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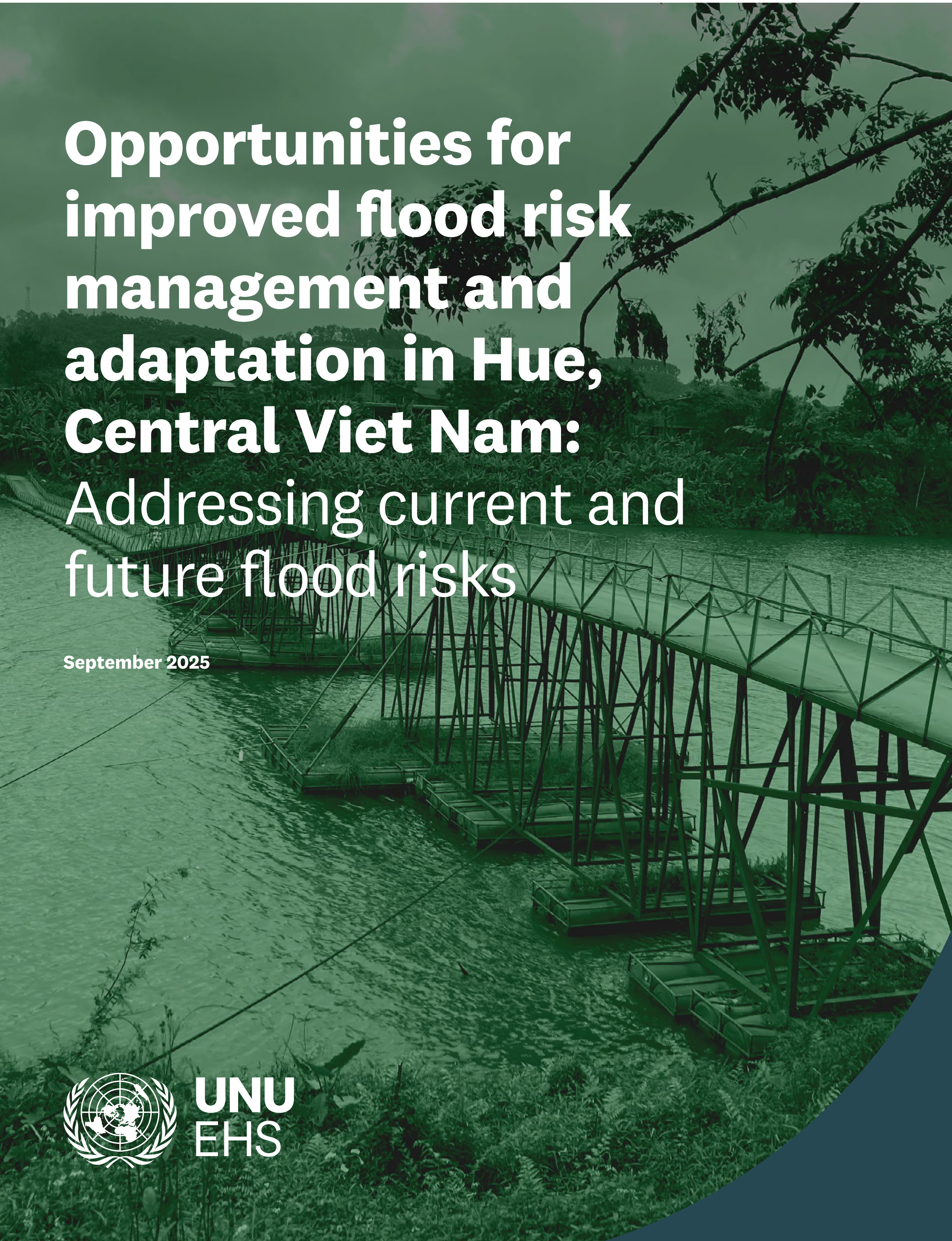

Opportunities for improved flood risk management and adaptation in Hue, Central Viet Nam: Addressing current and future flood risks

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FLOOD ADAPT VN

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Glossary

Climate change adaptation refers to the process of adjustment to actual or expected climate change effects. In the context of this report, adaptation measures seek to avert or minimize harm from flood risks. They may be institutional, behavioural, social, structural/physical and/or technological in nature or may be ecosystem-based adaptation measures.

Ecosystem-based adaptation refers to the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change – in the context of this report, floods. These measures are designed in a way that specifically addresses the goal of climate change adaptation.

Exposure refers to all people, physical structures, natural environment and other relevant elements or assets in a location that overlap with the flood hazard in a spatially explicit manner. Hence, high flood exposure means that many people and assets are expected to be affected by flood hazards.

Flood hazard refers to inundation with water of land surfaces (including urban areas, agricultural land, etc.) that are not usually covered by water. The inundation is limited to a specific duration. It can vary in terms of intensity (i.e. inundation height and duration) and in terms of frequency or likelihood (i.e. the expected or observed number of occurrences over a given period, sometimes also referred to as "return period"). High flood hazard levels hence refer to intense and frequent inundation. Flood hazards are also commonly referred to as "flooding" or "floods". The types of floods depend on the cause: fluvial, pluvial and coastal flooding. Fluvial flooding occurs when a river or stream experiences overflow, often as a result of excessive rainfall. Pluvial flooding occurs when high rainfall intensities result in surface run-off, often exceeding drainage capacities of a given area. Coastal flooding occurs when storm surges, strong winds and high tides push seawater onto land.

Flood impact refers to adverse flood-induced impacts; for example, flood-related fatalities and severe injuries are usually considered a key flood impact. For this report, four key flood impacts with critical importance for the local context have been identified.

Flood risk is the outcome of the interaction of vulnerability, exposure and flood hazard, expressing the potential for impacts on people, physical structures and the natural environment in a given area. The higher the flood risk, the more impacts are expected.

Flood risk drivers are factors that directly influence flood risk, through its three subcomponents: hazard, exposure and vulnerability. For example, surfaces with a low infiltration rate can be considered an important risk driver as they increase flood hazard, while the inability to swim contributes to high vulnerability, thereby also driving flood risk.

Flood risk management is a holistic approach that aims to protect societies and safeguard economies, infrastructure and the environment from flood impacts. This is done through a combination of measures that involve assessing, reducing and managing disaster risk to build resilience across different timescales (from early action to long-term adaptation).

Representative Concentration Pathways (RCPs) are greenhouse gas concentration trajectories used in climate modelling to project future climate conditions. They represent possible pathways of expected greenhouse gas emissions. The most commonly used RCPs include RCP2.6 (strong mitigation, low emissions), RCP4.5 (moderate emissions, stabilization), RCP6.0 (higher emissions, stabilization) and RCP8.5 (high emissions, "worst case scenario"). These trajectories help scientists assess potential climate impacts under these different emission level scenarios.

River basin is an area of land defined by a shared natural drainage of water. Basins are often characterized by a series of streams merging into a larger river with a common outflow, often a body of water such as a lake or sea.

Root causes are factors that affect risk drivers and thereby indirectly affect flood risk. Root causes are usually underlying circumstances and processes that are difficult to change. For example, climate change is a substantial root cause of flood risk as it alters rainfall, affecting flood hazard levels, or alters human health conditions, affecting vulnerability to floods.

Scenario refers to a plausible future pathway under specific conditions. In the present report, scenarios are used to explore possible futures under different conditions, such as different levels of emissions (RCPs) or socioeconomic development (SSPs). Scenarios help policymakers and researchers evaluate potential risks and adaptation strategies.

Shared Socioeconomic Pathways (SSPs) are narratives describing different potential scenarios for global socioeconomic development that could influence greenhouse gas emissions and climate adaptation efforts. They are independent of RCPs but can be combined with them to model climate change impacts. The main pathways are SSP1 (“Sustainability”), SSP2 (“Middle of the Road”), SSP3 (“Regional Rivalry”), SSP4 (“Inequality”), and SSP5 (“Fossil-fuelled Development”). Each of these SSPs describes possible societal changes that affect emissions, adaptation capacity and vulnerability.

Vulnerability refers to the degree to which exposed people and assets are susceptible and capable of coping with and adapting to flood risk impacts. If exposed people are highly vulnerable, severe adverse impacts are to be expected.

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Tóm tắt

Thành phố Huế - miền Trung Việt Nam, đang đối mặt với nhiều thách thức nghiêm trọng do tình trạng lũ lụt thường xuyên, và ngày càng trầm trọng hơn do tác động của biến đổi khí hậu, quá trình đô thị hóa nhanh và vấn đề suy thoái môi trường. Dựa trên những phân tích từ Báo cáo Rủi ro FloodAdaptVN: "Rủi ro lũ lụt tại Huế, miền Trung Việt Nam" (Sett và cộng sự, 2025) - nghiên cứu các nguyên nhân gốc rễ và các yếu tố tác động chính đến rủi ro và ảnh hưởng của lũ lụt, báo cáo này chuyển hướng sang các cơ hội giải pháp có thể hành động để thúc đẩy quản lý rủi ro lũ lụt và thích ứng với biến đổi khí hậu tại Huế, miền Trung Việt Nam.

Báo cáo này xác định và đánh giá các nhóm giải pháp cho quản lý rủi ro lũ lụt và thích ứng với biến đổi khí hậu, đồng thời chứng minh cách các biện pháp này có thể giải quyết các thách thức hiện tại liên quan đến lũ lụt ở Huế. Quá trình đánh giá tập trung vào các điểm can thiệp cụ thể, gắn liền với các rủi ro chính được xác định thông qua phương pháp tiếp cận có sự tham gia dựa trên báo cáo cáo Rủi ro FloodAdaptVN: "Rủi ro lũ lụt tại Huế, miền Trung Việt Nam" (Sett và cộng sự, 2025), đồng thời được bổ sung bằng các đánh giá dựa trên tài liệu về tiềm năng cho quản lý rủi ro lũ lụt và thích ứng với biến đổi khí hậu, các cơ hội phát triển đi kèm, cũng như cân nhắc những đánh đổi cần thiết nhằm hỗ trợ quá trình ra quyết định dựa trên bằng chứng.

Những phát hiện chính:

- Có nhiều điểm khởi đầu để triển khai các giải pháp hỗ trợ nhằm cải thiện quản lý rủi ro lũ lụt và thích ứng với biến đổi khí hậu tại Huế. Ví dụ, khi áp dụng các biện pháp giải quyết đồng thời nhiều nguyên nhân gốc rễ gây ra rủi ro lũ lụt, hiệu quả giảm thiểu rủi ro sẽ được lan tỏa rộng hơn. Ngoài ra, phân tích theo lưu vực cho thấy từng giải pháp riêng lẻ, đặc biệt là các giải pháp dựa vào hệ sinh thái có thể được điều chỉnh để phù hợp với các khu vực địa lý khác nhau như vùng núi, vùng ven đô, khu vực đô thị và vùng ven biển. Cuối cùng, sự phức tạp của rủi ro lũ lụt ở Huế và tác động của lụt lên người dân cũng rất đa dạng, nên cần phải áp dụng nhiều biện pháp khác nhau, phù hợp với các mục tiêu quản lý cụ thể và định hướng phát triển của địa phương.
- Tính đa dạng của các giải pháp, bao gồm giải pháp công trình, xã hội và thể chế, có tính bổ trợ, giúp giải quyết toàn diện tính phức tạp của rủi ro lũ lụt và tác động của biến đổi khí hậu.
- Lợi ích và đánh đổi của từng giải pháp là khác nhau. Mỗi giải pháp giải quyết một số nguyên nhân gốc rễ và tác nhân dẫn đến lũ lụt, do đó chúng có thể bổ trợ cho nhau. Trong bối cảnh đó, các giải pháp không chỉ giúp giảm thiểu rủi ro mà còn mở ra nhiều cơ hội phát triển, dù vẫn tiềm ẩn một số đánh đổi cần được cân nhắc.

Khuyến nghị chính:

- **Hiểu rõ rủi ro là yếu tố then chốt để xác định giải pháp phù hợp:** Để xác định các giải pháp phù hợp và giải quyết tận gốc vấn đề lũ lụt trên toàn lưu vực, cần hiểu rõ tính phức tạp của rủi ro lũ lụt, bao gồm mọi khía cạnh liên quan đến điều kiện kinh tế - xã hội cũng như xu hướng biến đổi khí hậu trong tương lai.
- **Xây dựng các nhóm giải pháp phù hợp với bối cảnh rủi ro lũ lụt và biến đổi khí hậu:** Việc đối mặt với tính phức tạp của rủi ro lũ lụt tại Huế, bao gồm nguy cơ, mức độ phơi nhiễm và tính dễ bị tổn thương, cùng với sự khó dự đoán về diễn biến và tác động của biến đổi khí hậu trong tương lai, đòi hỏi một cách tiếp cận tổng hợp. Cách tiếp cận này cần kết hợp giữa các giải pháp công trình, xã hội, thể chế và dựa vào hệ sinh thái, áp dụng trên toàn bộ từ vùng thượng nguồn, trung nguồn đến hạ nguồn. Những biện pháp được trình bày và đánh giá trong báo cáo này góp phần xây dựng một chiến lược quản lý rủi ro toàn diện thông qua việc phát triển các nhóm giải pháp. Khác với cách tiếp cận đơn lẻ, nhóm giải pháp này có khả năng xử lý hiệu quả nhiều nguyên nhân gốc rễ và các yếu tố thúc đẩy rủi ro lũ lụt, đồng thời xem xét các dự báo về biến đổi khí hậu và kinh tế - xã hội, giúp nâng cao hiệu quả tổng thể trong việc đạt được các mục tiêu quản lý rủi ro lũ lụt và thích ứng với biến đổi khí hậu.
- **Cần xác định thứ tự ưu tiên và triển khai các nhóm giải pháp:** Ở giai đoạn tiếp theo, các giải pháp cần được đánh giá và thảo luận thông qua một quy trình tham vấn có sự tham gia, dựa trên các mục tiêu đã đặt ra cho quản lý rủi ro lũ lụt

và thích ứng với biến đổi khí hậu, đồng thời xét đến mức độ khả thi trong điều kiện thực tế của địa phương. Việc xác định thứ tự ưu tiên cho các nhóm giải pháp sẽ là nền tảng cho việc lập kế hoạch các bước chi tiết để triển khai.

Báo cáo này là một phần của Dự án FloodAdaptVN – Phương pháp tiếp cận dựa vào hệ sinh thái để quản lý rủi ro lũ lụt nhằm phát triển đô thị theo hướng thích ứng và bền vững ở miền trung Việt Nam. Mục tiêu của dự án là giảm thiểu rủi ro lũ lụt tại khu vực miền Trung Việt Nam thông qua việc tích hợp các chiến lược thích ứng dựa vào hệ sinh thái vào khung quản lý rủi ro lũ lụt. Thông tin chi tiết có thể xem tại trang web dự án: https://floodadapt.eoc.dlr.de

Executive summary

Hue city, located in Central Viet Nam, faces significant challenges due to recurrent flooding, which is being exacerbated by climate change, rapid urbanization and environmental degradation. Building on insights from the FloodAdaptVN Risk Report *Flood risks in Hue, Central Viet Nam* (Sett and others, 2025), which examines the root causes and drivers of key flood risks and impacts, this report shifts the focus to opportunities for actionable solutions to advance flood risk management and adaptation in Hue, Central Viet Nam.

