# Flood Risk Perception Under the Levee Effect: Adaptive Management Strategies for Heterogeneous Individuals

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**Abstract**
As climate change leads to increasingly frequent extreme rainfall events, the risk of urban flooding disasters is rising. Urban areas commonly adopt structural flood control measures to mitigate flood risks. However, this may create a "levee effect," giving residents a false sense of security and promoting development in high-risk areas, ultimately increasing long-term risks. This study takes Tainan City as an example, using a literature review and spatial analysis to identify potential areas affected by the levee effect. A stratified random sampling method is employed for a questionnaire survey, followed by cross-analysis to explore the differences in risk perception among different groups. The research aims to enhance risk awareness, promote practical response actions, and provide references for adaptation strategies and policy planning.

**Keywords:** Levee Effect, Risk Perception, Adaptive Strategies, Flood Risk Management, Cross-tabulation Analysis

## 1. Introduction

As climate change increases the frequency of extreme rainfall events, which are becoming increasingly normalized, urban flooding disasters are becoming more severe, directly threatening the safety of residents' lives and property. In response to the rising risk of flooding, urban areas tend to adopt structural flood control engineering facilities, aiming to effectively mitigate the impact during flood events and ensure that cities do not experience flooding.

However, research indicates that these flood-prone areas often create a false sense of security among people, as urban managers rely on structural measures that can show significant improvements in the short term. This leads to the misconception that flood control projects can provide absolute protection while failing to recognize that, in the context of long-term changes due to climate change, the protective standards of flood control projects and facilities have technical and cost limitations. The reliance on structural measures can shift people's perception of flood risk, potentially accelerating development in high-risk areas and ultimately increasing long-term risk. This contradictory phenomenon is referred to as the "levee effect" (Burby,2006; Collenteur et al., 2015).

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report emphasizes that future adaptation efforts must shift from short-term disaster response and incremental adjustments to the current system to long-term transformative adaptation that can change the fundamental characteristics of social-ecological systems. This also signifies the importance of transitioning flood risk management from structural to non-structural measures. Risk perception, as a subjective assessment of the likelihood of threats and potential damages(Grothmann & Reusswig, 2006)and reduce the need for public risk management. But, research on the determinants of private households' prevention of damage by natural hazards is rare, especially in Germany. To answer the question of why some people take precautionary action while others do not, a socio-psychological model based on Protection Motivation Theory (PMT , is considered a core element in formulating effective flood management strategies (Kellens et al., 2011). Human dynamic behaviour plays a crucial role in flood risk management, and the dynamic changes in risk perception, attitudes, and adaptive behaviour are areas that current research urgently needs to deepen (Bubeck et al., 2012).

Although the concept of the levee effect has been widely discussed, the universality of its impact on changes in risk perception and whether it creates a similar "illusion" for everyone still requires further exploration. Individual differences in conditions, such as education level, age, socioeconomic background, and past disaster experiences, have been shown to significantly influence personal risk assessment(Babcicky & Seebauer, 2017; Grothmann & Reusswig, 2006). In past discussions of the levee effect, it has often been directly concluded that flood control and disaster reduction measures lead to a decrease in risk perception, with less consideration given to how individual differences may play a moderating role in risk perception. As a result, the varying degrees to which flood control measures affect risk perception across different groups may have been overlooked, or it may not be the primary factor influencing their risk perception.

This study aims to re-examine the relationship between the levee effect and risk perception, considering individual differences in areas potentially affected by the levee effect. It explores the cognitive differences among various groups when facing flood risks to develop appropriate adaptive strategies for different groups. The empirical research will be conducted in Tainan, Taiwan. First, a systematic literature review will be carried out to organize relevant risk perceptions and risk measurement indicators from past flood management, which will inform the design of the questionnaire. Second, spatial analysis will be used to identify potential levee effect areas, and a stratified random sampling survey will be conducted in those areas. The survey results will be analysed through cross-analysis to compare the differences in risk perception and influencing factors among different groups. The goal is to promote more precise risk management and flood prevention behaviours in the future, enabling effective responses to flood risks. This can serve as a reference for adaptive management and planning policies, enhancing residents' awareness of flood risks.

