacerbate compound coastal flood risk (IPCC 2021). Vietnam, like many other countries in Southeast Asia, is highly vulnerable to flood risk (Nguyen et al. 2019). Flood risk disasters in the region are common, with the floods in Central Vietnam in October 2020 being the most devastating in decades, costing the lives of hundreds of people and inducing severe economic and livelihood damage (Bohane 2020). Vietnam is also expected to be among the countries most strongly affected by future SLR (Neumann et al. 2015). Consequently, Central Vietnam provides a relevant case study area for analyzing migration behavior under increased flood risk from SLR. Although migration can be a way to adapt against natural hazard risk, it is much more complex and life-defining than *in situ* adaptation, and it can dramatically alter people's livelihoods. Therefore, to properly account for the broader context in which migration decisions are made, this study analyzes drivers of migration using a conceptual framework that incorporates theoretical insights on risk mitigation behavior (e.g., Brewer et al. 2004) as well as sustainable livelihoods (Kniveton et al. 2008; Serrat 2017). Data on a comprehensive set of flood risk and livelihood indicators are collected in the survey and assessed for their influence on permanent migration intentions using regression techniques.

The remainder of this paper is structured as follows. Section 2 explains the theoretical framework of this study. Section 3 discusses the survey methodology, variables, and statistical techniques. Section 4 presents the results of the analyses. Section 5 provides a discussion and conclusion.

2 Theoretical framework

This paper analyzes the impact of (increased) flood risk on migration intentions in Vietnam. The conceptual framework used in this analysis is built on two pillars. First, migration can be seen as an adaptation measure used to reduce individual or household exposure to flood risk. Second, migration is researched in its broader context through the sustainable livelihoods approach, capturing the quality of people's livelihood and how this is affected by flood risk. The following sections explain these two theoretical approaches in more depth.

2.1 Migration as adaptation to flood risk

Given the potentially devastating impact of flood hazards on people's lives, people at high risk of being affected by flood hazards may want to protect themselves against such risk. Besides the actual flood risk people face, perceived risk is of importance as well. A theoretical explanation for the positive relationship between perceived risk and risk mitigation behavior is provided by the "motivational hypothesis," which posits that people support preventive measures to reduce the risk they perceive as being high (Brewer et al. 2004). This reasoning is also applied in other psychological and economic theories of decision making under risk, including protection motivation theory and subjective expected utility theory, in which risk perceptions are a key component (Rogers 1975; Seifert et al. 2013). There is already a large collection of empirical studies investigating the influence of (perceived) risk on people's decision to implement *in situ* risk mitigation measures against flooding (Koerth et al. 2017).

Similar to *in situ* adaptation, migration can be a way for people to adapt to and reduce exposure to flood risk (Zander & Garnett 2020). Hence, theoretical applications of risk mitigation behavior are relevant for the study of migration as well. This holds in circumstances where migration is of a voluntary nature and people retain agency in terms of their adaptation decisions (Vinke et al. 2020). This study investigates the role of flood risk in the migration decision-making process by (1) gauging permanent migration intentions under current conditions and under hypothetical scenarios of more frequent severe flooding, (2) examining how permanent migration intentions are associated with flood risk perceptions and the number of floods experienced in the past, and (3) studying how migration intentions are influenced by the implementation of household-level *in situ* flood adaptation, which lowers flood risk.

2.2 More than flood risk: recognizing sustainable livelihoods

Although migration can be a way to adapt against increased flood risk, it is also in many ways a different and much more drastic decision than *in situ* adaptation. The impacts of migration reach much further than the achieved reduction in risk; they often influence people's whole livelihood. Hence, a migration decision is not something that is taken up lightly. Furthermore, migration is not a linear process and other livelihood factors than security from flood risk are likely to be considered in the decision or may even be primary drivers of migration (Abu et al. 2014; Adger et al. 2021; Hauer et al. 2020). Taking this into account, this study analyzes migration intentions by also embedding it in the quality of people's livelihoods and how this is affected by flood risk. This is done by applying insights from the sustainable livelihoods approach (SLA).

According to Kniveton et al. (2008), "the Sustainable Livelihoods Approach seeks to explain the responses of households to external vulnerabilities in terms of the natural, physical, financial, human, and social assets and different coping strategies available to households" (p. 7). In SLA, individuals or households aim to consolidate or expand on five livelihood assets to maintain a livelihood that is sustainable in the long term and resilient to shocks. The livelihood assets contain, but are not confined to, the following aspects: *human capital*—health, education, and skills; *social capital*—social networks, connections, and participation; *natural capital*—land, food, and agricultural resources; *physical capital*—housing, infrastructure, and access to water and sanitation; and *financial capital*—income

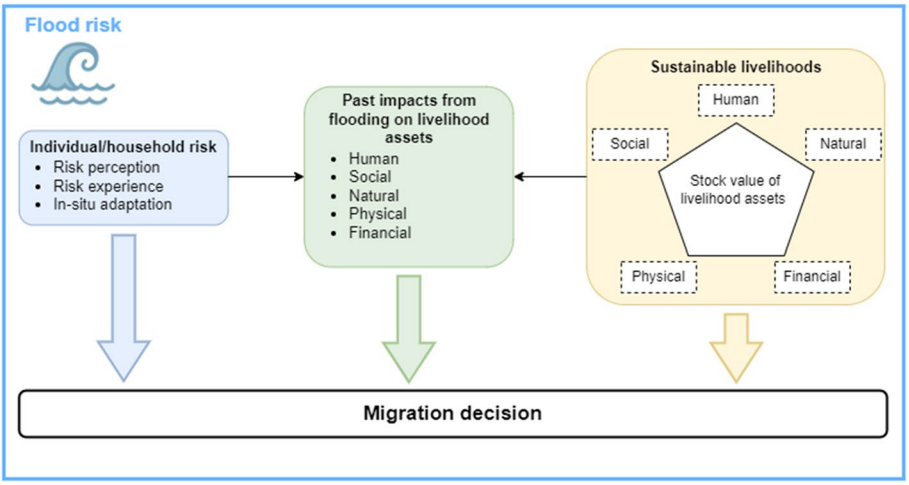


Fig. 1 Conceptual framework of migration under flood risk in Vietnam. The wave icon is provided by loading.io

and savings (DFID 2000; Serrat 2017; UNDP 2017). Vulnerability of livelihoods to shocks, seasonal developments, and long-term trends play a central role in SLA. Shocks, such as flooding, can hamper assets by destroying infrastructure or agricultural land, depleting savings, or by impacting the health of household or community members. To improve upon livelihood outcomes, people can decide to pursue livelihood strategies, such as *in situ* adaptation or migration (Brocklesby & Fisher 2003; Kniveton et al. 2008).

SLA has been applied in numerous studies on sustainable development and poverty alleviation and has also been utilized to explain migration behavior (e.g. Brocklesby & Fisher 2003; Mallick et al. 2020; UNDP 2017). Migration can be pursued as a livelihood strategy when people believe they can expand on their livelihood assets by living somewhere else. To properly apply SLA in our research context of migration under flood risk, both the stock of the five livelihood assets available to people as well as the vulnerability of these assets to flood risk are assessed. Both namely determine if migration as a livelihood strategy is a viable and attractive option in response to increased flood risk. As people aim to improve or sustain their livelihoods, we can expect, following SLA, that migration intentions are higher among people with lower livelihood assets (human, financial, physical, social, and natural), as well as among people whose livelihood assets are more vulnerable to flood risk. Nevertheless, we also consider that financial and other capital constraints may inhibit people in their migration decision, especially in a lower-income context like Vietnam.