The report identifies and evaluates a set of diverse measures for flood risk management and climate change adaptation and demonstrates how these measures can address existing flood-related challenges within Hue. The evaluation of measures highlights the specific entry points for risk reduction in relation to key flood risks identified using a participatory approach in the FloodAdaptVN risk report, *Flood risks in Hue, Central Viet Nam* (Sett and others, 2025). This is complemented by literature-based assessments of the potential benefits for flood risk management and climate change adaptation, as well as additional development opportunities and potential trade-offs, to support evidence-based decision-making.

Key findings

- There are multiple entry points for implementing measures to support improved flood risk management and climate change adaptation in Hue. For example, implementing measures to address the diverse root causes of flood risk could have cascading benefits in reducing flood risk. In addition, catchment-based analysis has shown that individual measures can be tailored to be implemented in different geographical regions of Hue, such as mountainous, peri-urban, urban and coastal regions. This is particularly relevant for ecosystem-based measures. Lastly, the complexity of flood risk in Hue and the diverse flood impacts that affect its population require a variety of measures that could align with specific management objectives and government development goals.
- The variety of measures – such as structural/physical, social and institutional options – complement each other in addressing the complexity of flood risks and impacts of climate change.
- The different measures have specific benefits and trade-offs. Individual measures address different root causes and drivers of flood risks, and as such complement each other. Against this background, measures can also provide a variety of additional development benefits, although they also come with trade-offs.

Key recommendations

- **Understand risk as a key to identifying tailored solutions**

  An understanding of the complexities of flood risk, with all its dimensions and future climate and socioeconomic variability, is needed in order to identify tailored solutions to address the overall catchment.
- **Derive bundles of measures tailored to the risk and climate change context**

  Addressing the complexity of flood risks in Hue – encompassing hazard, exposure and vulnerability, as well as uncertainties due to climate and socioeconomic change – requires an integrated approach that combines structural, social, institutional and ecosystem-based measures across upstream, midstream and downstream areas. The measures presented and evaluated in this report, grouped into bundles, contribute to the development of a comprehensive risk management strategy. Unlike single-solution approaches, these effectively tackle a combination of diverse root causes and drivers of flood risks, taking climate change and socioeconomic projections into account, creating synergies and enhancing overall performance in achieving flood risk management and adaptation goals.

- **Prioritize bundles of measures to be implemented**

  As a next step, bundles of measures need to be evaluated and discussed using a participatory process, bearing in mind objectives set for flood risk management and climate change adaptation, as well as their feasibility in the local context. Prioritizing a bundle of measures forms the basis for planning the detailed steps to implement it.

This report is part of the project Integrating Ecosystem-based Approaches into Flood Risk Management for Adaptive and Sustainable Urban Development in Central Viet Nam (FloodAdaptVN). The project aims to reduce flood risks in Central Viet Nam by incorporating ecosystem-based adaptation strategies into flood risk management frameworks. More information can be accessed through the project website: https://floodadapt.eoc.dlr.de/

Lời tựa

Lũ lụt vẫn là một thách thức nghiêm trọng và tái diễn thường xuyên tại thành phố Huế, bắt nguồn từ đặc điểm địa lý của khu vực và ngày càng trầm trọng hơn bởi biến đổi khí hậu, đô thị hóa nhanh và suy thoái môi trường. Trong bối cảnh đó, Ban Chỉ huy Phòng chống thiên tai và Tìm kiếm cứu nạn nhận thấy sự cần thiết không chỉ là hiểu rõ các nguyên nhân gốc rễ gây ra rủi ro lũ lụt tại Huế, mà còn phải xác định các giải pháp khả thi và hiệu quả để giải quyết vấn đề này.

Báo cáo "Cơ hội cải thiện quản lý rủi ro và thích ứng với lũ lụt tại Huế, miền Trung Việt Nam", được xây dựng trên cơ sở kết quả của Báo cáo Rủi ro FloodAdaptVN "Rủi ro lũ lụt tại Huế, miền Trung Việt Nam". Trong khi báo cáo trước đó đã giúp làm rõ các yếu tố thúc đẩy và tác động của rủi ro lũ lụt tại Huế, ấn phẩm mới này mang lại sự chuyển hướng kịp thời và cần thiết sang việc đề xuất các giải pháp cụ thể nhằm giảm thiểu rủi ro lũ lụt và thích ứng với biến đổi khí hậu.

Báo cáo trình bày nhiều giải pháp kỹ thuật, xã hội và thể chế, đồng thời cung cấp đánh giá hữu ích về cách các giải pháp này có thể hỗ trợ công tác giảm thiểu rủi ro lũ lụt trong bối cảnh của thành phố Huế. Bằng việc thúc đẩy tích hợp nhiều loại giải pháp như một chiến lược toàn diện để đối phó với rủi ro lũ lụt, báo cáo đưa ra định hướng để giải quyết đồng thời nhiều nguyên nhân gốc rễ và yếu tố gây ra rủi ro lũ lụt.

Với vai trò là cơ quan chịu trách nhiệm điều phối các nỗ lực phòng chống và ứng phó thiên tai tại thành phố Huế, chúng tôi đánh giá cao báo cáo này như một đóng góp quan trọng cho công việc của mình. Báo cáo sẽ hỗ trợ chính quyền địa phương, các phòng ban chuyên môn và các đối tác liên quan trong việc xác định và triển khai các giải pháp thực tiễn phù hợp với các mục tiêu phát triển của tỉnh và góp phần bảo vệ đời sống của người dân.

Đặng Văn Hòa

Chánh Văn phòng Ban Chỉ huy Phòng chống thiên tai và Tìm kiếm cứu nạn thành phố Huế, Việt Nam

Foreword

Flooding remains a serious and recurring challenge in Hue city, driven by the region's geographical characteristics and increasingly intensified by climate change, rapid urbanization and environmental degradation. In this context, the Steering Committee for Disaster Prevention and Search and Rescue recognizes the need not only to understand the root causes of flood risk in Hue, but also to identify viable and effective measures to address the flood issue.

This new report, *Opportunities for improved flood risk management and adaptation in Hue, Central Viet Nam,* builds on the findings of the earlier FloodAdaptVN risk report *Flood risks in Hue, Central Viet Nam*. While the previous report helped to clarify the underlying drivers and impacts of flood risk in our region, this new publication offers a timely and much-needed shift in focus towards concrete measures for flood risk reduction and climate adaptation.

The report presents a wide array of structural, social and institutional measures, and provides a valuable assessment of how these can support flood risk reduction in the context of Hue. By promoting the integration of diverse types of measures as a comprehensive strategy to address flood risk, the report offers guidance on how to simultaneously address multiple root causes and drivers of flood risk.

As the agency responsible for coordinating disaster prevention and response efforts in the city of Hue, we welcome this report as an important contribution to our work. It will support local authorities, technical departments and development partners in identifying and implementing practical solutions that align with the province's development goals and help safeguard the well-being of our citizens.

Đặng Văn Hòa

Chief of the Office of the Steering Committee for Natural Disaster Prevention and Search and Rescue of Hue City, Viet Nam

1. Introduction

In recent decades, climate, socioeconomic and environmental change have exacerbated flood risks in Central Viet Nam, leading to severe adverse impacts (Ngo-Duc, 2014; Sett and others, 2025). In Viet Nam, flooding causes approximately 97 per cent of the country's annual losses from climate-related disasters (Nguyen and others, 2021a). From 2004 to 2023, floods impacted over 9.7 million individuals, caused 1,843 fatalities and incurred direct damages amounting to US$4.1 billion (Nguyen and others, 2021b; CRED, 2023). Urbanization following the Doi Moi reforms in 1986 has worsened flood risks in many cities, and this has been compounded by climate change, population growth and development of infrastructure in flood-prone zones (Sudmeier-Rieux and others, 2015; Huong and Pathirana, 2013). Central Viet Nam, particularly Hue city, faces significant flood risks exacerbated by the hydrology of the Huong River system and human interventions. Despite structural measures such as water reservoirs and floodgates, floods disrupt lives and hinder sustainable development, as highlighted by the devastating floods of 1999, 2020 and 2023, which resulted in substantial loss of life and damage to infrastructure (Nguyen and others, 2021a; van Dau and others, 2017).

Understanding past impacts, as well as current and future projections of flood risks, is crucial for effective resilience building. Against this background, extensive research in the context of the BMFTR-funded FloodAdaptVN project has analysed the root causes and risk drivers of the following four key flood impacts, which were identified for Hue during a participatory research process: (1) severe health impacts; (2) disruption of agricultural livelihoods (especially rice production); (3) disruption of transportation (individual mobility); and (4) water contamination with cascading effects on people and nature (Sett and others, 2025). In addition, the projection of future flood hazards and exposure under different climate change scenarios, as well as future vulnerabilities under different socioeconomic development pathways, have been modelled and assessed (Vu and others, 2025b). People, agriculture, transportation and water quality are at high flood risk throughout Hue and this is expected to be further exacerbated due to climate change and new urban development. These risks have interconnected root causes, which lead to cascading impacts (Sett and others, 2024). In the city of Hue, new urban and downstream peri-urban areas already face the highest aggregated risks, while core urban and upstream peri-urban areas experience slightly lower but still significant risk levels.

To effectively manage these risks and adapt to climate change, measures that address current and future risks from different angles should be implemented in Hue. In recent years, the municipal authorities have made concerted efforts to address the issue of urban flooding, including investing in building and managing hydropower dams to control flood levels, upgrading the city's drainage infrastructure and building extensive coastal protection walls (Vu and others, 2025a). However, these interventions have not yet reduced the flood risks faced by the city's residents, particularly those living in more urbanized and low-lying areas (Thanh Tu and Nitivattananon, 2011). Moreover, flood risks are expected to worsen due to future climatic trends (Sett and others, 2024; Redmond and others, 2015; MONRE, 2020).

This report addresses these challenges by exploring measures that can contribute to the management of current and future flood risks and adaptation to climate change in Hue. Specifically, it includes the following:

- an understanding of flood risks and their impacts in the study area (Chapter 3)
- an overview of measures identified for flood risk reduction and climate change adaptation (Chapter 4)
- an evaluation of measures in relation to their potential benefits for flood risk reduction and climate change adaptation, as well as additional development opportunities and trade-offs (Chapter 5)

The report closes with key recommendations on a way forward to implement solutions as part of a comprehensive flood risk management and adaptation strategy and to support evidence-based decision-making in Hue (Chapter 6).

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2. Hydrological and landscape characteristics of Hue

Hue is the key area of focus of the FloodAdaptVN project. Located in Central Viet Nam, the city encompasses several river basins and landscapes, which range from inland mountain forests in the west to flat coastal lands in the east (Figure 1). This chapter briefly describes hydrological and landscape characteristics relevant to flood risk management in Hue, complementing the more detailed description of the study area by Sett and others (2025).

To understand the flood risks and identify tailored solutions, we need to consider the hydrology at the catchment level and view the city of Hue as an element in an interconnected landscape, characterized by different ecosystems (Figure 1).

For this study, the landscape around Hue has been divided into four distinct but interconnected regions – the mountain, peri-urban, urban and coastal regions. These are described below and illustrated in Figure 2.

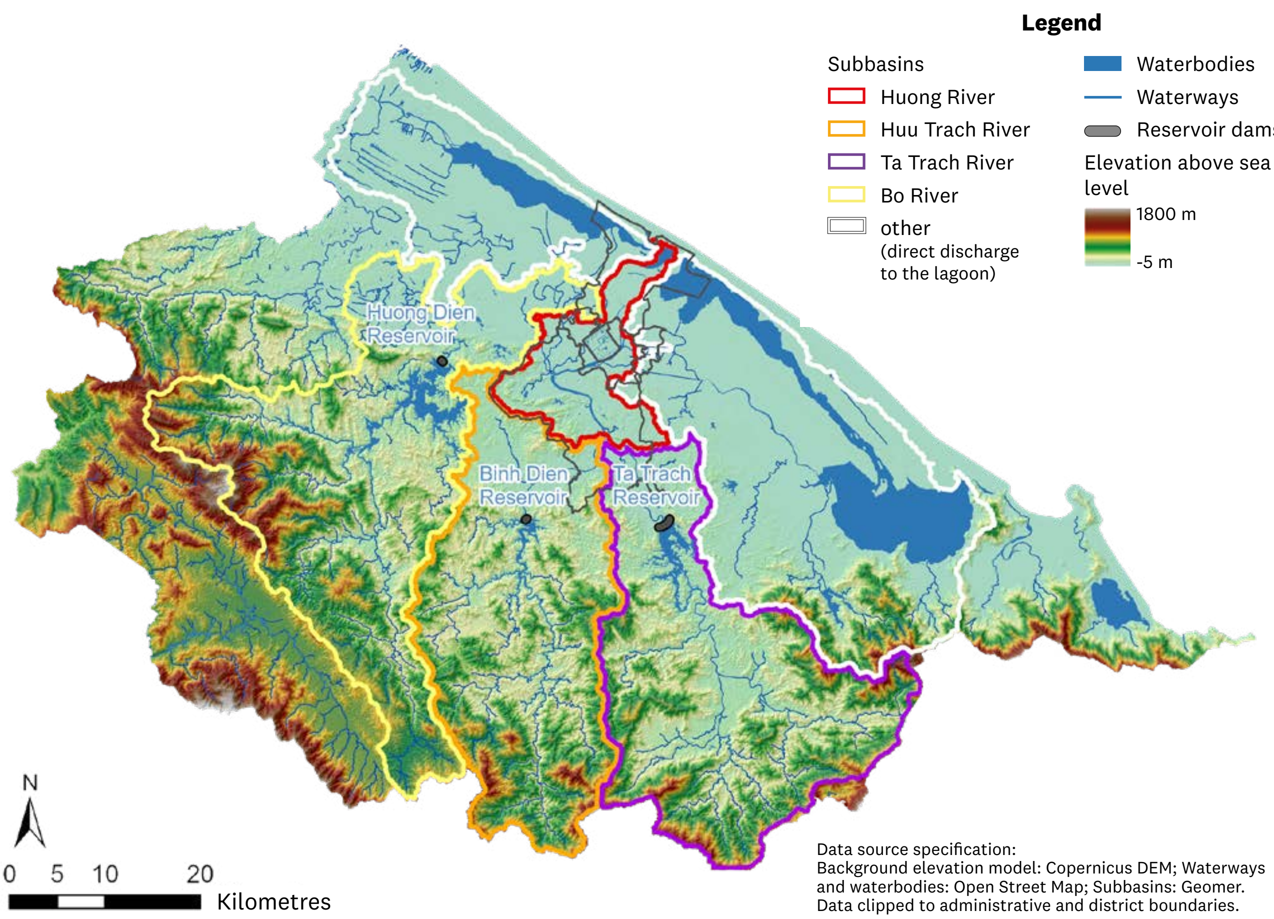

Figure 1: Relevant basins, topography, water reservoirs, waterways and lagoons in the city of Hue

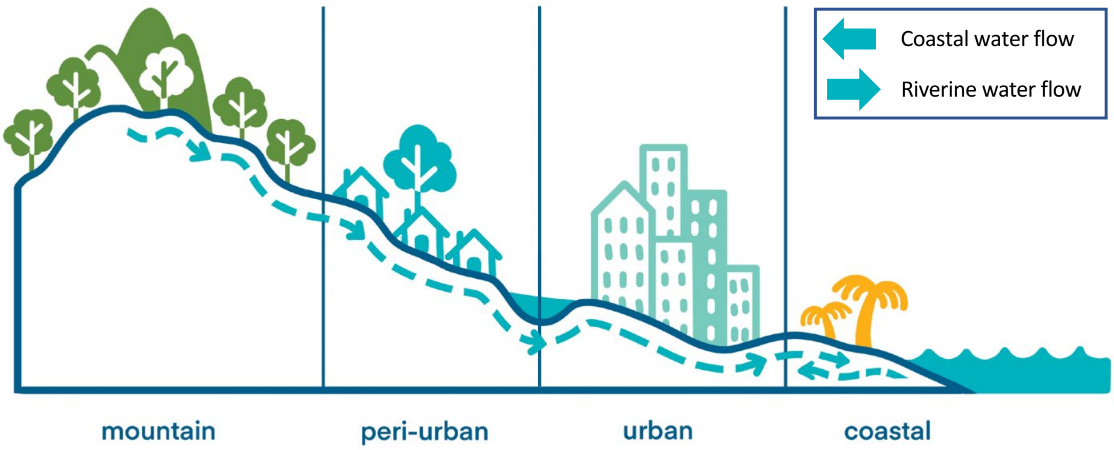

Figure 2: Transect representation of the Huong River basin, illustrating the mountain, peri-urban, urban and coastal regions and the direction of water flow influencing flood risk (Illustration: Caitlyn Eberle).