## 2. Discussion on the levee effect and flood risk

### 2.1 Basic Concepts of Disaster Risk Management

This study takes “disaster risk and risk management” as the core perspective for exploring flood disasters. First, it follows the definitions provided by the United Nations Office for Disaster Risk Reduction (UNISDR, 2016) to define the core concepts.

**Table 1:** Definition of related terms

<table>
<tr><td rowspan="5">Disaster Risk</td><td>The potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society, or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity.</td></tr>
<tr><td>1. Hazard: A dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury, or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.</td></tr>
<tr><td>2. Vulnerability: The conditions determined by physical, social, economic, and environmental factors or processes that increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards.</td></tr>
<tr><td>3. Exposure: The situation of people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas. Measures of exposure can include the number of people or types of assets in an area.</td></tr>
<tr><td>4. Capacity: The combination of all the strengths, attributes, and resources available within an organisation, community, or society to manage and reduce disaster risks and strengthen resilience. Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.</td></tr>
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| | |
|---|---|
| Hazard | A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. The mere occurrence of a flood event (hazard) does not constitute a flood disaster; only when the flood causes actual damage to social or environmental systems, such as loss of life or property, can it be called a disaster. |
| Residual Risk | The disaster risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. |
| Disaster Risk Management | The application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk, and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. |
| Disaster Risk Reduction, DRR | Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development. Disaster risk reduction can be divided into structural, which includes the application of engineering techniques such as dams and levees, and non-structural, which includes building codes, land-use planning laws and their enforcement, research and assessment, information resources, and public awareness programmes. |

2.2 The Levee Effect in Flood-Prone Areas
The "Levee Effect" is a phenomenon of concern in the field of flood management, originating from White's (1958) study on land use in the floodplains of the United States. White pointed out that while flood control projects reduce the frequency of flood disasters, they also create a false sense of security, which encourages urban development and the concentration of population and assets in floodplain areas, thereby forming new potential sources of risk (White, 1958). In the context of industrialization , the sense of security provided by flood control projects has led to the gradual neglect of the fact that "engineering measures have their limits, and residual risks always exist". Therefore, the continuous increase in flood damage is primarily not due to an increase in the frequency or intensity of floods, but rather because flood control projects enhance the value of floodplain locations, leading to urban expansion and increasing the exposure of assets and populations, which in turn raises long-term flood disaster risks(Deeming et al., 2012) .

The "false sense of security" created by flood control projects often stems from an overreliance on these engineering solutions, leading to accelerated land development and urbanization. Under this perception, originally protected areas gradually transformed into "safe" areas, resulting in increased population migration and more prosperous commercial activities (Burby, 2006). Parker and Tapsell (2009) describe this phenomenon as the "Escalator Effect," which means that while flood control measures can effectively manage high-frequency, low-intensity flood events, they may significantly increase disaster losses when low-frequency, high-intensity events occur. Burby (2006) uses Hurricane Katrina's devastating impact on New Orleans as an example, emphasizing that the government's structural disaster reduction strategies and insurance systems have facilitated the expansion of high-risk areas, creating the "Safe Development Paradox," which ultimately exacerbates the severity of disasters.

The levee effect is not limited to the levees themselves; any measures taken through flood control projects to reduce disaster risks may produce similar effects. This phenomenon is commonly observed in floodplains with a "lack of effective land use regulation" (Parker, 1995). Research by Kuo et al. (2015) shows that residents of Benhe Village in Kaohsiung, due to the effective flood reduction provided by a retention pond during Typhoon Morakot, became complacent about subsequent disaster preparedness. As a result, they faced greater losses during Typhoon Fanapi, confirming that other types of structural flood control measures can also lead to similar outcomes.

In the context of extreme rainfall events caused by climate change, areas with high exposure may face catastrophic losses that exceed expectations when encountering extreme flood events that surpass the design standards of flood control. These areas may experience more severe socio-economic impacts and long-term population effects than unprotected regions.