2.3 Conceptual framework

The conceptual framework depicted in Fig. 1 brings the risk mitigation and the SLA approaches together in explaining migration behavior. It illustrates how under increased flood risk, migration is influenced by the (perceived) risk of households/individuals (blue box) and by the quality of people's livelihood assets (yellow box). In addition, migration is triggered by the vulnerability of livelihood assets to flood risk (green box), which combines the risk and SLA approaches, and is operationalized as past impacts from flooding on the livelihood assets.

3 Methods

3.1 Case study description

Thừa Thiên-Huế province is a coastal province in Central Vietnam (see Figure S.1). Main geographic features of the province include the mountain range along the Laotian border, the Huong (Perfume) River that winds its way through the provincial capital Huế city, as well as the Tam Giang Lagoon and adjacent floodplains. As of 2020, about 1.13 million people inhabited the province with almost equal shares both in terms of gender as well as people living in rural and urban areas (Government of Thừa Thiên-Huế Province 2022).

Thừa Thiên-Huế faces high risks of pluvial, fluvial, and coastal flooding. Often, these three flood types occur simultaneously leading to compound flooding, for instance, due to typhoons that frequently make landfall in central Vietnam (Nguyen et al. 2019). After severe flood events in 1999 and 2017, the province experienced another major flood in October 2020 following a series of tropical cyclones, inundating about 270 square kilometers of land. Based on an analysis of satellite images, the United Nations Institute for Training and Research (UNITAR 2020) estimated that about 100,000 people were exposed to the flood or lived close to the affected areas. In the future, flood risk is projected to further increase in the province due to climate change and associated SLR, as well as ongoing human development and activities in coastal areas (Thuc et al. 2016).

3.2 Survey methodology and sampling

The survey was implemented in April 2021 in four selected locations in Thừa Thiên-Huế province (see Figure S.1). The selection of the four locations was based on representing the province's geographical diversity related to (compound) coastal flood risk and potential differences in terms of urban, peri-urban and rural populations, and the expert judgment of a local NGO working for many years on disaster risk reduction in the region. The locations are Thuận Lộc (urban area), Phú Dương (peri-urban area), Hải Dương (rural area), and Quảng Lợi (rural area). All four locations are highly vulnerable to flood risk, which is exemplified by the fact that 90% of the survey respondents indicated they were affected by the October 2020 flood event.

Given data-scarcity in this developing country's context, which did not allow for detailed stratification at the commune level, we employed a non-probability quota sampling strategy. In each of the four locations, 100 respondents were interviewed face-to-face by eight experienced and trained local enumerators. Following permission from commune authorities, households in each location were randomly approached to ask for their participation in the survey until the quota of 100 respondents was reached. For each household, one person was interviewed. This person did not have to be the head of the household. Only respondents above the age of 18 years old and in good health were approached. In each commune, several interviewers covered different parts of the commune to avoid clustering. Overall, 400 people were interviewed to ensure sufficient statistical power. The survey was approved by local and university ethics authorities and required informed consent from the respondents. The questionnaire covered various topics in the following order: livelihood assets (well-being), mental health, risk perceptions, migration intentions, flood impacts, *in situ* adaptation, local ecosystem services, and information on the socio-economic status of the respondent. The large majority of questions were derived from the literature and extensively pre-tested, piloted, and employed in previous research in the study region (e.g.,

Hagedoorn et al. 2020; Hudson et al. 2021). We found no major differences between the characteristics of our sample and those of the actual population of interest, although the sample is slightly biased towards women (59.8%) and rural areas. A more detailed explanation of our sampling strategy and representativeness can be found in the Supplementary Information, section A.

3.3 Operationalization of variables

This section discusses the operationalization of the variables used in the analysis, following the elements of the conceptual framework presented in Fig. 1. All variables and their description and coding are depicted in Table S.1 in the Supplementary Information. Small variations in the number of responses is due to missing or do not know answers. The full survey questions and answer options are provided in Table S.2.

3.3.1 Dependent variable: permanent migration intentions

Permanent migration intentions are measured using three survey questions depicting permanent migration intentions in the current situation as well as under hypothetical flood scenarios. Permanent migration is defined as long-term migration from the place people currently live. With this definition, we account for the fact that people may move within the same village or elsewhere in the study area. By defining permanent migration as migration for the long term, we furthermore account for the possibility that people could eventually conduct return migration while at the same time making sure that we refer to the long term and not to temporary or seasonal migration. The first question asks respondents about the likelihood that in the coming five years they will permanently relocate from the place they currently live. The second question asks respondents about the likelihood that they will permanently relocate from the place they currently live when severe flood events like the October 2020 flood would occur twice as often as at present. The third question is similar to the second but presents a scenario of flood events like the October 2020 flood occurring five times as often. Presenting flood risk scenarios to respondents through changes in flood frequency has been applied and tested in several previous studies on individual protective behavior (e.g., Botzen and van den Bergh 2012a; Brouwer et al. 2014) and the scenarios are based on model expectations of increased (extreme) flood frequency under SLR (Kirezci et al. 2020; Vitousek et al. 2017). Referring to the recent October 2020 flood in the flood scenarios provides a reference point for respondents to envision the risk and correspondingly their response to it. For each of the three questions, the answer options are the same: (1) will not relocate permanently (0% chance to relocate permanently), (2) unlikely (1–39% chance), (3) not likely/not unlikely (40–60% chance), (4) likely (61–99% chance), (5) will relocate permanently for certain (100% chance to relocate permanently), and (6) do not know/no answer. The combination of a qualitative and quantitative measure improves comprehension of the numerical values while specifying the qualitative indicators. This increased comprehension was deemed especially important for the lower income context of Vietnam, where education levels are generally lower (Grosh & Glewwe 2000).

3.3.2 Flood risk indicators

Three survey questions are used to measure (perceived) risk of respondents to flood hazards. First, flood risk perceptions are obtained by asking respondents to what extent they perceive

flooding to be a threat for them personally, which is a common way to measure risk perceptions (Hagen 2013). Answer options for this question are on a 5-point scale ranging from 'no threat at all' to 'very high threat.' Second, flood experience is measured by asking respondents how often they experienced home flooding in the past 10 years (meaning water reached or entered their home), ranging from (1) no flood experience to (7) six or more floods. Third, the implementation of *in situ* flood adaptation is elicited by asking respondents if they elevated their floor or entrance level, which is a common and effective measure to provide protection against flood impacts and to subsequently decrease flood risk (Radhakrishnan et al. 2018). Due to the high occurrence of compound floods in the case study area with interacting coastal, fluvial and pluvial flooding, we do not specify the flood type when asking for respondent's flood perceptions and experiences (Nguyen et al. 2019).