The upstream mountain region includes forests and water reservoirs, all of which are critical for flood risk management. The region's three main reservoirs – Huong Dien, Binh Dien and Ta Trach – regulate water flow but require careful management to balance flood control with hydropower generation (van Berchum and others, 2014). The area integrates the Bach Ma National Park and various types of forest (MARD, 2020), which help reduce floods by retaining rainwater and reducing erosion and run-off in the downstream areas (Lü and others, 2021; Reinhardt-Imjela and others, 2018). However, deforestation and land use changes threaten these key functions of ecosystems in the region (Pham and others, 2018). The upstream mountain region has little to no impact in the context of flooding (Sett and others, 2025) but provides a great opportunity for reducing the severity of fluvial flood hazards in downstream regions. The urban and peri-urban regions include the city of Hue and its surrounding areas. Urban areas are densely populated with impervious surfaces, while peri-urban areas transition towards rural regions, featuring more aquaculture and agriculture (Ruby, 2005; Capital Regional District, 2024). This region is the hotspot for impacts due to flooding and it is exposed to all three types of flood hazards: fluvial, pluvial and coastal flooding. The coastal region of Hue features diverse ecosystems, including mangroves, wetlands, sand dunes and coastal forests, which serve as habitats for various species (Tuan, 2012). These coastal ecosystems play a key role in flood risk reduction in acting as natural barriers to protect inland areas from coastal flooding by absorbing wave energy, preventing erosion and stabilizing landforms (McIvor and others, 2013; Bruland, 2008). This area also includes peri-urban settlements reliant on agriculture and aquaculture, both of which are vulnerable to floods, storms and sea level rise (Sett and others, 2025; Tuan, 2012). With a 128 km coastline, the city has significant coastal resources which support tourism, fisheries and local industries (van Tuyen and others, 2023). The Tam Giang Lagoon, the largest lagoon system in South-East Asia, spans 70 km with an area of 216 km², extending across five districts (McIvor and others, 2013; Bruland, 2008; van Tuyen, 1997).

The regions are hydrologically linked through the Huong, Huu Trach, Ta Trach and Bo River basins (Figure 1), which are key elements in flood hazard propagation and flood risks in the city. Changes in the condition of upstream areas (encompassing the mountain and peri-urban regions) affect the hydrology in downstream areas (the urban and coastal regions), which can either increase or decrease flood risks in the region. In addition, the conditions in the coastal region can increase or decrease flood risks in the city of Hue, mainly in the context of coastal flooding.

The regions vary significantly in extent and characteristics and are thus subject to different hydrological conditions. At the same time, they offer diverse entry points for implementing flood risk reduction and adaptation measures. Therefore, the recommendations related to specific measures in this report will be presented according to these regions.

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3. Flood risks and impacts

Hue city faces growing flood risks due to its coastal location, rapid urban growth and the increasing impacts of climate change. Floods in Hue are mainly related to fluvial floods (overflow of rivers and streams due to excessive rainfall) (Benito and Hudson, 2010), pluvial floods (which occur when heavy rainfall overwhelms the drainage capacity of a certain area, leading to an accumulation of water on the surface) (Prokić and others, 2019) and coastal floods (which occur when storm surges, strong winds and high tides combine to push seawater inland from the coastline) (Idier and others, 2020).

The severe floods of 2020, which caused tragic loss of life and major disruptions to homes, transport, agriculture and public health, highlighted how floods can trigger far-reaching and interconnected impacts across different sectors and systems.

Flood risks are not just about rising water levels; they are about how people, systems and places are exposed and how prepared they are to cope with and adapt to flooding. To better prepare for future events and identify entry points for enhanced risk management and adaptation, the FloodAdaptVN project has assessed current and future flood risks in Hue. This included analysing:

- where flooding may occur (flood hazard)
- who and what might be affected (exposure, including people, infrastructure and ecosystems)
- how severely they may be impacted (vulnerability)
- which factors increase flood risks (root causes)
- which impacts were observed and how they are connected

Through consultations with local stakeholders, four key flood impacts have been identified as most relevant and these have informed the risk assessments conducted in the project:

1. health impacts, including fatalities, injuries and disease outbreaks
2. disruption to rice-based agriculture, a key livelihood in the region
3. transportation disruption, especially affecting daily mobility
4. water contamination, harming people and the environment

Findings from the assessment of risks related to these key impacts have already been published in the FloodAdaptVN risk report *Flood risks in Hue, Central Viet Nam* (Sett and others, 2025) and in a more in-depth academic paper (Sett and others, 2024). Below, we summarize five key takeaways from the above report and the future risk scenarios.

1. Floods lead to severe direct and cascading impacts, which must be considered in adaptation planning

Hue has been severely affected by floods, particularly through adverse health impacts, disruptions to rice-based livelihoods and individual transportation, and water contamination. These impacts do not occur in isolation; they are interconnected and can trigger cascading and systemic impacts (Figure 3). For example, recent floods directly damaged crops or indirectly affected them through the spill of contaminated water onto agricultural fields, thereby reducing agricultural incomes of farmers. Similarly, disruption to transportation during past floods impeded mobility and prevented people from accessing their workplace and customers from accessing goods and services, thereby also disrupting non-agricultural livelihoods. Lastly, flood-related health impacts, such as injuries or diseases (including those induced by water contamination spills), prevented people from realizing their livelihoods, therefore further disrupting economic opportunities for people in Hue. At the same

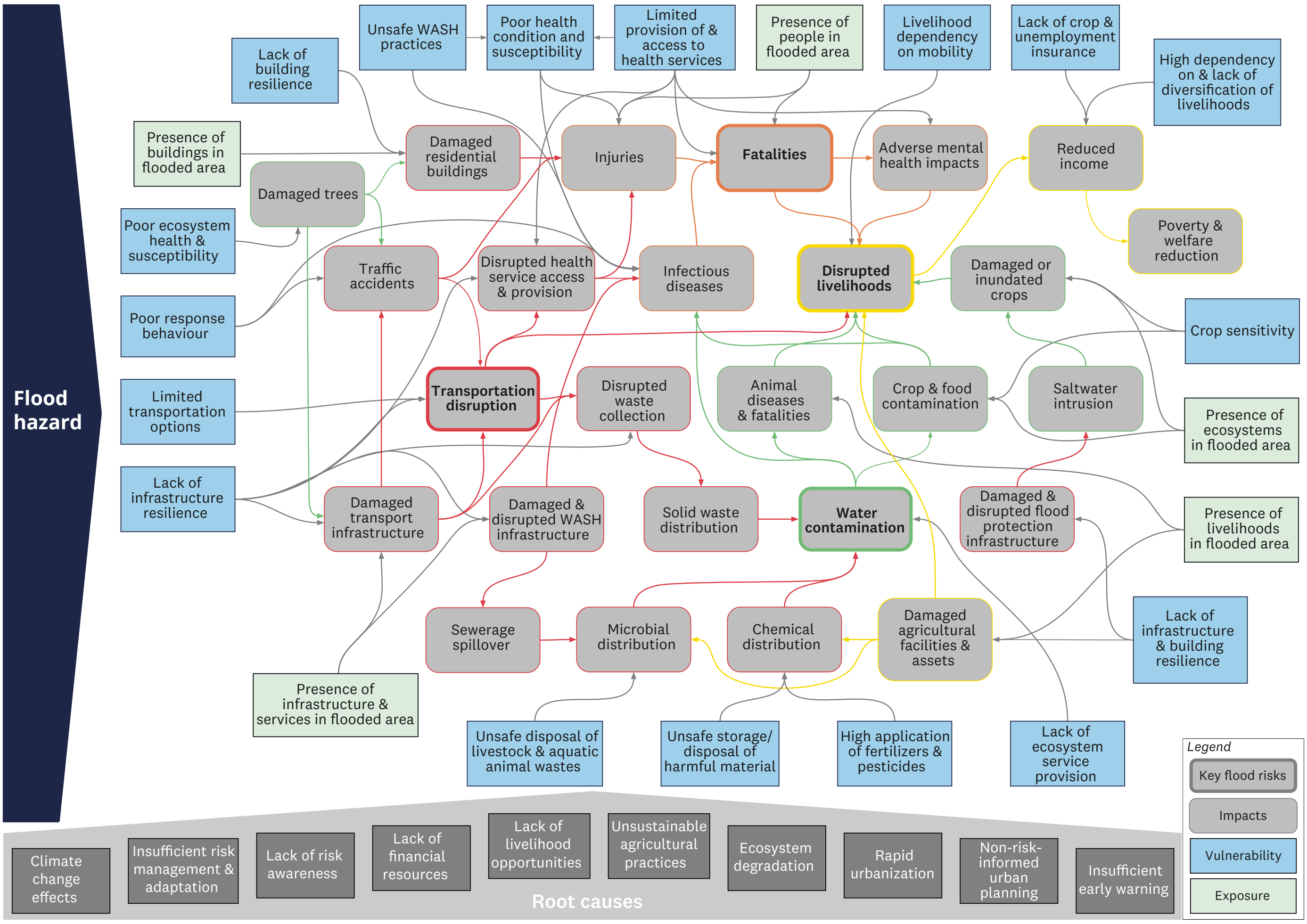

Figure 3: Cascading and systemic flood risks in the city of Hue, Central Viet Nam. Flood risks and impacts, as well as their underlying risk drivers, are deeply interconnected. Source: Sett and others (2024).

time, disruptions to livelihoods have affected people's incomes and thereby limited access to insurance, healthcare and transportation, ultimately reinforcing vulnerability to future flood events. This demonstrates how all four key flood impacts are strongly interlinked. Furthermore, our research shows strong interconnections not only between the impacts but also between their underlying risk drivers. For example, the exposure and vulnerability of infrastructure not only contributed to transport disruptions in past flood events; it also directly caused health and economic impacts. Similarly, inadequate preparedness and response strategies have the potential to escalate cascading effects of all four key risks. For instance, poor water, sanitation and hygiene (WASH) practices facilitate disease outbreaks resulting from water contamination, exacerbating public health challenges.

2. Large parts of Hue are already prone to high flood hazard levels, with increased extent and height of inundation expected in the future

Our research shows that almost half (46 per cent) of Hue's total area is currently prone to exceptional floods such as the 2020 event. While upstream areas are less affected, almost 90 per cent of the new urban development and downstream regions are prone to flooding, which can exceed 2 metres in some areas. Future flood hazards will intensify. Locations that were previously unaffected will be affected, while inundation levels in locations that were already affected will increase. Figure 4 portrays the extent of flood hazard and depths of inundation under moderate climate and socioeconomic development scenarios that are considered realistic by local experts.

3. Flood exposure is widespread and will further increase given future urban growth

Large parts of Hue's population, economic activities, infrastructure and environment are already exposed to floods. More than three quarters (76 per cent) of Hue's population currently live in areas prone to floods. In addition, 94 per cent of health facilities in the citadel, as well as 99 per cent of rice paddies and 72 per cent of roads in the downstream region, are in a flood zone. Scenarios produced as part of the project indicate that the number of people and assets in flood-prone

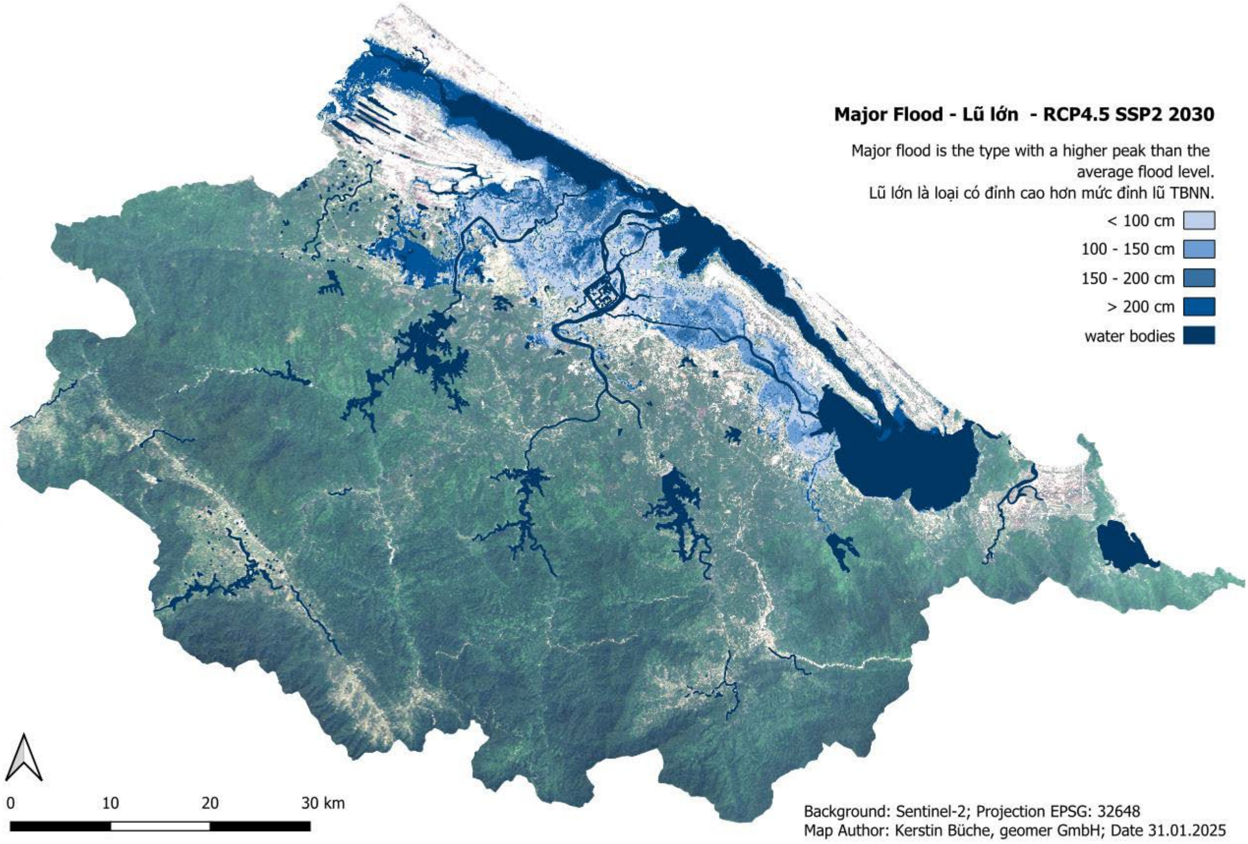

Figure 4: Extent of flood hazard and depths of inundation under moderate climate and socioeconomic development scenarios. Source: Bachofer and others (2025).

locations will increase as Hue rapidly expands, mainly in low-lying areas, indicating increased expected impacts in the future.