Therefore, the core issue of the levee effect, in addition to the lack of appropriate and continuous land use management and spatial planning constraints, also highlights the complex dynamic relationship between human society and natural hydrological systems, referred to as "coupled human-water systems." However, existing flood risk assessments often overlook the interactions between human behaviour and hydrological systems, failing to capture the long-term impacts of policies on behaviour and risk dynamics (Kuhlicke et al., 2020)we argue that these changes represent a wider behavioral turn in flood risk management (FRM. Consequently, flood prevention strategies cannot solely rely on single structural measures. From a long-term perspective, contemporary flood risk management must go beyond engineering thinking and shift towards a more comprehensive understanding of risk and adaptive strategies.

2.3 Characteristics of Flood Risk Due to Levee Effects

2.3.1 Harm Reduction

Structural flood control measures primarily target the "harm" aspect of risk, directly reducing potential casualties, property losses, and socio-economic activities by decreasing flood events. As illustrated in Fig. 1, the Farmer's curve is used in disaster risk reduction research to illustrate the relationship between the frequency and intensity of disaster events, which follows a power law distribution and exhibits an inverse relationship. After the construction of flood control projects, the actual disasters that occur will be low-frequency but high-intensity, harmful events. Since such events occur less frequently, there will be a phenomenon of reduced flooding and improvement in the short term (Renaud et al., 2013).

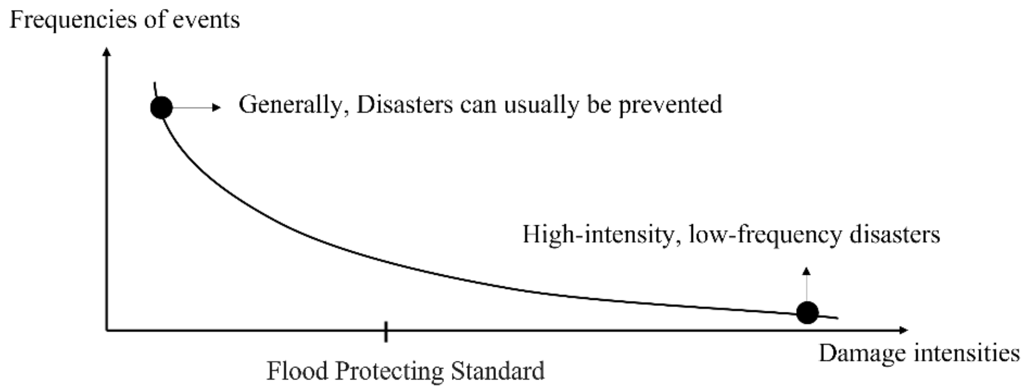


**Fig. 1.** The Relationship Between Farmer's Curve and Disaster Events

2.3.2 Spatial Concentration and Increased Residual Risk

As flood control infrastructure becomes more complete, floodplain areas may attract more population and development activities, leading to a concentration of risks and the emergence of residual risks. In disaster risk management, residual risk is defined as "the disaster risk that cannot be managed even after effective measures to reduce disaster risk have been taken" (UNISDR, 2016).

The causes of residual risk, based on its operational definition, can be divided into two perspectives: one is that "perfect engineering design and maintenance can eliminate the risks of flood control projects," and the other is that "there are limits to engineering design standards, and residual risks will inevitably exist in flood control projects" (Chang & Hsu, 2021; Domeneghetti et al., 2015; Pinter et al., 2016)

There is still a lack of understanding and management research on addressing residual flood fronts in studies related to levee effects. However, in flood risk management, residual risks are still challenging to identify independently, which slows down the transfer of knowledge between cases(Wang et al., 2024).

2.3.3 Conceptual Framework and Influencing Factors of Flood Risk Perception
In the integrated flood risk management framework, public risk perception is a key factor in promoting effective disaster preparedness behaviours and enhancing community resilience. Risk perception is not merely a passive reception of objective disaster data; rather, it is a complex and subjective psychological construction process that involves individuals' interpretation and evaluation of the likelihood of a disaster occurring and its potential consequences (Kellens et al., 2011).