3.3.3 Livelihood assets

The quality of the five livelihood assets described by SLA are measured as follows. *Human capital* is measured by asking respondents for their highest completed education level and for their health satisfaction. Health satisfaction is measured on a 10-point scale ranging from feeling 'totally unhappy' to feeling 'totally happy' with one's own health. This is an established way of asking for subjective well-being of different life domains such as health (van Praag et al. 2003). Similarly, *financial capital* is measured by asking respondents for their financial satisfaction on a 10-point scale ranging from 'totally unhappy' to 'totally happy.' *Physical capital* is measured by asking respondents if they own their house (DFID 2000). *Social capital* is measured by asking respondents about their social network both in and outside their place of residence. A strong social network inside one's place of residence is expected to be associated with lower intentions to migrate, while a strong social network outside one's place of residence is expected to facilitate migration by acting as a pull factor (Haug 2008). Social capital in the place of residence is captured by asking respondents how many friends or relatives they have in their commune with whom they are close enough to share private feelings with (Myer et al. 2008), with seven answer categories ranging from none to six or more people. To measure external social networks, respondents are asked how many of their close family and friends live somewhere else than in the case study area, be it in other parts of Vietnam or in another country. A 5-point scale is used for this question, ranging from 'none' to 'almost all or all.' *Natural capital* is measured as the percentage of household food consumption the household gathers from natural resources, including seafood catch, farm production, and other natural resources, which has been used before in similar low-income country contexts (Bubeck et al. 2019).

3.3.4 Flood impacts on livelihood assets

Flood impacts on *human capital* are measured by asking respondents if they were injured by the 2020 flood and if they had to evacuate because of the 2020 flood, with both questions relating to the health and safety aspect of human capital. Flood impact on *financial capital* is measured by asking respondents to what extent they received government support or aid to recover from the 2020 flood, being an indicator of the extent to which the financial impact of the flood was alleviated (Birkmann 2011). To measure flood impact on *physical capital*, respondents are asked to what extent they suffered damage to their home and its contents during the 2020 flood. The flood impact on *social capital* is measured by asking respondents to what extent they received help from their community to recover from

the 2020 flood, which could relieve flood impacts and increase community bonding (Chang 2010). Finally, flood impact on *natural capital* is measured by asking respondents to what extent they suffered a loss of livestock, agricultural resources, or fisheries as a result of the 2020 flood. Five-point scales are used for the flood impact questions for financial, physical, social, and natural capital with the response choices 'none', 'a little', 'some', 'a lot', and 'extreme'. The flood impact questions were only asked to respondents who stated to have been affected by the 2020 flood (90% of the sample).

3.3.5 Control variables

Age, gender, household size, and marriage status are included as control variables in the analyses. Younger male individuals are often seen as being more likely to migrate than older and female individuals, although existing studies on the relationship between coastal hazards and migration find mixed results for age and gender (Duijndam et al. 2022). Household size could influence the odds of migration because migration of household members is sometimes employed as a household strategy to diversify income sources and reduce risk, and this can be easier to facilitate by larger households (de Haas 2010). Marriage status is included as a control variable because married individuals are generally less flexible in their livelihood choices. In addition, marriage itself can be an important reason for migration (Bélanger & Linh 2011).[1]

3.4 Analytical strategy

To analyze the relationship between the explanatory variables and permanent migration intentions we employ statistical regression analyses using STATA 16. Regression analysis is a useful and commonly applied quantitative methodology to assess the relationship between a dependent variable and explanatory variables and to assess if these relationships are statistically significant (Wooldridge 2010). As explained in Section 3.3, we measure permanent migration intentions under current conditions and under two hypothetical scenarios of more frequent severe flooding. Because the answer options of these three questions are identical, their responses can be pooled into a single dependent variable, which we apply in our analysis. To account for the clustered nature of this pooled data, with responses to the three migration questions being clustered within individual respondents, we conduct random effects linear regression models and include dummies for the two flood scenarios (Robson & Pevalin 2016; Wooldridge 2010). We estimate four regression models, based on the three pillars of our conceptual framework (see Fig. 1). Models 1–3 assess the influence of respectively flood risk indicators, livelihood indicators, and flood impacts on migration intentions. Model 4 combines the three sets of variables. A VIF analysis reveals there are no worrying signs of multi-collinearity in the model specifications (all VIFs < 3). We apply a linear model as the main model because the likelihood of migration is measured with categories containing percentages[2] and this statistical method allows for a more meaningful interpretation of the regression coefficients by showing marginal effects. In addition to the main specifications, we

[1] We acknowledge that our analyses omit some variables that are potentially relevant in people's migration decision, such as migration status, employment status, and occupation type (see e.g. Abu et al. 2014; McLeman 2014), which is due to missing/limited observations in our survey. This may be accounted for in future research on the topic.

[2] For answer options displaying a range of percentages we use the middle value.

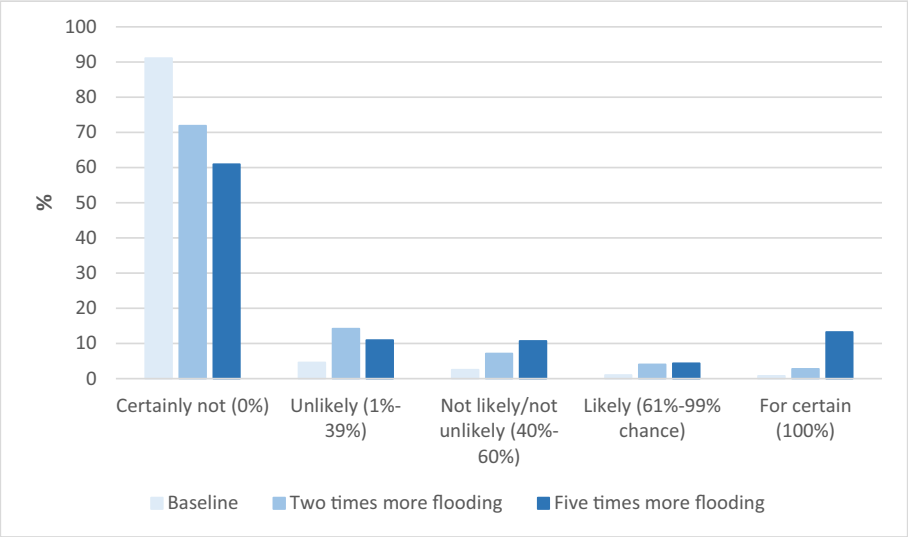


Fig. 2 Permanent migration intentions, currently, and under scenarios of more frequent severe flooding

analyze interaction effects of the explanatory variables with the flood scenario dummies. This allows us to examine whether the effects of the explanatory variables on migration intentions differ under the different scenarios of flood risk.

4 Results

4.1 Descriptive statistics of permanent migration

Figure 2 displays the descriptive statistics of permanent migration intentions within our sample. Around 90% of the respondents reported that in the coming 5 years they will certainly not migrate. Only around 2% of the respondents indicate that it is likely or certain that they will permanently migrate in the coming 5 years. Given the drastic impact of migration on the lives of people, these apparently small numbers are not surprising. Almost 30% of respondents indicate a non-zero probability of permanent migration would severe flood events occur twice as often. This increases to 40% in a scenario of five times more frequent severe flooding. More than 13% of respondents state they will permanently migrate for certain in this scenario. Results from paired *t*-tests show that these findings are statistically significant; migration intentions are significantly higher for the flood scenarios compared to the present scenario, while migration intentions are also significantly higher for the five times compared to the two times more frequent flood scenario.