4. Vulnerabilities exacerbate impacts and will increase if no actions are taken

Vulnerability patterns differ across Hue, due to the city's diverse urban regions. For example, the upstream region is characterized by the highest vulnerability to transport disruption, while the downstream region is particularly vulnerable to water contamination. Key vulnerability drivers include poor response behaviour, poor building conditions, lack of insurance and poor ecosystem health. Under current developments, vulnerabilities will increase for most people in Hue in the future, leading to an expected increase in impacts across the city.

5. Underlying root causes fuel flood risks and should be addressed to counteract increasing flood risks

Flood risks are fuelled by underlying root causes (i.e. structures, policies, processes, norms and values). For example, the transformation of ecosystems into highly sealed, densely populated urban areas, as observed in particular in the new development region in Hue, intensifies flood hazards, exposure and vulnerabilities, causing adverse impacts on health, livelihoods, transport and water quality. Climate change, insufficient risk management and challenges in risk-informed planning further contribute to increasing risks. To counteract risk intensification sustainably, these underlying root causes should be addressed.

4. Identification of measures for flood risk management and climate change adaptation in Hue

Given the current and future flood risks, this chapter elaborates on concrete measures identified as opportunities to address the challenges presented in Chapter 3. First, it provides an overview of all assessments carried out under the FloodAdaptVN project, and the flood-related challenges identified as a result (Table 1). Based on this understanding, flood risk management and adaptation measures were identified (Table 2) as a basis for further evaluation (Chapter 5).

4.1 Information basis used for identifying measures

Table 1 summarizes the different approaches used to obtain a comprehensive understanding of flood-related challenges in Hue. These go beyond understanding the risk context, also elaborating on the ecosystem context, the social context and the institutional context. While there are many elements in understanding risk, this overview of context-specific assessments helps to identify and elaborate on concrete measures for flood risk reduction and climate change adaptation in Hue in a more targeted manner.

Table 1: Overview of approaches used to support the identification of measures

Context	Assessment/ Method	Information product	Main flood-related challenges identified
Flood risk context	Participatory co-development of conceptual risk models	Impact chains for four key flood impacts and overarching impact web (Sett and others, 2024; Sett and others, 2025)	• Common root causes are ecosystem degradation, lack of financial resources, lack of risk awareness, rapid urbanization, non-risk-informed planning, livelihood dependency on natural resources, insufficient risk management and adaptation, and insufficient early warning.
	Household survey	Vulnerability maps	• There is a lack of awareness among the households surveyed, with 40 per cent of them being unfamiliar with the roles and responsibilities of the flood risk governance system. • Many households surveyed lack the necessary resources, capacities and guidance. • There is low understanding of expected flood damage and the importance of adaptation.

Context	Assessment/ Method	Information product	Main flood-related challenges identified
Flood risk context	Spatial risk assessment	Flood hazard maps, flood exposure and vulnerability maps, and risk tables for the four key flood impacts (Sett and others, 2025)	• Hotspots of flood hazard in the coastal/ downstream region. • Hotspots of flood exposure in the citadel and new urban development areas. • Hotspots of flood vulnerability in the peri-urban upstream and downstream regions.
	Future risk assessment	Future flood hazard and exposure maps, and future vulnerability projections for the four key flood impacts in different scenarios (Sett and others, 2025)	• Future hazard severity is projected to increase substantially. • Future exposure hotspots are projected in the coastal areas. • Future vulnerability levels strongly depend on socioeconomic development pathways, with projected stagnation of vulnerability under current trends.
Ecosystem context	Urban growth models	Maps of urban growth on different land cover classes (Obaitor and others, 2025b)	• Projected expansion of urban areas into areas that provide many ecosystem services, including flood hazard reduction benefits, could increase future flood risk.
	Consultations with local authorities and experts in the field of natural resource management and planning	A catalogue of ecosystem-based measures to inspire adaptation in Central Viet Nam (Annex 1)	• There is an opportunity and need for targeted EbA projects in coastal and lagoon areas, that support both ecosystem conservation and the sustainability of local livelihoods. • Forest conservation and reforestation near the hydropower dams are essential to address erosion and sedimentation challenges in the upstream region.
	Field visits to key ecosystems and areas implementing Ecosystem-based Adaptation (EbA)		
	Ecosystem service assessment	Ecosystem services supply maps (Ortiz Vargas and others, 2025)	• The evergreen broadleaf forest in the upstream area of the basin is the ecosystem that is perceived to provide the most ecosystem services.
Social context	SSPs narratives workshop	Local scenarios for future socioeconomic pathways (Obaitor and others, 2025a)	• The resulting narratives established behind the local SSP2 and SSP3 pathways highlight possible socioeconomic trends that will have a negative impact on ecosystems critical for flood risk reduction.

Context	Assessment/ Method	Information product	Main flood-related challenges identified
Policy and stakeholder/ institutional context	Policy framework analysis to identify entry points and challenges for adaptation and flood risk reduction	Policy and action report (Bachofer and others, 2025)	• Integration of EbA into disaster management remains limited; stronger policy frameworks and efforts are required to scale up and scale out. • Socioeconomic development is often prioritized over sustainable spatial planning, climate adaptation and flood risk management. • Weak integration of adaptation into spatial planning highlights the need for risk-informed, cross-sectoral governance. • Climate change adaptation needs to become a cross-cutting theme for all sectors; however, better tools are needed for informed decision-making. • Insufficient data availability calls for a shared repository to improve access and coordination. It is crucial to enhance interprovincial cooperation for sustainable flood management, requiring a shift from project-based collaboration to integrated planning. • There is an emphasis on capacity development in policies but it needs further implementation. • Stable funding needs to be secured; this can be done by embedding climate adaptation and flood risk reduction into budget planning at all levels. • Adaptation measures need to be included in financial plans and public budgets to be feasible and implementable.
	Consultations with local government representative from the disaster risk management field		
	Analysis of the institutional framework and stakeholder network		

4.2 Overview of measures identified to address the challenges in improving flood risk management

An understanding of the challenges allowed the identification of 34 measures to address the flood-related challenges identified in Table 1 and enhance current flood risk management and adaptation efforts. The measures identified (Table 2) have been clustered according to the classification of adaptation measures in the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) (Noble and others, 2014) (Figure 5).

Structural/physical options

- **Engineered and built environment measures** refer to hard infrastructure or structural measures implemented to address flood risks and support adaptation.
- **Technological measures** refer to innovations and tools to enhance flood risk management and address climate impacts. The FloodAdaptVN project developed a specific tool named FRAME (Flood Risk Adaptation Measures and Evaluation) which falls into this category (FloodAdaptVN, 2025).
- **Ecosystem-based measures** refer to the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change.

Social options

- **Educational measures** aim to build long-term capacities and improve individual and community understanding through awareness-raising and skills-building.

Institutional options

- **Economic measures** are diverse; they could include taxes, subsidies, insurance, catastrophe bonds, revolving funds, payments for ecosystem

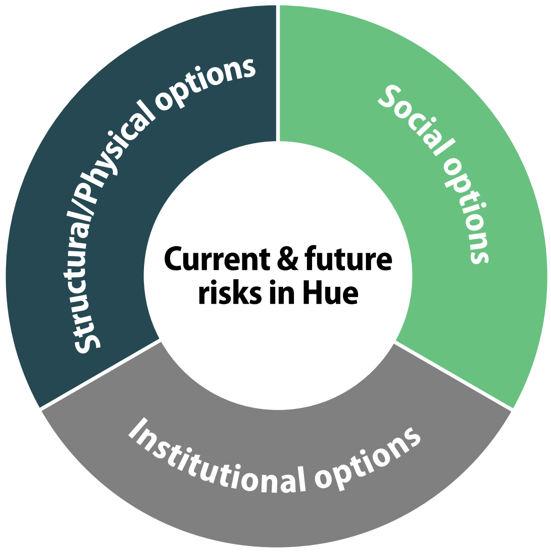

Figure 5: Portfolio of types of measure to address current and future risks

services and any other economic mechanisms that support adaptation and risk reduction efforts.

- **Law and regulation measures** are regulations to improve flood risk management and enable adaptation. Key measures in this category include land zoning laws, building standards, easements to guide development, water regulations, disaster risk reduction laws and insurance incentives to enhance resilience.
- **Government policies and programmes** include national, regional and local adaptation plans that mainstream climate change. Urban upgrading, municipal water management and disaster preparedness enhance resilience.

Table 2: Measures identified as opportunities to improve flood risk management and adaptation in Hue. Measures with an asterisk (*) were identified in the risk report and are presented here alongside newly identified measures.

#	Measures and short concept	Category	Flood type addressed	Location
Structural/physical options				
1	Urban flood wall system: construct or upgrade flood walls in the city to protect infrastructure and reduce damage from high water levels.	Engineered and built environment	Pluvial and fluvial	Urban
2	Structural housing modifications:* use physical modifications or construction techniques to reduce a building's vulnerability to flood damage.	Engineered and built environment	Pluvial and fluvial	Urban
3	Forest monitoring system (quantity and quality conditions): use tools and protocols to regularly evaluate forest health, informing interventions that reduce erosion and flood risks.	Technological	Pluvial and fluvial	Mountain
4	Impact-based early warning system (watershed level):* implement a watershed-wide system to forecast flood impacts and coordinate targeted responses across multiple zones.	Technological	All	All
5	Restoration of mangroves: maintain and expand mangrove ecosystems to shield the lagoon from storm surges, enhance biodiversity and lower flood risks.	Ecosystem-based	Coastal	Coastal
6	Restoration and conservation of urban water channels: revitalize and protect urban canals and channels to improve drainage capacity and reduce flood accumulation.	Ecosystem-based	Pluvial and fluvial	Urban
7	Climate-smart agriculture: adopt farming practices that improve resilience to floods, conserve resources and stabilize production in peri-urban zones.	Ecosystem-based	Pluvial and fluvial	Peri-urban
8	Establishment of agroforestry in riparian buffers:* integrate trees into agricultural lands to bolster soil stability, enhance water retention and reduce flood vulnerability in riparian buffers. Implementation of this measure in this specific location will reduce erosion, filter run-off and moderate flood impacts.	Ecosystem-based	Pluvial and fluvial	Mountain and peri-urban

#	Measures and short concept	Category	Flood type addressed	Location
9	Sustainable management of forests:* implement sustainable forestry practices to maintain healthy forest cover, reduce erosion and manage water run-off.	Ecosystem-based	Pluvial and fluvial	Mountain
10	Establishment, conservation and restoration of coastal forest: protect and reinforce coastal forests to stabilize shorelines, reduce erosion and buffer against flood impacts.	Ecosystem-based	Coastal	Coastal
11	Conservation and restoration of sand dunes: preserve and rehabilitate sand dunes to serve as natural barriers against coastal flooding and erosion.	Ecosystem-based	Coastal	Coastal
12	Implementation of permeable pavement or pavement removal: replace or retrofit impervious surfaces with permeable pavement to increase water infiltration and reduce urban flood run-off, or remove pavement from surfaces that do not necessarily need sealing.	Ecosystem-based	Pluvial and fluvial	Urban
13	Establishment and conservation of urban vegetation: plant and maintain trees and other urban greenery to improve stormwater infiltration.	Ecosystem-based	Pluvial and fluvial	Urban
14	Conservation of traditional home gardens: safeguard traditional home gardens to enhance local food sources, biodiversity and stormwater retention in urban areas.	Ecosystem-based	Pluvial and fluvial	Urban
15	Establishment and conservation of green open spaces: develop and preserve parks and other green areas to naturally absorb water and reduce urban flooding.	Ecosystem-based	Pluvial and fluvial	Urban
16	Establishment, conservation and restoration of green corridors: create and maintain connected green spaces that facilitate water flow, reduce flood peaks and support peri-urban biodiversity.	Ecosystem-based	Pluvial and fluvial	Peri-urban
17	Restoration and conservation of urban waterbodies: rehabilitate lakes and ponds to store floodwater and regulate water flow in urban environments.	Ecosystem-based	Pluvial and fluvial	Urban
18	Floodplain reconnection and restoration: re-establish natural floodplains to temporarily hold excess water, lowering flood peaks and safeguarding communities.	Ecosystem-based	Pluvial and fluvial	Urban
19	Conservation and restoration of vegetated riparian buffers: maintain and restore vegetation in riparian buffers to reduce erosion, filter run-off and moderate flood impacts.	Ecosystem-based	Pluvial and fluvial	Peri-urban
20	Restoration of riverbanks: stabilize and revitalize riverbanks to lessen erosion, enhance water conveyance and reduce flood risk.	Ecosystem-based	Pluvial and fluvial	Peri-urban
21	Establishment, conservation and restoration of vegetated filter strips: plant and preserve vegetated strips to trap sediments, reduce run-off pollution and help control flooding in peri-urban areas.	Ecosystem-based	Pluvial and fluvial	Peri-urban
Social options				
22	Flood risk awareness campaigns:* implement ongoing public outreach to educate communities about flood risks and encourage proactive preparedness.	Educational	All	All

#	Measures and short concept	Category	Flood type addressed	Location
23	Adaptation knowledge sharing and learning:* enhance knowledge, skills training and platforms for sharing best practices for improving flood protection and self-efficacy in implementing necessary measures.	Educational	All	All
24	Citizen flood drills (preparedness): conduct regular community drills to enhance public awareness, preparedness and effective response to flood events.	Educational	All	All
Institutional options				
25	Crop insurance:* provide insurance options for coastal farmers to minimize financial losses and encourage resilient agricultural practices.	Economic	All	All
26	Flood risk-informed planning and development:* incorporate flood hazard data into land-use decisions to guide safer development and reduce potential flood damage.	Laws and regulations	All	All
27	Multi-level and cross-sector flood risk governance:* coordinate government bodies and stakeholders at all levels to jointly develop and implement flood risk strategies.	Government policies and programmes	All	All
28	Housing modification programme for private homeowners: provide guidance and support for retrofitting homes to reduce flood damage and enhance household resilience.	Government policies and programmes	Pluvial and fluvial	Urban
29	Citizen flood competence centre (including consultancy services): establish a resource hub offering training, expertise and services to build community flood resilience.	Government policies and programmes	Pluvial and fluvial	Urban
30	Forest seed banking: collect and store seeds of local trees to preserve genetic diversity, support reforestation and strengthen flood resilience.	Government policies and programmes	Pluvial and fluvial	Mountain
31	Establishment of a watershed management commission: form a governing body to coordinate and integrate comprehensive flood risk management efforts across the entire watershed.	Government policies and programmes	All	All
32	Establishment of a forest-shareholder system: engage local communities as stakeholders in forest ownership and management to support conservation.	Government policies and programmes	Pluvial and fluvial	Mountain
33	Blue carbon programme for the lagoon: promote the restoration of coastal wetlands and seagrasses to sequester carbon and enhance lagoon protection against flooding.	Government policies and programmes	Coastal	Coastal
34	Establishment of mechanisms for cooperation: create formal frameworks that foster collaboration among institutions, communities and sectors for comprehensive flood risk management.	Government policies and programmes	All	All
35	Forest certification insurance: offer insurance incentives linked to sustainable forest certification, enhancing forest health and flood protection.	Government policies and programmes	Pluvial and fluvial	Mountain

In the case of ecosystem-based options, more information can be found in Annex 1. For the rest of the measures, please refer to the FloodAdaptVN risk report *Flood risks in Hue, Central Viet Nam* (Sett and others, 2025).