Individual flood risk perception is a dynamic and multifaceted process. Traditional approaches often fail to account for the interactions between physical and human systems (Fig. 2, top). They thus cannot fully capture the evolving human responses to and interactions with levee effects. Changes in flood risk should be understood as the result of coupled dynamics between hydrological and social systems, involving continuous interactions and feedback loops between society and the physical environment. The formation and evolution of this perception are influenced by a wide range of internal and external factors (Fig. 2, bottom)(Di Baldassarre et al., 2015), and the heterogeneity of these factors forms the basis of individual differences in flood risk perception(Bubeck et al., 2012; Lechowska, 2018).

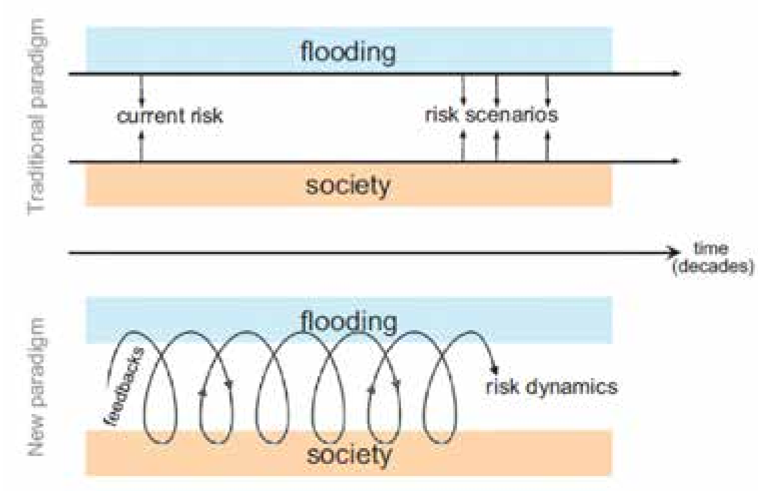


Fig. 2: Changes in Flood Risk
(Di Baldassarre et al., 2015)

Flood Risk Perception Influencing Factors :
a. Experiential Factors
An individual's direct or indirect experience with flooding is one of the most significant influences on risk perception. People who have experienced floods tend to perceive a higher level of threat, exhibit a stronger motivation to take adaptive actions, and consider themselves more vulnerable(Grothmann & Reusswig, 2006)and reduce the need for public risk management. But, research on the determinants of private households' prevention of damage by natural hazards is rare, especially in Germany. To answer the question of why some people take precautionary action while others do not, a socio-psychological model based on Protection Motivation Theory (PMT.

However, empirical studies also show that experience-based risk perception is not fixed—it tends to diminish over time, mainly when no subsequent disasters occur. Individuals may forget past impacts and underestimate future risks (Bubeck et al., 2012; Wachinger et al., 2013).

b. Socio-demographic Characteristics
Variables such as age, gender, education level, socioeconomic status (e.g., household income, occupation, property value), duration of residence, and place of household registration have all been widely shown to significantly influence personal risk assessments (Babcicky & Seebauer, 2017; Lechowska, 2022). For example, individuals with higher education levels are generally better at understanding complex risk information and the scientific basis of flood control infrastructure. Additionally, individuals from different socioeconomic backgrounds vary in vulnerability, resource access, and coping capacity.

c. Geographic and Environmental Exposure
The physical proximity of individuals to potential flood hazards, such as rivers or coastlines, the elevation of their location, and whether they live in officially designated floodplains or hazard-prone areas directly affect how exposed they perceive themselves to be (Ludy & Kondolf, 2012). These objective geographic features are transformed into subjective perceptions through everyday lived experience.

d. Knowledge and Information Access
An individual's knowledge of floods, understanding of the function and limitations of local flood control infrastructure, and awareness of official warnings and disaster preparedness information play a critical role in shaping risk perception. Effective risk communication must translate complex technical knowledge into accessible language for the public to reduce gaps in understanding (Kellens et al., 2011; Merz et al., 2009). Additionally, the credibility of information sources and the mode of dissemination (e.g., government, media, family and friends, or social media) significantly influence information acceptance and perception formation.