Respondents who indicated that they might stay were asked for their three main reasons for this. Reasons most mentioned were place attachment (45%),[3] having family

[3] We have not included place attachment as a control variable in the regressions, because almost all respondents (97%) reported that they were (strongly) attached to their place of residence, resulting in too little variation.

and/or friends living in their place of residence (44%), and job obligations (32%). 9% of respondents mentioned that they wanted to migrate but that they do not have the means to do so, while 20% mentioned that migration is too expensive. Respondents who indicated they might migrate were also asked for their three main reasons to do so. This question was asked before scenarios of increased flooding were presented to the respondent to avoid potential bias.[4] The most often mentioned reasons were to remove themselves from coastal threats such as flooding, saltwater intrusion, erosion, and storms (71%), job opportunities elsewhere (46%), and joining family members, friends, or a partner (31%). When asked about the location respondents would likely migrate to in case of migration, most responded the same district (59%) or the same province (17%) while fewer people were likely to move to another part in Vietnam (5%) or to another country (1%). Another 18% of respondents did not know their likely migration destination or refused to answer.

4.2 Determinants of permanent migration intentions

Table 1 displays the results of the random effects linear regression models on permanent migration intentions, incorporating the explanatory variables corresponding to the conceptual framework presented in Fig. 1. Model 1 shows the results of the random effects model including the flood risk scenarios and flood risk indicators. The highly significant and positive coefficients for the flood risk scenarios confirm the pattern found in the descriptive statistics. The reported likelihood of migration under the two times and five times more frequent flood scenarios increases on average with respectively 9 and 20 percentage points compared to present intentions. Flood risk perception and number of floods experienced are not significantly associated with migration intentions. As expected, the implementation of *in situ* flood adaptation is negatively associated with migration intentions; having elevated one's floor or entrance level is associated with a 9-percentage point lower reported likelihood of migration.

Model 2 shows how the livelihood assets influence permanent migration intentions. Although SLA suggests that people with a lower livelihood quality may be more inclined to migrate, in order to improve upon their livelihoods, this is not clearly supported by our data. For instance, health satisfaction and financial satisfaction have an insignificant positive association with migration intentions.[5] Solely social capital is strongly and significantly related to permanent migration intentions. First, respondents who have more people in their community with whom they are close with have lower migration intentions. Second, respondents with a relatively large external social network of people have higher migration intentions.

Model 3 shows the influence of experienced impacts from the 2020 flood, associated with the five livelihood indicators. Flood impacts on human health and safety increase migration intentions; evacuation experience is positively and strongly significantly associated with migration intentions, while having been injured shows a positive but insignificant association. The insignificance of the latter result may be due to the low number of

[4] The question was asked after risk perceptions of flooding, which was needed to avoid that perceptions were influenced by the flood scenarios. Nevertheless, this could potentially have primed respondents here to some extent.

[5] Model I in Table S.3 performs the same analysis as Model 2 in Table 1 except that it assesses household income instead of financial satisfaction as an indicator of financial capital. This variable is not used in the main model because of a considerable number of missing values. Similar to financial satisfaction, the effect of household income is insignificant.

Table 1 Determinants of permanent migration intentions, random effects linear regressions

Variable	Model 1	Model 2	Model 3	Model 4
2x more flooding	8.813***	8.463***	9.468***	9.262***
	(1.183)	(1.178)	(1.327)	(1.344)
5x more flooding	20.421***	19.983***	21.430***	21.405***
	(1.767)	(1.780)	(1.955)	(2.002)
Perceived risk of flooding	− 0.366			1.149
	(0.982)			(1.134)
Flood experience	0.906			0.019
	(0.580)			(0.656)
In-situ flood adaptation	− 8.800***			− 6.789***
	(2.176)			(2.296)
Education		− 0.722		0.474
		(1.156)		(1.212)
Health satisfaction		0.524		0.421
		(0.572)		(0.583)
Financial satisfaction		0.440		0.881
		(0.574)		(0.585)
Home ownership		2.052		3.285
		(3.439)		(3.495)
Closeness to community		− 1.228***		− 1.286***
		(0.447)		(0.485)
External social network		3.752***		4.390***
		(0.978)		(1.027)
Food from natural resources		− 0.017		− 0.004
		(0.048)		(0.060)
Injured			9.307	10.049
			(6.369)	(6.307)
Evacuate			9.523***	8.473***
			(2.834)	(2.715)
Government aid			− 3.667**	-3.687**
			(1.468)	(1.480)
Flood damage home			1.792	1.338
			(1.158)	(1.155)
Community aid			− 2.177*	− 1.970
			(1.215)	(1.246)
Flood damage natural resources			− 1.440	− 0.559
			(1.215)	(0.918)
Age	− 0.073	− 0.112	− 0.063	-0.071
	(0.080)	(0.108)	(0.092)	(0.122)
Gender	3.162	4.844**	3.093	4.315*
	(2.217)	(2.399)	(2.304)	(2.593)
Household size	1.523**	1.407**	2.062***	1.540**
	(0.671)	(0.675)	(0.726)	(0.704)
Married	− 1.791	− 3.871	− 2.517	− 3.675
	(2.857)	(2.876)	(3.192)	(3.114)

Table 1 (continued)

Variable	Model 1	Model 2	Model 3	Model 4
Location (base: Hải Dương)				
Quảng Lợi	− 1.556	− 1.140	− 2.020	− 4.456
	(3.046)	(3.165)	(2.936)	(3.168)
Thuận Lộc	− 0.699	1.293	− 2.413	− 5.005
	(3.155)	(3.169)	(3.767)	(3.989)
Phú Dương	1.721	3.409	3.309	1.441
	(3.051)	(3.085)	(3.629)	(3.483)
Constant	2.795	− 7.857	5.161	− 11.297
	(6.759)	(9.691)	(8.183)	(12.704)
N observations	1173	1152	1025	992
N individuals	396	389	346	335
R^2 within	0.211	0.206	0.216	0.215
R^2 between	0.088	0.097	0.129	0.222
R^2 overall	0.141	0.144	0.168	0.219
Wald χ^2	147.92***	147.89***	140.79***	154.67***