5. Evaluation of measures for flood risk reduction and adaptation

The aim of this chapter is to evaluate measures in terms of their potential benefits for flood risk reduction and climate change adaptation, taking into consideration additional development opportunities and trade-offs. Specifically, this will be done through mapping entry points for flood risk reduction and adaptation measures, in relation to the detailed understanding of key flood impacts (Analysis I), which will be complemented by literature-based research to evaluate the contribution of measures beyond the key risks (Analysis II). The "four eyes" principle was applied in evaluating each measure, to ensure quality and consistency of results. The results from the evaluation will support the recommendations of the report in Chapter 6.

5.1 Evaluation approach

The evaluation approach presented in this report involves theoretically assessing how a selection of 12 measures could address the current and future flood risks in Hue and beyond. We show how some of the measures identified (Table 2) can address the root causes and drivers of the key flood impacts, and how they are relevant to the flood-related challenges (Table 1). Our emphasis on root causes aligns with recent calls for more transformative approaches to adaptation (Schipper, 2020; Filho and others, 2022). Effective adaptation should address the root causes of risks, not merely the symptoms of impacts, to help ensure the sustainability of adaptation (Filho and others, 2022; Schipper, 2020; Birkmann and McMillan, 2020; Blaikie and others, 2014).

Nine of the measures identified have already been featured in the FloodAdaptVN risk report *Flood risks in Hue, Central Viet Nam* (Sett and others, 2025). These are: 1) structural housing modification; 2) impact-based early warning systems; 3) flood risk-informed planning and development; 4) multi-level and cross-sector flood risk governance; 5) crop insurance; 6) flood risk awareness; 7) adaptation knowledge sharing and learning; 8) agroforestry in riparian buffers; and 9) sustainable forest management. The identification of these nine measures therefore builds on flood risk understanding and the different flood-related challenges identified across the different assessments (Table 1). Given the EbA focus of the FloodAdaptVN project, three additional EbA measures were identified, to ensure a balanced representation of different regions across the catchment (Figure 2) in the compendium of options evaluated in this report. This approach highlights the importance and value of considering a landscape perspective, which allows us to plan and implement a range of options effective at the catchment level. The EbA measures identified – 1) restoration of mangroves; 2) restoration and conservation of urban waterbodies; and 3) climate-smart agriculture – were chosen based on the flood-related challenges identified across various ecosystem assessments (Table 1) and the findings of the catalogue of ecosystem-based measures to inspire adaptation in Central Viet Nam (Annex 1). The latter is an informational product featuring 16 EbA measures identified through a mixed method approach. This included consultations with local experts about opportunities and challenges for implementation of EbA measures across the Huong River catchment, as well as a literature review on the benefits of locally tailored EbA measures in addressing the three key components of flood risk. The three EbA measures mentioned above were selected from the full list of EbA measures featured in the catalogue due to the strong evidence of their effectiveness in risk reduction, their ability to provide many ecosystem services, and their capacity to address the flood-related challenges found in the ecosystem context, while also representing different landscapes in the catchment (Annex 1).

1. **Analysis I: Contribution of measures to addressing key flood impacts**

   This analysis examines the possible influence of the measures on the root causes and drivers of flood risks, building on the findings from the four impact chains presented in the FloodAdaptVN risk report (Sett and others, 2025). For each individual measure, the evaluation details which root causes and drivers are theoretically addressed by the measure and explains how and why, based on scientific evidence from the literature. Using impact chains to evaluate measures directly relates to the key flood impacts, which were identified by local stakeholders during the early stage of the FloodAdaptVN project.

2. **Analysis II: Development opportunities and trade-offs**

   This analysis evaluates the measures in relation to potential additional benefits, opportunities, trade-offs and conflicts. In this analysis, the assessment considers broader contributions from each measure, beyond the four key flood impacts identified and addressed in Analysis I. The assessment of positive contributions focuses on benefits such as enhanced ecosystem services – including biodiversity conservation, carbon sequestration and water quality improvements – as well as social benefits such as increased social cohesion and improved livelihoods. Conversely, the assessment of negative contributions refers to potential trade-offs that were identified. These include possible conflicts or negative impacts such as resource competition or displacement, or unintended ecological consequences that could arise during implementation. The evaluation drew on multiple data sources found in relevant academic literature.

This variety in the analysis ensures that measures are evaluated not only in terms of their flood risk reduction potential, but also in terms of their alignment with long-term sustainability considerations and local development priorities, and their capacity to address climate change adaptation needs and enhance resilience in Hue.

5.2 Results of evaluation

This section presents the findings of the evaluation of each measure to address flood risk reduction and climate change adaptation in Hue. Each evaluation starts by introducing the respective measure, documents the findings under Analysis I and Analysis II, and ends with a short conclusion on the respective evaluation.

5.2.1 Structural housing modifications

This measure involves physical modifications or construction techniques to reduce a building's vulnerability to flood damage (Hidayati and others, 2023). Examples include elevating housing structures, using flood-resistant materials, applying dry or wet floodproofing, and building flood barriers around the house (Mannucci and others, 2022).

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type. Instead, it supports impact reduction in relation to all flood hazard types that affect Hue, as building modifications such as higher elevation, which is common in Central Viet Nam, provide shelter to protect people (Kreibich and others, 2005). As a result, it could reduce the exposure of people and their well-being, and the exposure of buildings and infrastructure, both of which are elements in the impact chain for the key flood impact of *severe health impacts*.

In terms of root causes of the identified key risks, the measure has the capacity to address "insufficient risk management and adaptation" (a specific root cause of the flood hazard) and "non-risk-informed urban planning" which is related to the key flood impact of *severe health impacts*. Making modifications to houses is a way of managing flood risk and promoting adaptation (Hidayati and others, 2023; Creach and others, 2020). The measure could also be implemented as part of an institutional programme with government support for more risk-informed urban planning (Sett and others, 2025). As a result, the positive effects of addressing these root causes can influence the vulnerability drivers "lack of infrastructure resilience" and "poor building conditions". Kreibich and others (2005) found that this type of measure represents an improvement in building conditions, with higher floors spared from the immediate effects of flooding.

Figure 6: House with a raised foundation

Analysis II: Development opportunities and trade-offs

Structural housing modifications often require less additional space compared with other urban measures and are therefore especially effective in densely populated centres (de Ruig and others, 2020). However, in terms of possible negative contributions, structural housing modifications can encourage high-risk construction, which is particularly critical if risk uncertainties (flooding probability, damage function, expected house lifetime) are not properly accounted for (de Ruig and others, 2020).

Conclusion of the evaluation

This measure addresses two root causes and two key vulnerability drivers that mainly relate to the key flood impact of *severe health impacts*. In addition, this measure is convenient in heavily populated areas, as it does not require extra space.

5.2.2 Impact-based early warning

Impact-based early warning systems are designed to go beyond forecasting weather events, in predicting the potential impacts of those events on communities, infrastructure and the environment (Najafi and others, 2024; Tarchiani and others, 2020). This type of system needs to be established by combining hazard forecasts with vulnerability and exposure data to provide actionable information, helping decision makers and the public to prepare for and respond effectively to potential risks (Najafi and others, 2024). The focus is on what the hazard will do, rather than just what the hazard is, enabling more targeted and impactful early warning messages (Mitheu and others, 2023).

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type. Instead, it supports impact reduction for all flood hazard types that affect Hue, as with appropriate warning, measures can be taken to reduce the exposure of all elements presented in the different key flood impacts (Potter and others, 2021). However, more specifically the measure can contribute to better reservoir management, which can then influence fluvial floods (Lellyett and others, 2022).

Figure 7: Flood marker indicating potential future flood height

This measure can directly address the root cause “insufficient early warning” and directly relates to the vulnerability driver “poor response behaviour” for both of the key flood impacts *severe health impacts* and *individual transportation disruptions*. Being warned in time and provided with an overview of expected impacts can help people to better prepare and respond and reduce impacts (Potter and others, 2021; Tarchiani and others, 2020).

Analysis II: Development opportunities and trade-offs

Impact-based early warning has the opportunity to build on existing warning systems in Hue and already has broad social acceptance among the population (Pham and others, 2024). However, it could be challenging to implement, as it does require certain infrastructure and also high-level technical knowledge for maintenance, which requires extensive training to be effective (Najafi and others, 2024; Potter and others, 2021). Furthermore, it is crucial that warnings are delivered in a timely manner and take into account the diversity of population groups (Tarchiani and others, 2020).

Conclusion of the evaluation

The measure can address one root cause and one vulnerability driver for both *severe health impacts* and *individual transportation disruptions*. This measure could build on current early warning systems, which would make it easier to implement.

5.2.3 Flood risk-informed planning and development

This measure aims to integrate the findings of flood risk assessments into land use planning, infrastructure development and policymaking to minimize flood impacts on communities and the environment (UFCOP, 2017; Opitz-Stapleton and others, 2019). Implementation of this depends on having appropriate risk assessments and the support of decision makers to facilitate the integration of risk information into planning and development decisions (Shao and others, 2019; Handmer, 1996).

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type. Instead, it supports impact reduction for all flood hazard types that affect Hue, as it can help to improve urban planning in a risk-informed way and support decisions that reduce exposure for the elements associated with the key flood impacts (Connective Cities, 2022). This is particularly relevant for exposed elements such as buildings and infrastructure, ecosystems and their services, and people and their well-being.

As this measure clearly addresses the lack of risk-informed planning, it can influence the root cause "non-risk-informed urban planning" related to *severe health impacts*, *individual transportation disruptions* and *water contamination*. This can then influence the vulnerability drivers "lack of infrastructure resilience", "poor building conditions and characteristics", "lack of public transportation alternatives", "poor road conditions" and "low sewage system capacity and resilience". The measure will promote integration of risk information into many institutional processes that undermine the vulnerability drivers just mentioned, ensuring more risk-informed planning and development of the city (UFCOP, 2017; Opitz-Stapleton and others, 2019).

Analysis II: Development opportunities and trade-offs

Risk-informed planning and development has a range of co-benefits that can be perceived as positive additional contributions. Risk-informed planning can involve implementing measures that also contribute to climate change mitigation (Zhou and others, 2024). Flood risk reduction planning can involve measures (e.g. open green spaces) that also address other

Figure 8: Riparian buffer zone in Hue city

hazards (e.g. heatwaves) (UFCOP, 2017; Connective Cities, 2022). A potential trade-off is the restriction of land for urban expansion to address the need for accommodation, and the requirement for resettlement and redevelopment of urban areas to appropriate flood-safe areas (Der Sarkissian and others, 2022).

Conclusion of the evaluation

The measure can address one root cause and five vulnerability drivers of *severe health impacts*, *individual transportation disruptions* and *water contamination*. Due to the institutional nature of this measure, an additional benefit is that it could cascade into other processes relating to climate change adaptation and disaster preparedness for other hazards.

5.2.4 Multi-level and cross-sector flood risk governance

This measure refers to a collaborative approach to managing flood risks, involving coordination across different levels of government (local, regional, national and international) and different sectors (public, private and civil society) (Menoni and others, 2024). It aims to ensure comprehensive, inclusive and effective flood risk management (Menoni and others, 2024; Wu and others, 2024). It will require, among other things, defined responsibilities at the different levels of governance, improved legislation to allow multi-level and cross-sectoral collaboration, stakeholder engagement, coordination mechanisms, platforms to share information across levels and sectors, and good risk understanding (Thistlethwaite and Henstra, 2019; Bisaro and others, 2020; Driessen and others, 2016; Matczak and Hegger, 2020).

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Figure 9: FloodAdaptVN project regional networking forum meeting in May 2023

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type. Instead, it supports impact reduction for all flood hazard types that affect Hue, as it is an institutional measure that promotes better collaboration and coordination to address all types of floods. As a result, it also has the capacity to address all the exposure components for all the key flood impacts.

In terms of root causes for all the key flood impacts, this measure can address "non-risk-informed urban planning", "lack of risk awareness", "insufficient reservoir management" and "insufficient risk management and adaptation". Due to its institutional nature, it can contribute to more risk-informed urban planning and the establishment of infrastructure that is more resilient to the expected hazards (Menoni and others, 2024; Azizi and others, 2025). Additionally, the measure can promote better coordination across governmental, private and community stakeholders, leading to more effective flood prevention and response strategies (Menoni and others, 2024) in Hue. Furthermore, it can promote more collaborative approaches – for example, integrating risk concerns into hydropower objectives – and thus influence the root causes "insufficient reservoir management" and "lack of risk awareness" (den Boer and others, 2019; Wyrwoll and Grafton, 2022).

As a result of addressing the root causes mentioned above, local government can take better decisions in relation to risk management. This could attenuate the vulnerability drivers "poor building conditions and characteristics", "lack of infrastructure resilience", "lack of public transportation alternatives", "poor road conditions", "low sewage system capacity and resilience", "unsafe WASH provision and practices", "poor response behaviour", "unsafe storage/ disposal of harmful materials and matters", "lack of infrastructure and building resilience" and "poor ecosystem health and susceptibility".

Analysis II: Development opportunities and trade-offs

Multi-level and cross-sector flood risk governance shows some additional positive contributions, such as enhancing coherence among different sectoral policies (as long as institutional fragmentation is avoided), which ensures more efficient resource allocation to address flood risk management (Benson and Lorenzoni, 2017). It may also have negative consequences, such as coordination challenges where conflicting objectives among different interest groups or stakeholders become unresolvable or responsibilities appear more fragmented (Nordbeck and others, 2023).

Conclusion of the evaluation

This measure has the capacity to address four root causes and ten vulnerability drivers of the four key flood impacts. As an additional positive aspect, its implementation can enhance policy coherence and improve resource allocation.

5.2.5 Crop insurance

Crop insurance is a financial risk transfer tool designed to protect farmers from economic losses due to flood-related crop damage (Mcleman and Smit, 2006). While it does not directly reduce the physical risk of floods, it reduces the socioeconomic impacts by enhancing resilience and capacity to recover (Surminski, 2014). Establishment of this measure could be slightly complex, as it will require good understanding of flood risks, understanding of the situation for local farmers, design of a contextualized crop insurance product, a company or institution that handles the management (registration, premium collection and claims management), and development of the legal frameworks and institutional aspects needed for the insurance (Di Falco and others, 2014; Schaefer and Zissener, 2016; Ramm and others, 2018).

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type. Instead, it alleviates the impact of all flood hazard types that affect Hue, as it is an institutional measure that provides economic payouts to people who have been affected by any type of flood (Mcleman and Smit, 2006).