e. Social Influence and Social Capital
Social networks, community norms, trust in neighbors, and mutual assistance (i.e., social capital) indirectly influence individual risk perception by shaping how information is exchanged, how experiences are shared, and how collective behaviours form (Babcicky & Seebauer, 2017; De Dominicis et al., 2015). The perceptions of risk held by community members can reinforce each other and lead to collective interpretations.

f. Trust in Disaster Management Institutions
People tend to trust government agencies and experts perceived to possess disaster-related knowledge and to bear responsibility for reducing risk. However, the public often lacks a clear understanding of flood magnitudes and may not recognize the possibility of events exceeding infrastructure protection levels (Bradford et al., 2012). When land within protected areas is no longer officially recognized as flood-prone due to the presence of flood defenses, residents may continue living or working in such areas under the assumption that they are entirely safe. Governments, in turn, use tax revenue to protect these residents(Deeming et al., 2012). This mutually reinforcing relationship can increase public dependency on the government and reduce individual risk awareness.

These diverse and complex factors shape individuals' heterogeneous perceptions of flood risk. This subjectivity explains why the public's perception of risk often differs from the objective risk assessments made by experts based on scientific data(Glaus et al., 2020) . Research on the "risk perception paradox" indicates that people's judgments about risk are often influenced by intuition, emotions, and cognitive biases rather than being entirely rational; disaster risk perception is often composed of complex causal relationships and multiple intervening factors. For example, it is commonly believed that a higher perception of risk leads individuals to take protective actions. However, this is not necessarily true and still depends on various contextual factors, particularly personal memories of past losses or imaginations of disasters, which can influence individuals' actions.

At the same time, people's trust in managers also affects their risk perception (Wachinger et al., 2013). The study by (Ludy & Kondolf, 2012) pointed out that even when most residents are well-educated professionals, new development projects in flood-prone areas can lead them to be unaware of the real flood risks they face, believing instead that a once-in-a-hundred-years levee can protect them from all floods. Therefore, the perception of flood risk is a complex process that requires a deep understanding of the interactions among these influencing factors.

## 3. Methodology

### 3.1 Research design-case study strategy

This study adopts a case study approach that integrates qualitative and quantitative methods, with Tainan City in Taiwan as the empirical study area. As one of the core metropolitan cities in southern Taiwan, Tainan has experienced rapid urbanization and has invested significantly in flood mitigation infrastructure, conditions that make it a likely context for the emergence of the levee effect. Given that the levels of urban development and flood vulnerability vary across districts in Tainan, the study focuses on areas that have experienced severe flood events and exhibit high degrees of urbanization and centrality.

The quantitative analysis aims to assess changes in residual flood risk over time. Spatial analysis techniques are employed to identify the clustering of flood-prone points and examine changes in their spatial distribution. Specifically, global Moran's I is first applied to determine whether spatial clustering of flood events exists within specific periods. This is followed by using Local Indicators of Spatial Association (LISA) to explore local variations in spatial patterns, identifying the spatial relationships between each unit and its neighboring areas. These analyses define the potential spatial scope of the levee effect, within which qualitative questionnaire surveys are subsequently conducted.

### 3.2 Background of the study area

After the major infrastructure works under Tainan City's 2006 "Flood-Prone Area Mitigation Project" were completed, significant changes in land use and urban development patterns were observed in certain areas, such as Yusheng Village in the East District and Sanjia Village in Rende District. These areas have since been identified as potential zones exhibiting the levee effect (Chang & Hsu, 2021).

In recent years, due to the increasing influence of extreme climate events, statistics from the Water Resources Bureau show that rainfall in 37 districts of Tainan has exceeded the design standards of local drainage systems, resulting in flooding. Moreover, compared to previous typhoon events, the cumulative rainfall over 1-hour, 3-hour, and 24-hour periods in flatland areas has surpassed the levels recorded during Typhoon Morakot—the most recent major flood disaster in Taiwan (see Table 1). This indicates that areas potentially affected by the levee effect also face residual flood risk issues.