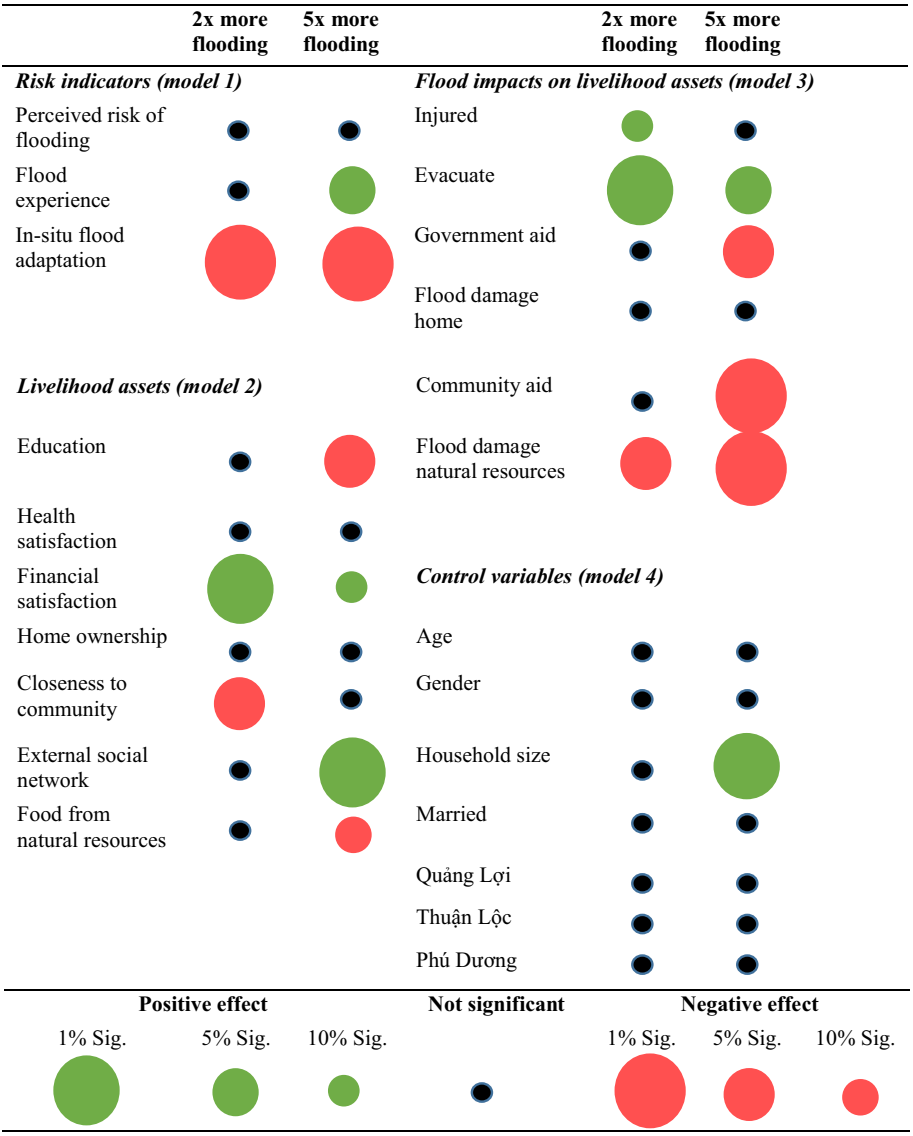
Robust standard errors in parentheses. The levels of significance are as follows: *$p < 0.1$, **$p < 0.05$, and ***$p < 0.01$

respondents that experienced injury (6% of the sample). Reception of aid in the aftermath of flooding also seems important. Respondents who received more government aid display significantly lower migration intentions. The same holds for receiving help from the community. The extent of flood damage experienced to one's home or contents is positively, but insignificantly, associated with migration intentions. Suffering a loss of natural resources has a negative and insignificant association.

Model 4 combines the variables incorporated in Models 1–3. The main findings in this extended model remain the same, although there are some slight changes in the significance levels of some variables. The control variables age, gender, location, and marriage status are mostly insignificantly associated with permanent migration intentions. Gender is only significant in Models 2 and 4, with women reporting higher migration intentions than men. Household size is the only control variable that is consistently significant; respondents living in larger households report a higher likelihood of permanent migration.

Because migration intentions are measured simultaneously in qualitative terms (on a scale from migrating 'certainly not' to 'certainly') and in quantitative terms (likelihood of migration in percentages), both linear and ordinal regression methods are appropriate. Therefore, as a robustness check for the random effects linear regression models in Table 1, Table S.4 in the Supplementary Information shows the results of random effects ordered logistic regression models applying the same variables and specifications as in Table 1. The results are largely similar, indicating the robustness of our findings to the model specification. The only notable changes are that reception of government aid is somewhat less significant and flood experience and injury from flooding are somewhat more significant in the random effects ordered logistic models.

Table 2 Random effects linear regression of permanent migration intentions, with interaction effects



4 models with interaction effects are estimated. Model 1 with flood risk indicators, model 2 with livelihood assets, model 3 with flood impacts on livelihood assets, and model 4 with control variables. Control variables without interactions are included in all models. The full model estimations are shown in Table S.5

4.3 Interaction analysis

Table 2 summarizes the outcome of random effects linear regression models incorporating interaction terms of the explanatory variables with the flood scenario variables. This interaction analysis adds to the findings in Table 1 by allowing us to examine whether the effects of the explanatory variables on migration differ under the different scenarios of flood risk.

The full model results are shown in Table S.5. To prevent over-specification, four separate regression models are estimated including interactions with (1) flood risk indicators, (2) livelihood assets, (3) flood impacts, and (4) control variables. All models include the (non-interacted) control variables. Red circles indicate a significantly negative effect while green circles indicate a significantly positive effect. A larger size of the circle means the result is more significant, while a black circle indicates that the result is insignificant.

There are several interesting findings. First, the interaction effects between *in situ* adaptation and both scenarios of more frequent severe flooding are negative and strongly significant, meaning that people who have adapted their home to flooding through elevation are significantly less likely to intent to migrate under increased flood risk. Flood experience is significantly positively associated with migration intentions under the five times more frequent flood scenario, while flood risk perceptions are insignificantly associated with migration intentions under both flood scenarios. Regarding the interaction terms with livelihood assets, we notice again that a strong social network within the community is associated with lower migration intentions while a relatively large external social network is associated with higher migration intentions, although the former (latter) is only significant in the two times (five times) more frequent flood scenario. Furthermore, the interaction terms for financial satisfaction are positive and significant.[6] Some interesting results can also be seen for the flood impact variables. First, evacuation experience is associated with higher migration intentions under both flood scenarios. Second, respondents who received more government aid or community aid after the 2020 flood report a significantly lower likelihood of migration under the five times more frequent flood scenario. Third, respondents who suffered a higher loss of natural resources due to the flooding are less likely to migrate under both flood risk scenarios. The results for the control variables are insignificant, except for household size which shows a positive association under the five times more frequent flood scenario.

5 Discussion and conclusion

5.1 Discussion

Descriptive statistics showed that under current conditions few respondents consider to permanently migrate away, with 90% of respondents reporting they will stay for certain in the coming 5 years. Things change considerably when respondents are confronted with hypothetical scenarios of increased flood risk, with around 30% (40%) considering migration to some extent and 3% (13%) reporting that they will migrate away for certain under a scenario when severe flooding in the area, as during October 2020, would occur two (five) times as frequently. Given that by 2060 the population living in the 100-year floodplain is expected to surpass 50 million people in Vietnam and 400 million people globally (Neumann et al. 2015), more frequent and extreme flooding as expected under SLR would result in the permanent migration of millions of people, would these percentages hold more generally and intentions translate to actual behavior. Of the survey respondents, a large majority indicated that in case of migration they would relocate to somewhere in the same district or province, which corresponds well with the notion that most migration under

[6] Substituting financial satisfaction for household income, however, does not show any significant effects.

SLR will likely be of an internal and short-distance nature (McLeman 2014). However, this may prove a major policy challenge for countries like Vietnam given the number of people affected and the large areas that face SLR risk.