However, it mainly addresses the key flood impact of *disruption of agricultural livelihoods*. In terms of root causes of this key flood impact, the measure addresses “insufficient risk management and adaptation”, as the insurance itself is a measure that promotes better risk management and adaptation and reduces the severity of the impacts of this key flood impact (Di Falco and others, 2014; Yoder and others, 2025). As a result, it entirely influences the vulnerability driver “lack of crop insurance”.

Figure 10: Crop fields in peri-urban areas of Hue

Analysis II: Development opportunities and trade-offs

Overall, crop insurance shows multifaceted benefits and positive contributions. Insurance coverage can reduce “stress sales” in the aftermath of flooding by providing more economic stability for policyholders, as well as by reducing mental stress (Mazviona and others, 2024). Crop insurance can stabilize production levels and reduce the risk of crop failures, ensuring consistent availabilities on markets (Kurdyś-Kujawska and others, 2021). However, crop insurance has some potential negative trade-offs, such as the occurrence of “moral hazard”, where farmers change their behaviour after obtaining the insurance and may take fewer preventive measures, assuming that insurance will cover losses (Kurdyś-Kujawska and others, 2021; Mcleman and Smit, 2006; Surminski, 2014). Also, insurance premium costs may be a burden for smallholder farmers (Surminski, 2014; Hossain, 2024). Financial mechanisms such as insurance may also exclude marginalized farmers who lack access to formal financial services or land ownership, exacerbating inequalities (Hossain, 2024).

Conclusion of the evaluation

Crop insurance addresses one root cause and one vulnerability driver of the key flood impact of *disruption of agricultural livelihoods*. As an additional positive aspect, the measure can offer economic and market stability in the event of flooding.

5.2.6 Flood risk awareness-raising

This measure aims to build a culture of resilience and readiness within vulnerable communities, by raising awareness of flood risk (Osberghaus and Hinrichs, 2021). Risk awareness can be built through flood awareness campaigns that educate communities about flood risks, safety protocols and preparedness actions to minimize impacts during flood events (Osberghaus and Hinrichs, 2021; Burningham and others, 2008). These campaigns could use workshops, informational materials and media outreach to improve public knowledge and encourage proactive behaviours (Garcia and others, 2021; Maidl and Buchecker, 2015).

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type. Instead, it alleviates the impact of all flood hazard types that affect Hue, as it is a social measure that provides information and educational awareness to help people to prepare and cope with the impacts of any type of flood (Osberghaus and Hinrichs, 2021). This can cascade into exposure reduction benefits for all elements related to the four key flood impacts.

In terms of the root causes for the four key flood impacts, this measure can address "lack of risk awareness", "ecosystem degradation", "rapid urbanization", "insufficient reservoir management" and "non-risk-informed urban planning". This is because it supports better response, risk reduction and climate change adaptation decisions (Ionita and others, 2020; Glaus and others, 2020), which can influence all these root causes. Additionally, this measure can also influence the root cause "lack of valuing ecosystems and their services", as it could integrate information about the role of ecosystems into reducing flood risk (Sudmeier-Rieux and others, 2021), which would probably increase people's appreciation of ecosystems and their services (Renaud and Murti, 2014).

As a result of addressing several root causes, the benefits of this measure cascade into addressing several vulnerability drivers. It can prevent deterioration of human health in relation to *severe health impacts* and *water contamination,* as awareness and risk perception could influence "poor response behaviour", "unsafe WASH provision and practices" and "unsafe storage/disposal of harmful materials and matters" (Anthonj and others, 2022; Glaus and others, 2020; Osberghaus and Hinrichs, 2021; Maidl and Buchecker, 2015). In terms of vulnerability drivers of "poor ecosystem health", the measure could promote more sustainable decisions in relation to the management of natural resources, as it could improve understanding of the benefits of healthy ecosystems for disaster risk reduction (Rackelmann and others, 2023). More risk-aware decisions could also promote measures that improve sewage systems and address the vulnerability driver "low sewage system capacity and resilience" (Sun and others, 2011).

Figure 11: Workshop about flood risk adaptation and regional cooperation

Analysis II: Development opportunities and trade-offs

Risk awareness-raising can be more impactful than large-scale flood measures, as it can indirectly increase the capacities of communities to enhance the adoption of more protective measures (Mehryar and Surminski, 2021). However, this measure can also increase anxiety and fear towards flood risks as a consequence (Lee and Lee, 2019).

Conclusion of the evaluation

Risk awareness-raising is a measure that addresses six root causes and five vulnerability drivers of all the key flood impacts. Beyond its direct risk reduction benefits, risk awareness-raising can enhance better response behaviour.

5.2.7 Adaptation knowledge sharing and learning

Adaptation knowledge sharing and learning focuses on exchanging information, experiences and best practices to enhance collective capacity for adapting to climate change and disaster risks such as floods (Weichselgartner and Pigeon, 2015; Vasileiou and others, 2022). In order to implement this measure, it is key to build a platform (online or in person) that supports the exchange of knowledge and experiences among affected people, practitioners, researchers, policymakers and any other relevant stakeholders (Davis and Salamanca, 2013; Smith and others, 2013; Brouwers and others, 2022). Examples of such international online platforms include weADAPT (SEI, 2025) and PANORAMA Solutions (GIZ, 2025).

Analysis I: Contribution to addressing key flood impacts

The measure is not specific to a particular flood hazard type; instead it alleviates the impact of all flood hazard types that affect Hue. It is a social measure that promotes learning and helps people to prepare and cope with the impacts of any type of flood.

Figure 12: Flood risk reduction workshop in Hue

This measure addresses the root causes "insufficient risk management and adaptation", "lack of risk awareness", and "insufficient reservoir management" related to *severe health impacts* and a*gricultural livelihood disruptions*. Knowledge sharing and learning provides more chances for the community to understand risk, derive inspiration from successful approaches and take informed decisions (Vasileiou and others, 2022; Yousefi Mohammadi and others, 2024). Additionally, this measure can also influence the root cause "lack of valuing ecosystems and their services", as this platform could integrate information and promote exchange of experiences about the role of ecosystems in reducing flood risk (Sudmeier-Rieux and others, 2021), which would probably increase people's appreciation of ecosystems and their services given their potential for reducing flood risk (Renaud and Murti, 2014).

In terms of vulnerability drivers of both *severe health impacts* and *agricultural livelihood disruptions*, the benefits of addressing the above-mentioned root causes could also cascade into "poor response behaviour", as this measure can enhance people's level of knowledge (Vasileiou and others, 2022). Additionally, the vulnerability drivers "high dependency on agriculture as single livelihood source" and "lack of crop insurance" related to *agricultural livelihood disruptions* can be addressed in a similar way by incrementing people's knowledge (O'Donnell and others, 2018) and inspiring action, for example towards diversification of livelihoods. As a result, the measure can reduce exposure for the elements related to the key flood risks it addresses: people and their well-being, livelihoods and economic assets, buildings and infrastructure, and ecosystems and their services.

Analysis II: Development opportunities and trade-offs

Adaptation knowledge sharing and learning can support scaling-up of adaptation strategies via collection and dissemination of the knowledge of disparate stakeholders, making knowledge more accessible and encouraging greater participation in adaptation strategies by a range of stakeholders (O'Donnell and others, 2018). However, fear and anxiety about floods may increase as a result of the greater awareness of these risks associated with the spread of adaptation knowledge (Lee and Lee, 2019).

Conclusion of the evaluation

This measure addresses four root causes and three vulnerability drivers related to *severe health impacts* and *agricultural livelihood disruptions*. Additionally, it supports scaling-up of improved flood risk management and adaptation efforts by fostering stakeholder participation and knowledge exchange.

5.2.8 Establishment of agroforestry in riparian buffers

Agroforestry is a sustainable land management practice that combines trees or shrubs with crops or livestock on the same land, offering both ecological and economic benefits (Quandt and others, 2017). Riparian buffers are areas of natural or semi-natural vegetation, including grass, shrubs or trees, found directly adjacent to waterways (Climate Adapt, 2023; USDA, 2025; Drugge and Doty, 2019). Establishing agroforestry in riparian buffers requires clear delineation of buffer zones, thorough understanding of the site's ecological and physical characteristics, and participatory selection of suitable agroforestry systems in collaboration with local stakeholders (Raskin and Osborn, 2019; Gassner and Dobie, 2022; Schultz and others, 2019). Key steps include choosing appropriate species, choosing specific objectives in addition to flood risk reduction, planning for implementation and long-term sustainability, and ensuring active community engagement throughout the process (Raskin and Osborn, 2019; Gassner and Dobie, 2022; Schultz and others, 2019).

Analysis I: Contribution to addressing key flood impacts

The measure has a specific effect in influencing the reduction of floods, as the evidence shows that it can reduce flood peaks and delay run-off from pluvial and fluvial floods (Santoro and others, 2022; Udawatta, 2021). Furthermore, the measure can stabilize soil through tree roots, reduce erosion and sedimentation, and slow down surface run-off to increase water infiltration and lower flood peaks (Santoro and others, 2022; Udawatta, 2021). Additionally, agroforestry systems near rivers can act as natural buffer zones, absorbing floodwaters while enhancing biodiversity and soil health to improve landscape resilience (Ziana and others, 2020; Anderson and others, 2006).

This measure has the capacity to address several root causes relevant to all key flood impacts, such as "climate change effects", as it has better potential to sequester carbon compared with monocultural cultivation systems (Ramachandran Nair and others, 2010). The measure addresses the root cause "ecosystem degradation and loss of ecosystem services" through enhancement of soil quality, improved water filtration, biodiversity conservation and prevention of land degradation (Biswas and others, 2022; Mbow and others, 2014; Janzen and others, 2024). The root cause "lack of livelihood opportunities" is also addressed, as these systems provide many ecosystem services that can provide people with food and income sources (Mbow and others, 2014). In addition, the measure can address

Figure 13: Forest park next to river and riparian buffers

the root cause "lack of financial resources", as agroforestry systems – depending on the management objectives – can be a source of income that improves families' financial resources (Desmiwati and others, 2021). This is relevant for addressing *severe health impacts, individual transportation disruptions* and *agricultural livelihood disruptions*. It also addresses the root cause "unsustainable agricultural practices", as it is an integrated approach that promotes sustainable land use (Wilson and Lovell, 2016), which relates to *agricultural livelihood disruptions* and *water contamination*.

Addressing the above-mentioned root causes cascades into reducing vulnerability drivers. These include "poor ecosystem health and susceptibility", which is relevant for all key flood impacts, and "high dependency on agriculture as single livelihood source", which is relevant for reducing *agricultural livelihood disruptions* as the measure can support diversified agricultural livelihoods and strengthens financial resilience (Quandt and others, 2017; Rivest and others, 2013). As a result, it can reduce exposure for the elements related to all the key flood impacts: people and their well-being, livelihoods and economic assets, buildings and infrastructure, and ecosystems and their services.

Analysis II: Development opportunities and trade-offs

Agroforestry also provides many additional positive contributions. Among the most relevant are carbon sequestration and biodiversity enhancement, as well as wind protection (Castle and others, 2021; Fagerholm and others, 2016; Farinaccio and others, 2024). In some areas, it may also increase touristic and aesthetic values of the landscape (Fagerholm and others, 2016). However, there are also some negative consequences that should be kept in mind, such as potential conflicts with existing land use practices and reduced land area for extensive agriculture (Taillandier and others, 2023).

Conclusion of the evaluation

This measure addresses five root causes and one vulnerability driver of all the key flood impacts, and one additional vulnerability driver of *agricultural livelihood disruptions*. Being ecosystem-based, this measure has many additional benefits that enhance its relevance.

5.2.9 Sustainable forest management

Sustainable forest management in upstream regions of river catchments involves managing forests to balance ecological, social and economic objectives while maintaining their ability to regulate water and reduce flood risks (Bathurst and others, 2011). It is critical to define clear objectives for implementation of this measure – such as conservation, timber production or ecosystem services protection – and to ensure they are developed in collaboration with key stakeholders and development plans (Judd and others, 2013; Bhandari and Lamichhane, 2020; van Hensbergen and others, 2023). A thorough understanding of the forest's current status and characteristics is also crucial (Rackelmann and others, 2023). The process should actively promote stakeholder engagement, support the development of a management and business plan (where applicable), establish effective monitoring systems, ensure legal compliance and incorporate adaptive management to respond to changing conditions due to climate change and disaster risk (Judd and others, 2013; Bhandari and Lamichhane, 2020; van Hensbergen and others, 2023).

Analysis I: Contribution to addressing key flood impacts

The measure has a specific effect in influencing the reduction of pluvial and fluvial floods. Sustainable forest management helps control surface run-off, enhance water infiltration and stabilize soils, reducing erosion and sedimentation in downstream areas (Hümann and others, 2011; Peskett and others, 2021; Bathurst and others, 2011). By maintaining vegetation cover, it minimizes peak water flows during heavy rainfall, decreasing the likelihood and severity of floods (Bathurst and others, 2017; Černohous and others, 2017). Additionally, healthy forests support biodiversity, improve water quality and provide resources for local communities, contributing to both environmental and socioeconomic resilience in flood-prone regions (Nelson and others, 2020; Borma and others, 2022).

This measure can address the root cause "climate change effects" (Kauppi and others, 2022; Borma and others, 2022), as forests have the capacity to sequester and store carbon, therefore mitigating climate change. It can also address "ecosystem degradation and loss of ecosystem services" (Wei and Blanco, 2014), which is relevant for all the key flood impacts. This is because, compared with monocultures, more mixed systems can increase the diversity of ecosystem services provided by forests. Additionally, the measure can address the root cause "lack of livelihood opportunities", which is relevant to *agricultural livelihood disruptions*. It can also

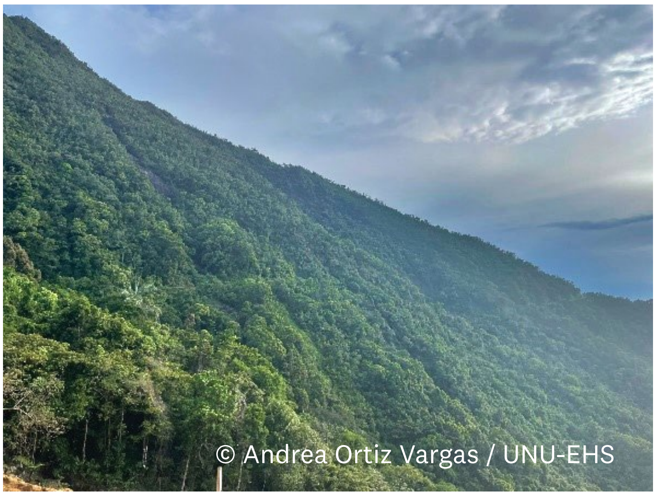

Figure 14: A region of the Bach Ma protected forest

address the root cause "lack of financial resources", related to *severe health impacts*, *agricultural livelihood disruptions* and *individual transportation disruptions,* as forests can provide income sources to local communities, offering additional livelihood opportunities (Celinah and Olawuyi, 2018; de Zoysa and Inoue, 2016).