**Table 2**. Accumulated Rainfall from Major Precipitation Events in Tainan (mm)

| Maximum Accumulated Rainfall | 2009 Typhoon Morakot | | 2018/08/23 Heavy Rain | | 2024 Typhoon Koinu | |
|---|---|---|---|---|---|---|
| | plain | Mountain area | plain | Mountain area | plain | Mountain area |
| 1 hour | 86.0 | 107.5 | 77 | 92.0 | 120.0 | 105.5 |
| 3 hour | 159.0 | 286.0 | 173 | 195.0 | 205.0 | 191.0 |
| 6 hour | 245.0 | 417.5 | 294 | 316.5 | 276.0 | 294.0 |
| 12 hour | 391.5 | 692.5 | 438 | 458.0 | 370.5 | 535.0 |
| 24 hour | 594.0 | 1089.5 | 735 | 843.5 | 567.5 | 919.0 |
| Total Accumulated Rainfall | 799.5 | 2316.0 | 827 | 923.5 | 881.0 | 1340.5 |

Source: Tainan City Government

3.3 Data collection and analysis

3.3.1 Questionnaire Design

This study draws upon existing literature on flood risk perception to design a comprehensive questionnaire that integrates various dimensions of how the levee effect influences risk perception. The questionnaire is structured into five main sections ( Table 3).

In addition, given that flood control infrastructure and flood-related adaptive measures significantly impact both the development and risk profiles of flood-prone urban areas, a mismatch between the expected outcomes of these measures and the adaptive behaviours of individuals may lead to what is referred to as the "adaptation gap" (Aerts et al., 2024). Therefore, this study incorporates the concept of adaptation constraints into the questionnaire to further explore the extent to which residents are willing to accept flood risks and how much effort they are prepared to invest in mitigating them. This approach allows for an in-depth examination of the potential factors that contribute to the emergence of adaptation gaps.

3.3.2 Sampling Method

The questionnaire survey will be conducted in areas identified through spatial analysis as potentially affected by the levee effect. This study adopts a stratified random sampling approach to ensure the representativeness of the responses and the generalizability of the findings. The sampling design aims to adequately include geographically distinct strata related to the levee effect, specifically, (1) areas where flooding has been alleviated but residual risk has increased, and (2) areas where both residual risk and flood severity remain high. At least 400 residents will be surveyed, with 200 respondents selected from each stratum, to ensure sufficient data coverage and diversity.

3.3.3 Data Analysis Method

This study employs cross-tabulation analysis as an initial exploratory tool to examine the distributional differences of key categorical variables across different spatial strata related to the levee effect. This analysis provides critical preliminary insights , enabling a more comprehensive understanding of how the levee effect influences residents' risk perceptions and adaptive behaviours.

**Table 3.** Questions and their justification

| Category | Question | Purpose |
|---|---|---|
| Flood Experience | During your time living in this village, have you ever experienced flooding caused by typhoons or heavy rainfall? | To understand whether respondents have experienced flood disasters in the past, and how these experiences have influenced their daily life and perception of flood severity. |
| | Have these flood events caused inconvenience in your daily life (e.g., health or property damage, commuting disruptions)? | |
| | How long has it been since you last experienced a flood disaster? | |
| | In recent years, Tainan City has implemented several flood mitigation projects. How has the severity of flooding near your home changed? | |
| | To what extent has flooding impacted your quality of daily life? | |