The regression results confirmed the strong influence of the flood risk scenarios, with migration intentions being significantly and substantially higher under both scenarios. Although this study is one of the first to research migration intentions under future flood risk scenarios, a previous study by Buchanan et al. (2019) in New York City also found that migration intentions were higher under a scenario of increased flooding, although in this case the scenario related to more frequent nuisance flooding. We also found interesting results for the other flood risk indicators incorporated in our regression analyses. Perceptions of flood risk were not a strong predictor of migration intentions in the main regression models. The interaction effects between risk perception and the flood scenarios were also insignificant. On the one hand, this seems to contradict the motivational hypothesis theory which describes that people want to protect themselves against the risk they perceive as high (Brewer et al. 2004). This weak link between perceptions and protective behavior is also observed in the broad *in situ* flood adaptation literature (Koerth et al. 2017) and in Vietnam specifically (Bubeck et al. 2012). On the other hand, in the survey, we asked about risk perceptions before we presented respondents with the flood scenarios, which means that respondents may have updated their beliefs about the risk when they were presented with the flood scenarios, independent of a priori risk perceptions (Botzen and van den Bergh 2012b). The number of floods experienced is insignificantly associated with migration intentions in the main regression specifications (Table 1), but shows a positive association when interacted with the most extreme flood scenario (Table 2). Hence, more experience does seem to influence people's behavior in case of strongly increased flood risk, perhaps because they can more easily bring to mind the potential devastation that floods can cause. Such a relationship is described by the availability heuristic which in multiple studies has been found to be empirically valid (Demski et al. 2017). Our findings further indicate that having already implemented *in situ* adaptation in the form of elevating one's floor or entrance level is strongly related to lower migration intentions. This can be explained by the fact that adaptation reduces flood risk and entails an investment in the current place of residence (Radhakrishnan et al. 2018).

Making the decision to migrate entails much more than flood risk reduction only and often impacts people's whole livelihood, which is why this article incorporated insights from the sustainable livelihoods approach. Of the livelihood assets, social capital is most strongly associated with migration intentions. Having a larger local (external) social network is associated with lower (higher) migration intentions, which is according to the expectations of social network theory (Haug 2008; Hunter et al. 2015). Being close to many people in one's current place of residence provides a barrier for migration, while knowing many people in other places of the country or abroad accommodates migration. Next to social connections, an external social network can also provide access to resources to facilitate migration (Lucas 2015). These results suggest that a domino effect of outmigration could occur when people start to leave the community under increased coastal risk, which would erode social networks within the community and increase external social networks for people remaining. To prevent the erosion of community networks, community-based adaptation can be fruitful as it can lead to a double dividend by reducing flood risk and increasing community bonding (Hudson et al. 2020). Other indicators of the livelihood assets (i.e., human, financial, physical, and natural capital) were insignificant in the main models, although the interaction effects between financial satisfaction and the flood scenarios were positive and significant. One reason for the low significance of most of the

livelihood indicators could be that while a lack of livelihood assets may motivate people to migrate away as hypothesized by SLA, it may also impede them from being capable of doing so (Hunter et al. 2015). The positive interaction effect for financial satisfaction may therefore reflect that people with higher financial satisfaction have more financial means to finance costly migration would they want to migrate under increased flood risk (Kaczan & Orgill-Meyer 2020).

The regression results indicate that past impacts of flooding are associated with migration intentions in multiple ways. First, having been personally compromised in one's health or safety during flooding through injury or evacuation is positively associated with intentions to migrate. The effect of evacuation experience is substantial and strongly significant. Evacuation can be a traumatic and costly experience and people can avoid this by moving away from increased flood risk (Munro et al. 2017). Receiving government aid and help from the community are significantly negatively associated with migration intentions. Both can help relieve the financial impacts of flooding and thereby aid to sustain livelihoods, while receiving help from the community can also increase community bonding. Interaction effects show that these results especially hold under the highest flood scenario. People who received aid may be hopeful that also under substantially increased flood risk they will receive sufficient help from community members or will be compensated by the government, which can incentivize them to stay. The importance of disaster aid and relief in people's migration decision has been documented in other studies as well (Dun 2011). The interaction analysis also revealed that respondents who suffered a loss of natural resources from flooding are significantly less likely to migrate under both scenarios of increased flood risk. Although this is somewhat surprising at first, a reason for this could be that people who suffered a loss of natural resources are also the ones most dependent on these local natural resources for their livelihoods. Such dependence on natural resources can make people inclined to stay even under severe flood risk (Laurice Jamero et al. 2017). Of the socio-demographic (control) variables, only household size was consistently significant and was positively associated with migration intentions. This could be explained by the fact that households sometimes employ migration as an income diversification strategy, which is easier to facilitate for larger households (de Haas 2010). The low significance of the other socio-demographic variables is in line with previous empirical research on the interrelationship between coastal hazards and migration (Duijndam et al. 2022).

5.2 Future research

Avenues for future empirical research on SLR and migration are plentiful (see Duijndam et al. (2022) for an overview). We outline here two additional recommendations based on the results from our Vietnam case study. First, our study focuses on migration intentions which is necessary to capture the impact of future changes in flood risk. However, longitudinal survey research is needed on whether intentions translate to actual behavior under increased environmental risk, and in what context or speed, which is vital to understand human migration behavior under climate change. Collecting longitudinal data is furthermore important in light of the complicated relationship between (intended) permanent migration and return migration found in the literature, where reasons for return migration may be a failure to integrate or earn a livelihood in the destination location, but may also be due to successful migration where the migrant brings resources and knowledge back to the source community (Gmelch 1980; Junge et al. 2015; Stark 2019). Investigating the extent and consequences of return migration under increased environmental risk is an important

avenue for future research. Second, our research focused solely on increased flood risk. For a complete overview of the migration impacts of SLR, it would be important to assess future scenarios of other SLR-related hazards as well, including increased salt-water intrusion and coastal erosion risk. The impacts on migration of more slow-onset hazards like erosion and saltwater intrusion may be profoundly different from the impacts of a rapid-onset hazard like flooding, for instance by allowing more time for collecting resources for migration as compared to drastic flood events that can instantly deplete household resources (Cattaneo et al. 2019; Kaczan & Orgill-Meyer 2020).

5.3 Concluding remarks

Our case study in flood-prone Vietnam provides one of the first empirical investigations of individual migration behavior under increased coastal risk. It shows a high intention of residents to permanently migrate under increased risk of severe flooding. Although intentions do not always translate to actual behavior, this result may imply the migration of millions of people from vulnerable coastal areas under future climatic change. We find that intentions to migrate are associated with several individual characteristics including the implementation of *in situ* flood adaptation, social networks in and outside place of residence, and past experiences during flooding such as evacuation or the reception of help from community members or the government. Our findings provide important information for planners and policymakers who should anticipate and plan for SLR-induced migration and aim to reduce negative impacts both for people who migrate and for those who remain. Such anticipation also includes investments in flood protection and support for household flood adaptation, which can reduce the need for migration. Findings also point towards the risk of people becoming trapped, with 9% of respondents reporting not having the means to migrate and 60% indicating that they would certainly not migrate even under the most extreme flood scenario. Although these individuals may not all be or become trapped, trapped populations provide a real danger to the people involved. Government authorities can mitigate this risk by providing monetary or informational support to individuals at risk, by enhancing community-based adaptation, and by offering viable alternative livelihood opportunities in place or in safer locations.

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Declarations

Competing interests The authors declare no competing interests.