In addressing the above-mentioned root causes, the measure can also address related vulnerability drivers. Sustainable forest management enhances human health by decreasing air pollution and improving water quality for nearby or downstream communities (Borma and others, 2022; Quijas and others, 2019). It also increases livelihood opportunities and financial income by providing timber and non-timber forest products (NTFPs) that can increase financial resources for local communities and enhance their living standards, which currently contribute to most of the previously mentioned vulnerability drivers (Nelson and others, 2020; Das and Mallick, 2023; Franca Barros and others, 2020). Against this background, the measure can address "high dependency on agriculture as single livelihood source", "limited access to health services", "unsafe WASH provision and practices" and "limited individual transportation options". Lastly, the measure can improve "poor ecosystem health and susceptibility", as the sustainability aspect is central to it (Bathurst and others, 2011). As a result, it can reduce exposure for the elements related to all key flood impacts: people and their well-being, livelihoods and economic assets, buildings and infrastructure, and ecosystems and their services.

Analysis II: Development opportunities and trade-offs

Sustainable forest management can provide additional positive contributions, such as increased production of sustainable biomass energy and the opportunity for enhanced stakeholder participation in land management and forest governance (Franca Barros and others, 2020; Bauer and others, 2018). This measure can also show some positive recreational contributions by enhancing touristic values, particularly in upstream mountain areas (Das and Mallick, 2023; Nelson and others, 2020). Nonetheless, sustainable forest management may also restrict access to land and resources, leading to social and economic tensions or placing a burden on local communities, which have limited capabilities to enforce regulations on sustainable forest management (FAO, 2015).

Conclusion of the evaluation

This measure addresses four root causes and five vulnerability drivers, relevant for all the key flood impacts. Furthermore, it offers broader additional benefits in relation to ecosystem services that can be provided as a result of the good health of the forest.

5.2.10 Mangrove restoration

This measure involves rehabilitating degraded or lost mangrove ecosystems, which are coastal wetlands that thrive in brackish water and provide crucial environmental services (Friess, 2016; Islam and others, 2024).

Analysis I: Contribution to addressing key flood impacts

Due to the location of mangroves, this measure mainly has the capacity to address coastal floods. This is because mangroves can act as a natural barrier to storm surges and coastal flooding (Hilmi and others, 2022). Their dense root systems stabilize coastlines and reduce erosion and sedimentation, while their ability to store water and slow down waves helps prevent floodwaters from reaching inland areas (Menéndez and others, 2020). Restoring mangroves can significantly increase coastal resilience to floods, particularly in the face of climate change and rising sea levels (Menéndez and others, 2020). As a result, the measure can reduce the exposure of all elements related to all the key flood impacts: people and their well-being, livelihoods and economic assets, buildings and infrastructure, and ecosystems and their services.

Figure 15: Mangrove forest along the Thua Thien Hue coast

This measure can address root causes related to all key flood impacts. "Climate change effects" are addressed as healthy mangroves are key ecosystems that support climate change mitigation due to their exceptional carbon storage and sequestration capacity (Song and others, 2023). "Ecosystem degradation and loss of ecosystem services" are directly addressed through the restoration of degraded areas, and mangroves are at the same time very important habitats for many species (Su and Gasparatos, 2023). The measure can also address the specific root cause "lack of livelihood opportunities" in relation to *agricultural livelihood disruptions,* as the measure can support biodiversity and provides resources for local communities to improve their livelihoods (Gargaran and others, 2024; Rahman and others, 2024; Pham, 2021). Lastly, this measure also addresses "lack of financial resources", which is a root cause of *agricultural livelihood disruptions,* as the multiple ecosystem services provided enhance the economy for families in the surrounding areas (Karanja and Saito, 2018; Munji and others, 2013).

Through addressing these root causes, the measure also contributes to addressing related vulnerability drivers such as "poor ecosystem health", through promoting the restoration of a large area of mangrove forest (Islam and others, 2024). It also addresses more socioeconomic vulnerability drivers, such as "limited access to health", "unsafe WASH provision and practices", "limited individual transportation options" and "high dependency on agriculture as single livelihood source", as the measure can provide economic income (Gargaran and others, 2024; Rahman and others, 2024; Pham, 2021; Karanja and Saito, 2018; Munji and others, 2013).

Despite not having a particular effect on the key flood risk of *water contamination,* it is worth mentioning that mangroves also provide protection against saltwater intrusion (Wang and others, 2010).

Analysis II: Development opportunities and trade-offs

Evaluation beyond the key flood impacts shows that mangrove restoration can support long-term climate change adaptation through additional benefits to those mentioned in the analysis above. Mangroves can help to reduce the impacts of other hazards related to climate change, such as sea level rise, through vertical accretion – where mangroves accumulate sediments and organic matter to maintain their elevation relative to sea level rise (Krauss and others, 2014). Furthermore, mangroves can improve water quality in coastal areas, by filtering pollutants and sediments (Hilmi and others, 2022). Additionally, evidence shows that they could be a cost-effective alternative to engineered solutions for disaster risk reduction and climate adaptation, aligning with global efforts to promote nature-based solutions (Menéndez and others, 2020). However, in order to provide these long-term benefits, it is crucial to reduce anthropogenic threats to mangroves and to promote their conservation and restoration (Boateng, 2018). In terms of negative consequences, there could be potential trade-offs such as land use conflicts and lack of interest from private investors (Lovelock and others, 2022).

Conclusion of the evaluation

This measure addresses four root causes and five vulnerability drivers, relevant for all the key flood impacts. Beyond flood risk reduction, mangroves offer broader resilience benefits, including protection against other coastal hazards.

5.2.11 Restoration and conservation of urban waterbodies

The restoration of natural urban waterbodies and waterways involves rehabilitating rivers, lakes, wetlands and streams within a city to improve their ability to manage run-off and enhance water retention (Gao and others, 2020; Rojas and others, 2022).

Analysis I: Contribution to addressing key flood impacts

Restoring natural urban waterbodies and waterways could help to reduce hazard and exposure for all types of floods that affect Hue. This process helps to reduce flood risks by restoring the natural functions of these ecosystems, including increasing water storage, slowing down stormwater flows and improving infiltration (Gao and others, 2020; Rojas and others, 2022). By reintroducing native vegetation, removing barriers and enhancing the connectivity of water systems, restoration increases the capacity of urban waterbodies to absorb excess water during heavy rainfall, reducing surface run-off and lowering the risk of flooding (Wang and others, 2022; Li and Wang, 2019; Gao and others, 2020). As a result, this measure can reduce the exposure of the elements related to all the key flood impacts: people and their well-being, livelihoods and economic assets, buildings and infrastructure, and ecosystems and their services.

The measure influences two root causes that affect all the key flood impacts. These are “limited drainage capacity” – as restoration of these waterbodies can improve this and allow the water to flow to less inundated areas (Gao and others, 2020; Wang and others, 2010; Rojas and others, 2022) – and “ecosystem degradation”, as the measure involves restoration and rehabilitation techniques that can enhance ecosystem conditions (Gao and others, 2020; Rojas and others, 2022).

In terms of vulnerability, the measure can address the common driver “poor ecosystem health”, as restoration of natural waterways has been shown to improve the condition of these lakes (Rojas and others, 2022; Gao and others, 2020). Additionally, it can address “limited individual transportation options”, as a vulnerability driver of *individual transportation disruption,* as these waterways are used as a common means of transport in Hue (Li and Wang, 2019). In relation to *water contamination*, this measure can address the vulnerability driver “low sewage system capacity”, as clearer waterways can reduce stress in water sewage systems (Vidal-Abarca Gutiérrez and others, 2023; Basak and others, 2021).

Figure 16: Huong River in Hue city

Analysis II: Development opportunities and trade-offs

Restoration of natural urban waterbodies and waterways can provide many additional positive contributions through the ecosystem services that natural waterbodies provide. These include provisioning services such as food and fuel (stemming from woody vegetation) (Langan and others, 2018; Kaiser and others, 2020), regulating services such as soil fertility and soil quality (Sheergojri and others, 2024), supporting services such as habitat creation (Basak and others, 2021) for species endemic to urban areas, and cultural services such as recreation and tourism (Agaton and Guila, 2023; Kaiser and others, 2020) as a result of the expansion of urban green spaces. Additionally, this measure contributes to improving water quality, enhancing biodiversity and creating recreational spaces, ultimately fostering more resilient and sustainable urban environments (Acreman and others, 2011; Sheergojri and others, 2024; Kaiser and others, 2020). However, there are also possible negative consequences in terms of reduced cost-effectiveness compared with conservation of existing waterbodies and waterways, particularly when restoration entails removal of existing hard infrastructure, reduced space for urban expansion, and land use conflict (river restoration versus dam construction) (Christopher and others, 2024; Cuenca-Cambronero and others, 2023).

Conclusion of the evaluation

This measure addresses two root causes and three vulnerability drivers, relevant for all the key flood impacts. Additionally, it provides valuable ecosystem services, including resource provisioning, habitat creation and recreational opportunities.

5.2.12 Climate-smart agriculture

Climate-smart agriculture is an approach to farming that aims to increase agricultural productivity, enhance resilience to climate change, and reduce greenhouse gas emissions where possible (FAO, 2025).

Analysis I: Contribution to addressing key flood impacts

The establishment of climate-smart agricultural practices can influence pluvial floods. This measure provides crop diversification schemes that can reduce run-off and the velocity of pluvial floods compared with large-scale monocultures (Lipper and others, 2014). As a result, it can reduce the exposure of the elements related to all the key flood impacts: people and their well-being, livelihoods and economic assets, buildings and infrastructure, and ecosystems and their services.

In relation to root causes, the measure addresses "unsustainable agricultural practices" that cause *agricultural livelihood disruptions* and *water contamination,* as it promotes practices such as improved water management, agroforestry and soil conservation, which enhance water infiltration, reduce surface run-off and prevent soil erosion (Basnayake and others, 2019). Climate-smart agriculture also includes adopting resilient crop varieties and farming techniques that withstand flooding and other climate impacts (Pegoraro and others, 2019). Additionally, the measure can address "ecosystem degradation" through enhancing soil fertility and improving water management (Eleblu and others, 2020), as well as "climate change effects" through promoting the use of low-emission techniques (Bhanuwanti and others, 2024), both of which are root causes of all the key flood impacts.

Figure 17: Aerial picture of agricultural systems in Hue

However, the establishment of climate-smart agriculture is a strategy that offers greater and more notable benefits in terms of vulnerability drivers. In relation to *severe health impacts* and *water contamination*, this measure can have an effect on the vulnerability driver "high application of fertilizers and pesticides", as it promotes integrated pest management procedures, which are better for human health conditions and reduce contaminants that could get into the soil and water (Lipper and others, 2014). Additionally, this measure addresses "poor ecosystem health", which is a vulnerability driver of many of the key flood impacts, as its application has proven to be more environmentally sustainable and less depleting than common monocultural practices (Lipper and others, 2014). Lastly, the measure reduces the vulnerability driver "use of sensitive, high-yield crops", as it aims to introduce more flood-resilient crops and smart cropping rotations that can potentially increase a system's resilience to floods (Pegoraro and others, 2019).

Analysis II: Development opportunities and trade-offs

Overall, climate-smart agriculture can make positive contributions such as reduced crop loss due to diversification and improved storage techniques that reduce spoilage by pests in the aftermath of flooding or reduce excessive humidity in storage (Singh and Singh, 2017). By integrating sustainability, adaptation and mitigation, climate-smart agriculture contributes to food security and reduces the vulnerability of farming communities to crop-related impacts (Zougmoré and others, 2018). In addition, this approach often integrates traditional farming methods (e.g. agroecological practices) and promotes locally adapted seed varieties (Mizik, 2021). However, climate-smart agriculture techniques may demand more human, technological and financial resources, and the usage of biopesticides could introduce new contaminants into water systems (Mizik, 2021).

Conclusion of the evaluation

This measure addresses two root causes and three vulnerability drivers, relevant for all the key flood impacts. Additionally, it supports food security and long-term agricultural resilience through improved storage techniques and the integration of traditional farming methods.

5.3 Towards a bundle of options for addressing current and future flood risks

The evaluation of the 12 measures gives an idea of the diversity of options suitable to address the four key flood impacts that were identified as critical by local stakeholders. In Figure 18, it can be seen that in summary, all the measures together have the capacity to address all root causes, with the exception of a hazard-specific root cause, as “weather and climate conditions” are intrinsic to the location of Hue. Since root causes give rise to drivers of vulnerability and exposure, which together define the risk context, addressing these root causes offers significant potential for effective risk reduction. For example, the measure of structural housing modification addresses two specific root causes – “non-risk-informed urban planning” and “insufficient risk management and adaptation” – which directly relate to multiple exposed elements and vulnerability drivers. While the specific measure of structural housing modification only relates to exposed elements and vulnerability drivers in relation to *severe health impacts*, this measure addresses root causes that are shared among all key risks, which inspires a more systematic planning and evaluation approach. Thus, addressing the root causes in flood risk management is an effective way to reduce disaster risk in a more systematic way and supports the transformation to long-term climate resilience (Blaikie and others, 2014; Filho and others, 2022; Schipper, 2020). As established during the evaluation, the expected influence of each measure is greater than represented in Figure 18; for easier interpretation, only the key entry points are shown here.

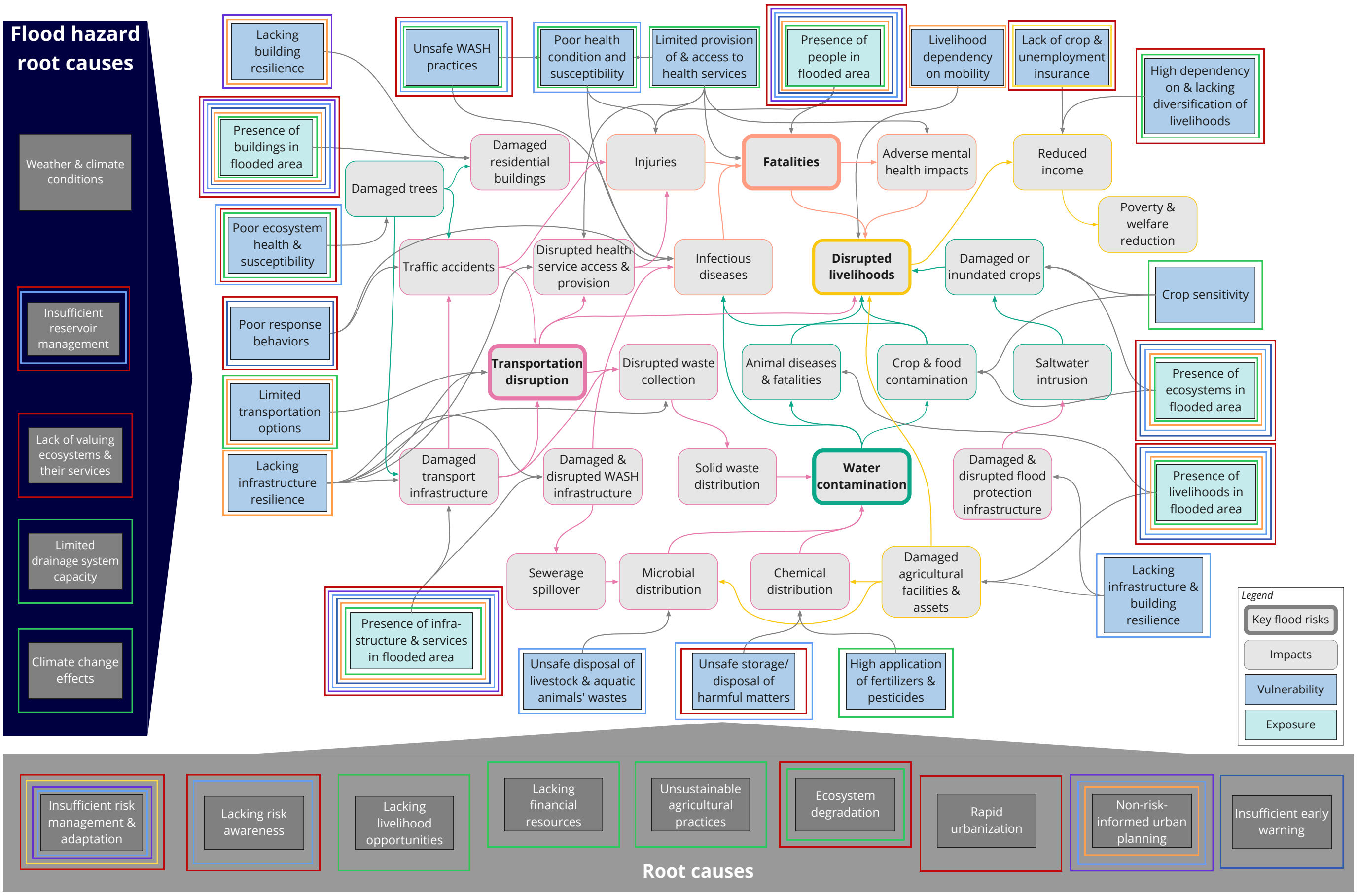

Figure 18: Overall impact web presenting the four key flood impacts and showing (through coloured frames of the respective component boxes) the influence that the different categories of measures can have over some drivers of flood risk in Hue. Source: adapted from Sett and others (2024).