| | | |
|---|---|---|
| Perceived Impact of Flooding | To what extent do you think flooding affects your personal safety? | To assess the respondent's subjective perception of the potential impacts of flooding, especially its effects on personal safety, property, and quality of daily life. |
| | To what extent do you think flooding affects your personal property? | |
| | To what extent do you think flooding affects your quality of daily life? | |
| Flood Risk Perception | I am aware that I live in a flood-prone area. | To explore respondents' subjective assessment of flood risk, including awareness of flood-prone conditions, perceived future risk, the impact of flood defenses, and confidence in individual and public preparedness. |
| | I believe there is a high possibility of flooding in my residential area in the future. | |
| | I feel less worried about floods because of the presence of flood control measures (e.g., levees). | |
| | Since the construction of flood control measures (e.g., levees), I believe the likelihood of flooding in my area has decreased. | |
| | I understand the flood prevention actions I can take in advance. | |
| | I believe that preventive actions taken before a flood can reduce flood-related losses. | |
| | I believe the government has the capacity to effectively manage flood disasters. | |
| | I believe the government provides sufficient information about the flood risks in my residential area. | |
| | I believe the government will take all necessary measures to protect me from flooding. | |
| | I believe the government fully considers flood risks when approving new developments or planning land use. | |

| | | |
|---|---|---|
| Flood Risk Acceptability | What level of flood risk do you personally find acceptable? | To assess the respondent's willingness to accept various levels of flood risk, how much they are willing to invest to reduce risk, and their sense of responsibility in managing flood risk. |
| | If your home is located in a flood-prone area, how much would you be willing to spend to reduce flood risk? | |
| | Do you believe individuals have a personal responsibility to take action to reduce flood risk? | |
| | Under what circumstances would you consider relocating from your current residence? | |
| Socio-demographic Characteristics | What is your age? | To collect basic demographic information for analyzing how individual heterogeneity influences flood risk perception and behaviour. |
| | What is your gender? | |
| | How long have you lived in this area? | |
| | What is your highest level of education? | |
| | What is your approximate monthly household income? | |

**Expected Results**

4.1 Risk Perception Heterogeneity under the Levee Effect

This study anticipates that individual flood experience, socio-demographic characteristics, and the level of trust in government-led flood management measures will significantly influence perceived flood risk. Through stratified random sampling, the study distinguishes between two types of areas: those where flooding has been alleviated but residual risk has increased and those where both flood severity and residual risk remain high. By comparing different groups, the study seeks to identify variations in flood experience perception, trust in government, and overall risk perception levels. This serves as a preliminary response to the hypothesis that the impact of levee effects on risk perception is not uniformly consistent across all populations.

4.2 Preliminary Insights on "Adaptation Gap"

This study incorporates the concept of adaptation limits in the questionnaire design, aiming to explore the public's acceptable level of flood risk and their willingness to make efforts to mitigate that risk. It is anticipated that potential cognitive factors leading to the "adaptation gap" will be identified from the collected data. These factors may include, but are not limited to, overestimating the effectiveness of structural flood control measures, underestimating personal responsibility, or overly relying on government.

**5. Conclusion**

This study addresses the long-standing oversight of individual heterogeneity in flood risk management by re-examining the complex interplay between the levee effect and flood risk perception. The potential distinctions of the levee effect are categorized into two types: "flooding situations are mitigated, but residual risk increases, and "flooding situations remain severe while residual risk continues to rise. This categorization reflects the diverse impacts of levee construction on actual flood scenarios under varying circumstances and explores the heterogeneity in flood risk perception among residents living in these environments.

Through empirical investigation, this study aims to uncover how residents' flood experiences, socio-demographic characteristics, and levels of trust in government disaster prevention measures collectively influence their perception and assessment of flood risk across various risk environments shaped by structural flood control interventions. However, merely enhancing risk awareness may be inadequate; if residents have a high tolerance for risk, they may still hesitate to take action despite acknowledging the threat. Therefore, it is crucial to examine variations in risk tolerance to gain a deeper understanding of the formation of adaptation gaps.This research aims to identify the social, psychological, and cognitive mechanisms underlying these heterogeneities, moving beyond the limitations of traditional "one-size-fits-all" flood control strategies. The goal is to develop differentiated policy designs tailored to groups with varying characteristics in the future. This approach will facilitate more precise risk management and flood prevention behaviours, serving as a reference for adaptation management and planning strategies.

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