References

Abu M, Codjoe SNA, Sward J (2014) Climate change and internal migration intentions in the forest-savannah transition zone of Ghana. Popul Environ 35(4):341–364. https://doi.org/10.1007/s11111-013-0191-y

Adger N, de Campos RS, Codjoe SNA, Siddiqui T, Hazra S, Das S, Adams H, Gavonel MF, Mortreux C, Abu M (2021) Perceived environmental risks and insecurity reduce future migration intentions in hazardous migration source areas. One Earth 4(1):146–157. https://doi.org/10.1016/j.oneear.2020.12.009

Bélanger D, Linh TG (2011) The impact of transnational migration on gender and marriage in sending communities of Vietnam. Curr Sociol 59(1):59–77. https://doi.org/10.1177/0011392110385970

Birkmann J (2011) First- and second-order adaptation to natural hazards and extreme events in the context of climate change. Nat Hazards 58(2):811–840. https://doi.org/10.1007/s11069-011-9806-8

Black R, Adger N, Arnell N, Dercon S, Geddes A, Thomas D (2011) The effect of environmental change on human migration. Glob Environ Chang 21:S3–S11. https://doi.org/10.1016/j.gloenvcha.2011.10.001

Bohane H (2020) Responding to central Vietnam's floods and landslides. The Diplomat. Retrieved June 22, 2021, from https://thediplomat.com/2020/11/responding-to-central-vietnams-floods-and-landslides/

Botzen W, van den Bergh J (2012a) Monetary valuation of insurance against flood risk under climate change. Int Econ Rev 53(3):1005–1026

Botzen W, van den Bergh J (2012b) Risk attitudes to low-probability climate change risks: WTP for flood insurance. J Econ Behav Organ 82(1):151–166. https://doi.org/10.1016/j.jebo.2012.01.005

Brewer N, Weinstein N, Cuite C, Herrington J (2004) Risk perceptions and their relation to risk behavior. Ann Behav Med 27(2):125–130. https://doi.org/10.1207/s15324796abm2702_7

Brocklesby MA, Fisher E (2003) Community development in sustainable livelihoods approaches—an introduction. Community Dev J 38(3):185–198. https://doi.org/10.1093/cdj/38.3.185

Brouwer R, Tinh BD, Tuan TH, Magnussen K, Navrud S (2014) Modeling demand for catastrophic flood risk insurance in coastal zones in Vietnam using choice experiments. Environ Dev Econ 19(2):228–249. https://doi.org/10.1017/S1355770X13000405

Bubeck P, Botzen W, Suu L, Aerts J (2012) Do flood risk perceptions provide useful insights for flood risk management? Findings from central Vietnam: flood risk perceptions and flood risk management. J Flood Risk Manag 5(4):295–302. https://doi.org/10.1111/j.1753-318X.2012.01151.x

Bubeck P, Hudson P, Pham M, Hagedoorn L, Le T, Brander L, Tran T, Haer T, Wolf S (2019) Strong roots, strong women: Women and ecosystem-based adaptation to flood risk in Central Vietnam. http://mail.wocan.org/sites/default/files/DKKV_61_RESILNAM.pdf

Buchanan M, Oppenheimer M, Parris A (2019) Values, bias, and stressors affect intentions to adapt to coastal flood risk: a case study from New York City. Weather Climate Soc 11(4):809–821. https://doi.org/10.1175/WCAS-D-18-0082.s1

Cattaneo C, Beine M, Fröhlich C, Kniveton D, Martinez-Zarzoso I, Mastrorillo M, Millock K, Piguet E, Schraven B (2019) Human migration in the era of climate change. Rev Environ Econ and Policy 13(2):189–206. https://doi.org/10.1093/reep/rez008

Chang K (2010) Community cohesion after a natural disaster: insights from a Carlisle flood. Disasters 34(2):289–302. https://doi.org/10.1111/j.0361-3666.2009.01129.x

Chen J, Mueller V (2018) Coastal climate change, soil salinity and human migration in Bangladesh. Nat Climate Chang 8(11):981–985. https://doi.org/10.1038/s41558-018-0313-8

Codjoe SNA, Nyamedor FH, Sward J, Dovie DB (2017) Environmental hazard and migration intentions in a coastal area in Ghana: a case of sea flooding. Population Environ 39(2):128–146. https://doi.org/10.1007/s11111-017-0284-0

de Haas H (2010) Migration and development: a theoretical perspective. Int Migr Rev 44(1):227–264. https://doi.org/10.1111/j.1747-7379.2009.00804.x

Demski C, Capstick S, Pidgeon N, Sposato RG, Spence A (2017) Experience of extreme weather affects climate change mitigation and adaptation responses. Climatic Change 140(2):149–164. https://doi.org/10.1007/s10584-016-1837-4

DFID (2000) Sustainable livelihoods guidance sheets. Department for International Development, London, UK

Duijndam SJ, Botzen WJW, Hagedoorn LC, Aerts JCJH (2022) Anticipating sea-level rise and human migration: a review of empirical evidence and avenues for future research. WIREs Clim Change 13(1):e747. https://doi.org/10.1002/wcc.747

Dun O (2011) Migration and displacement triggered by floods in the Mekong Delta: migration and displacement in the Mekong Delta. Int Migr 49:e200–e223. https://doi.org/10.1111/j.1468-2435.2010.00646.x

Gmelch G (1980) Return migration. Ann Rev Anthropol 9(1):135–159. https://doi.org/10.1146/annurev.an.09.100180.001031

Government of Thừa Thiên-Huế Province (2022) Population distribution. Retrieved January 28, 2022, from https://thuathienhue.gov.vn/vi-vn/Thong-tin-kinh-te-xa-hoi/cid/BC720E2C-8122-493C-8850-531999ECDD6F

Grosh M, Glewwe P (2000) Designing household survey questionnaires for developing countries. World Bank, Washington, DC

Hagedoorn L, Koetse M, van Beukering P, Brander L (2020) Time equals money? Valuing ecosystem-based adaptation in a developing country context. Environ Dev Econ 25(5):482–508. https://doi.org/10.1017/S1355770X20000108

Hagen B (2013) Public perceptions of climate change: risk, trust, and policy. Doctoral dissertation, Arizona State University, Tempe, USA

Hauer M, Fussell E, Mueller V, Burkett M, Call M, Abel K, McLeman R, Wrathall D (2020) Sea-level rise and human migration. Nature Rev Earth Environ 1(1):28–39. https://doi.org/10.1038/s43017-019-0002-9

Haug S (2008) Migration networks and migration decision-making. J Ethn Migr Stud 34(4):585–605. https://doi.org/10.1080/13691830801961605

Hudson P, Hagedoorn L, Bubeck P (2020) Potential linkages between social capital, flood risk perceptions, and self-efficacy. Int J Disaster Risk Sci 11(3):251–262. https://doi.org/10.1007/s13753-020-00259-w

Hudson P, Pham M, Hagedoorn L, Thieken A, Lasage R, & Bubeck P (2021) Self-stated recovery from flooding: empirical results from a survey in Central Vietnam. J Flood Risk Manag 14(1). https://doi.org/10.1111/jfr3.12680

Hunter L, Luna J, Norton R (2015) Environmental dimensions of migration. Ann Rev Sociol 41(1):377–397. https://doi.org/10.1146/annurev-soc-073014-112223

IPCC (2021) Climate Change 2021: the physical science basis. In: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK

Junge V, Revilla Diez J, Schätzl L (2015) Determinants and consequences of internal return migration in Thailand and Vietnam. World Dev 71:94–106. https://doi.org/10.1016/j.worlddev.2013.11.007

Kaczan D, Orgill-Meyer J (2020) The impact of climate change on migration: a synthesis of recent empirical insights. Clim Chang 158(3–4):281–300. https://doi.org/10.1007/s10584-019-02560-0

Kirezci E, Young I, Ranasinghe R, Muis S, Nicholls R, Lincke D, Hinkel J (2020) Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st Century. Scientific Rep 10(1):11629. https://doi.org/10.1038/s41598-020-67736-6

Kniveton D, Schmidt-Verkerk K, Smith C, Black R, (Red) (2008) Climate change and migration: improving methodologies to estimate flows. Internat, Organization for Migration

Koerth J, Vafeidis A, Hinkel J (2017) Household-level coastal adaptation and its drivers: a systematic case study review. Risk Analysis 37(4):629–646. https://doi.org/10.1111/risa.12663

Jamero L, Onuki M, Esteban M, Billones-Sensano XK, Tan N, Nellas A, Takagi H, Thao ND, Valenzuela VP (2017) Small-island communities in the Philippines prefer local measures to relocation in response to sea-level rise. Nat Climate Chang 7(8):581–586. https://doi.org/10.1038/nclimate3344

Lincke D, Hinkel J (2021) Coastal migration due to 21st century sea-level rise. Earth's Future 9(5). https://doi.org/10.1029/2020EF001965

Lucas R (2015) Internal migration in developing economies: an overview. KNOMAD's working paper, 6. KNOMAD

Mallick B, Sultana Z, Bennett C (2020) How do sustainable livelihoods influence environmental (non-)migration aspirations? Applied Geography. 124:102328. https://doi.org/10.1016/j.apgeog.2020.102328

Massey D, Arango J, Hugo G, Kouaouci A, Pellegrino A, Taylor E (1994) An evaluation of international migration theory: the North American case. Popul Dev Rev 20(4):699. https://doi.org/10.2307/2137660

McLeman R (2014) Climate and human migration: past experiences, future challenges. Cambridge University Press

Moftakhari H, Salvadori G, AghaKouchak A, Sanders B, Matthew R (2017) Compounding effects of sea level rise and fluvial flooding. Proc Natl Acad Sci 114(37):9785–9790. https://doi.org/10.1073/pnas.1620325114

Munro A, Kovats S, Rubin J, Waite TD, Bone A, Armstrong B (2017) Effect of evacuation and displacement on the association between flooding and mental health outcomes: a cross-sectional analysis of UK survey data. Lancet Planet Health 1(4):e134–e141. https://doi.org/10.1016/S2542-5196(17)30047-5

Myer L, Stein D, Grimsrud A, Seedat S, Williams D (2008) Social determinants of psychological distress in a nationally-representative sample of South African adults. Soc Sci Med 66(8):1828–1840. https://doi.org/10.1016/j.socscimed.2008.01.025

Myers S (2017) Planetary health: protecting human health on a rapidly changing planet. Lancet 390(10114):2860–2868. https://doi.org/10.1016/S0140-6736(17)32846-5

Neumann B, Vafeidis A, Zimmermann J, Nicholls R (2015) Future coastal population growth and exposure to sea-level rise and coastal flooding—a global assessment. PLOS ONE 10(3):e0118571. https://doi.org/10.1371/journal.pone.0118571

Nguyen K-A, Liou Y-A, Terry J (2019) Vulnerability of Vietnam to typhoons: a spatial assessment based on hazards, exposure and adaptive capacity. Sci Total Environ 682:31–46. https://doi.org/10.1016/j.scitotenv.2019.04.069

Radhakrishnan M, Nguyen HQ, Gersonius B, Pathirana A, Vinh KQ, Ashley R, Zevenbergen C (2018) Coping capacities for improving adaptation pathways for flood protection in Can Tho. Vietnam. Climatic Chang 149(1):29–41. https://doi.org/10.1007/s10584-017-1999-8

Robson K, Pevalin D (2016) Multilevel modeling in plain language. SAGE, Thousand Oaks, USA

Rogers R (1975) A protection motivation theory of fear appeals and attitude change. J Psychol 91(1):93–114. https://doi.org/10.1080/00223980.1975.9915803

Seifert I, Botzen W, Kreibich H, Aerts J (2013) Influence of flood risk characteristics on flood insurance demand: a comparison between Germany and the Netherlands. Nat Hazards Earth Syst Sci 13(7):1691–1705. https://doi.org/10.5194/nhess-13-1691-2013

Serrat O (2017) The sustainable livelihoods approach. In: Serrat O (ed) Knowledge solutions: tools, methods, and approaches to drive organizational performance. Springer, Singapore, pp 21–26. https://doi.org/10.1007/978-981-10-0983-9_5

Stark O (2019) Behavior in reverse: reasons for return migration. Behav Public Policy 3(1):104–126. https://doi.org/10.1017/bpp.2018.27

Thuc T, Van Thang N, Huong HTL, Van Khiem M, Hien NX, Phong DH (2016) Climate change and sea level rise scenarios for Vietnam. Ministry of Natural resources and Environment, Hanoi, Vietnam

UNDP (2017) Guidance note: application of the sustainable livelihoods framework in development projects. United Nations Development Programme, New York, USA

UNITAR (2020) Satellite detected waters in Thua Thien Hue Province of Viet Nam as of 29 October 2020. United Nations Institute for Training and Research. Retrieved January 28, 2022, from https://unosat-maps.web.cern.ch/VN/TC20201028VNM/UNOSAT_A3_Natural_Landscape_TC20201028VNM_ThuaThienHuei_VietNam_29102020.pdf

van Praag B, Frijters P, Ferrer-i-Carbonell A (2003) The anatomy of subjective well-being. J Econ Behav Organ 51(1):29–49. https://doi.org/10.1016/S0167-2681(02)00140-3

Vinke K, Bergmann J, Blocher J, Upadhyay H, Hoffmann R (2020) Migration as adaptation? Migr Stud 8(4):626–634. https://doi.org/10.1093/migration/mnaa029

Vitousek S, Barnard P, Fletcher C, Frazer N, Erikson L, Storlazzi C (2017) Doubling of coastal flooding frequency within decades due to sea-level rise. Scientific Reports 7(1):1399. https://doi.org/10.1038/s41598-017-01362-7

Wingens M, Windzio M, de Valk H, Aybek C (eds) (2011) A life-course perspective on migration and integration. Springer, Netherlands. https://doi.org/10.1007/978-94-007-1545-5

Wooldridge J (2010) Econometric analysis of cross section and panel data, 2nd edn. MIT Press, Cambridge, USA

Wrathall D, Mueller V, Clark P, Bell A, Oppenheimer M, Hauer M, Kulp S, Gilmore E, Adams H, Kopp R, Abel K, Call M, Chen J, deSherbinin A, Fussell E, Hay C, Jones B, Magliocca N, Marino E, … Warner K (2019) Meeting the looming policy challenge of sea-level change and human migration. Nat Clim Chang 9(12):898–901. https://doi.org/10.1038/s41558-019-0640-4

Zander KK, Garnett S (2020) Risk and experience drive the importance of natural hazards for peoples' mobility decisions. Clim Chang 162(3):1639–1654. https://doi.org/10.1007/s10584-020-02846-8

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