Note: the colour coding of the frames builds on Table 2 and represents the diversity of categories of measures to address flood risk, in line with IPCC AR5 (Noble and others, 2014). Green represents ecosystem-based measures; yellow represents economic measures; dark blue represents technological measures; light blue represents government policies and programmes; red represents educational measures; purple represents engineered and built environment measures; orange represents laws and regulations.

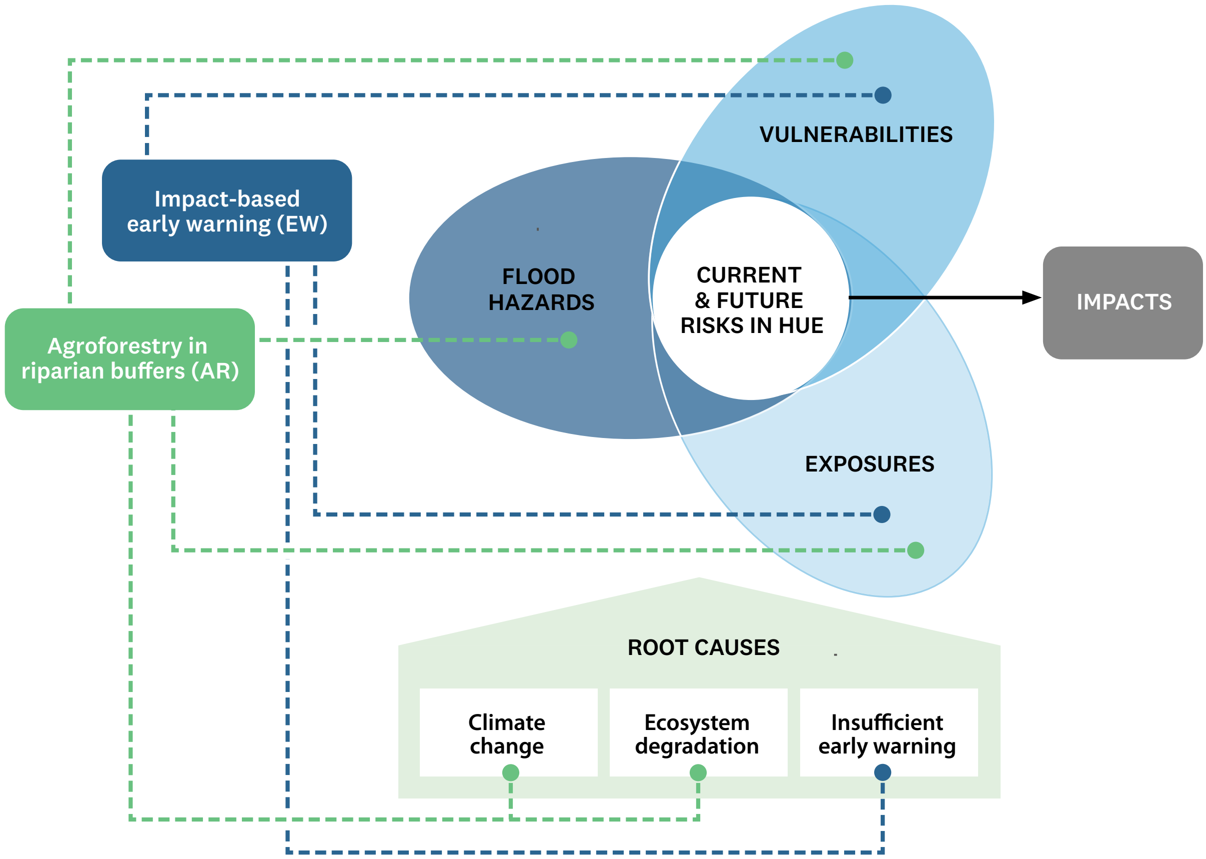

Figure 19: Example of a combination of two different types of measures to address the different components of current and future flood risks in Hue. Source: adapted from Sett and others (2025).

The evaluation of individual measures has also shown that one measure can address different root causes and vulnerability drivers. At the same time, the variety of types of measures addresses the risk components in different ways. Only a combination of different options that complement each other can address the complexity of flood risk in Hue. Encompassing flood exposure, hazard and vulnerability requires an integrated approach that combines structural, social, institutional and ecosystem-based measures across upstream, midstream and downstream areas. As a graphic representation, Figure 19 shows the example of two different types of measures and how they work together and complement each other to address current and future flood risks in Hue. The technological measure impact-based early warning (EW) mainly addresses components of exposure and vulnerability (Figure 19). However, it is also relevant to mention that EW can contribute to better reservoir management, in which case it can influence fluvial floods (Lellyett and others, 2022). While EW can only indirectly influence the flood hazard itself (e.g. through targeted reservoir management), the ecosystem-based measure of agroforestry in riparian buffers (AR) can complement this. Besides affecting vulnerability, it addresses the origin of floods, as it directly influences water regulation and infiltration, reduces flow velocity of discharge and promotes soil stability. This has an overall effect on the intensity and frequency of floods, and consequently also reduces exposure (Santoro and others, 2022). Furthermore, these two measures when used together can help to address different root causes (Figure 19).

We argue that it is necessary to adopt bundles of measures that complement each other and address the overall complexity of flood risk and climate change. To achieve this, decision makers need to reflect on their specific objectives to decide on the most suitable combination of measures to address the prevalent challenges and their aims and priorities. The measures presented in this report offer decision makers opportunities to develop comprehensive strategies through the use of bundles of measures. Unlike single-solution approaches, these can effectively tackle diverse flood risk drivers while maximizing risk reduction benefits, creating synergies and enhancing overall performance in achieving flood risk management and adaptation goals.

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6. Conclusion, recommendations and next steps

The report identifies multiple entry points for enhancing flood risk management and climate change adaptation in Hue, emphasizing that ecosystem-based measures can be strategically tailored to the region's diverse geographical zones such as mountainous, peri-urban, urban and coastal areas. Each measure offers specific benefits by targeting distinct root causes of flood risk, and together they complement one another while also providing additional development co-benefits, as well as potential trade-offs. The integration of diverse types of measures – including structural, social and institutional options – is essential to address the complex nature of flood risk and climate impacts.

An in-depth and dynamic understanding of flood risk, starting with the assessment of root causes as well as hazard characteristics, exposure patterns and vulnerability drivers, is fundamental to improving flood risk management and adaptation planning in Hue. This detailed risk understanding, although currently limited by the availability of spatially explicit data, is necessary to design strategies that integrate a diversity of types of measure across the entire catchment. It is recommended to move beyond single-solution approaches and to adopt comprehensive bundles or packages of measures that combine structural, social, institutional and ecosystem-based options across upstream, midstream and downstream areas. These bundled approaches complement one another by addressing multiple root causes and risk drivers, therefore addressing the complexity of flood risk in Hue. Additionally, the broader benefits of certain measures (particularly ecosystem-based ones) should be recognized, as they can support biodiversity, water quality, local economies and community resilience. A comprehensive prioritization of measures should consider these co-benefits alongside their risk reduction potential. Lastly, it is critical to consider socioecological interactions and the dynamics of regional landscapes, in order to identify appropriate and context-specific measures that strengthen resilience and reduce both current and future flood risks throughout Hue's diverse geographical areas.

To advance flood risk reduction and adaptation in Hue, the following next steps are envisioned for the upcoming implementation phase of the FloodAdaptVN project:

- The FloodAdaptVN team will derive bundles of adaptation measures, which focus on sequencing and complementing multifunctional solutions that reflect stakeholder priorities for a more resilient Hue.
- We plan to integrate a comprehensive cost-benefit analysis into the evaluation of nine of the selected measures, providing stakeholders and decision makers with the financial insights needed to assess economic viability and support evidence-based prioritization.
- To advance from planning to action, we will initiate "implementation dialogue" with key decision makers, using the results of this report as a foundation to co-develop a roadmap that outlines priority measures, responsible actors and necessary resources.

- By further integrating risk information and climate scenarios, the project will support transparent, data-driven and evidence-based planning.
- As part of our implementation strategy, we aim to identify suitable funding opportunities and innovative financing mechanisms. This includes developing project proposals or business models to support the concrete realization of bundled adaptation measures.
- A key future priority is strengthening institutional and individual capacities to identify, plan and monitor adaptation and risk reduction measures using a broad spectrum of methods. This includes the use of Earth observation, web-based tools such as FRAME, participatory planning instruments, and in-situ evaluation methods to foster locally adapted, knowledge-based solutions.

By addressing these next steps, Hue can move towards a more resilient and adaptive flood risk management framework, ensuring long-term sustainability and protection for its communities and ecosystems.

References

Acreman, M.C., and others (2011). Trade-Off in ecosystem services of the Somerset Levels and Moors wetlands. *Hydrological Sciences Journal*, vol. 56, No. 8, pp. 1543–1565. DOI: 10.1080/02626667.2011.629783

Agaton, Casper B., and Patricia M.C. Guila (2023). Ecosystem services valuation of constructed wetland as a nature-based solution to wastewater treatment. *Earth*, vol. 4, No. 1, pp. 78–92. DOI: 10.3390/earth4010006

Anderson, B.G., I.D. Rutherfurd and A.W. Western (2006). An analysis of the influence of riparian vegetation on the propagation of flood waves. *Environmental Modelling & Software*, vol. 21, No. 9, pp. 1290–1296. DOI: 10.1016/j.envsoft.2005.04.027

Anthonj, Carmen, and others (2022). Do health risk perceptions motivate water- and health-related behaviour? A systematic literature review. *The Science of the total environment*, vol. 819, p. 152902. DOI: 10.1016/j.scitotenv.2021.152902

Azizi, Koorosh, and others (2025). *Integrating Perspectives: Multi-Sectoral Insights into Gulf Coast Flood Governance*. DOI: 10.2139/ssrn.5125553

Bachofer, Felix, and others (2025). *Strengthening Flood Resilience in Huế - Insights from FloodAdaptVN. A Summary for Policymakers*. German Aerospace Center (DLR). DOI: 10.15489/hj8z2za81381

Barros, Daniela d.F., and others (2020). Effects of deforestation and other environmental variables on floodplain fish catch in the Amazon. *Fisheries Research*, vol. 230, p. 105643. DOI: 10.1016/j.fishres.2020.105643

Basak, Sayantani M., and others (2021). Social benefits of river restoration from ecosystem services perspective: a systematic review. *Environmental Science & Policy*, vol. 124, pp. 90–100. DOI: 10.1016/j.envsci.2021.06.005

Basnayake, Senaka, and others (2019). *Climate Smart Disaster Risk Reduction Interventions in Agriculture Sector – Flood Hazard: A Practitioner's Guidebook*. Asian Disaster Preparedness Center. DOI: 10.13140/RG.2.2.27324.39042

Bathurst, James C., and others (2011). Forest impact on floods due to extreme rainfall and snowmelt in four Latin American environments 1: field data analysis. *Journal of Hydrology*, vol. 400, Nos. 3-4, pp. 281–291. DOI: 10.1016/j.jhydrol.2010.11.044

Bathurst, James C., and others (2017). Forest impact on flood peak discharge and sediment yield in streamflow. In *River System Analysis and Management,* Nayan Sharma, ed. Singapore: Springer.

Bauer, T., and others (2018). The socio-economic impact of extreme precipitation and flooding on forest livelihoods: evidence from the Bolivian Amazon. *International Forestry Review*, vol. 20, No. 3, pp. 314–331. DOI: 10.1505/146554818824063050

Benito, Gerardo, and Paul F. Hudson (2010). Flood hazards: the context of fluvial geomorphology. In *Geomorphological Hazards and Disaster Prevention,* Irasema Alcántara-Ayala and Andrew S. Goudie, eds., Cambridge: Cambridge University Press.

Benson, David, and Irene Lorenzoni (2017). Climate change adaptation, flood risks and policy coherence in integrated water resources management in England. *Regional Environmental Change*, vol. 17, No. 7, pp. 1921–1932. DOI: 10.1007/s10113-016-0959-6

Bhandari, Ananta Ram, and Saroj Lamichhane (2020). *Sustainable Forest Management Resource Book*. WWF Nepal.

Bhanuwanti, Khursheed A.D., and others (2024). Climate smart agriculture: innovating sustainable practices for a changing climate. *Journal of Scientific Research and Reports*, vol. 30, No. 11, pp. 568–576. DOI: 10.9734/jsrr/2024/v30i112585

Birkmann, Jörn, and Joanna M. McMillan (2020). Linking hazard vulnerability, risk reduction, and adaptation. *Oxford Research Encyclopedia of Natural Hazard Science.* DOI: 10.1093/acrefore/9780199389407.013.145

Bisaro, Alexander, and others (2020). Multilevel governance of coastal flood risk reduction: a public finance perspective. *Environmental Science & Policy*, vol. 112, pp. 203–212. DOI: 10.1016/j.envsci.2020.05.018

Biswas, Benukar, and others (2022). Agroforestry offers multiple ecosystem services in degraded lateritic soils. *Journal of Cleaner Production*, vol. 365, p. 132768. DOI: 10.1016/j.jclepro.2022.132768

Blaikie, Piers, and others (2014). *At Risk: Natural Hazards, People's Vulnerability and Disasters*. London: Routledge.

Boateng, Isaac (2018). An assessment of vulnerability and adaptation of coastal mangroves of West Africa in the face of climate change. In *Threats to Mangrove Forests*, Christopher Makowski and Charles W. Finkl, eds., pp. 141–54. DOI: 10.1007/978-3-319-73016-5_7

Borma, L.S., and others (2022). Beyond carbon: the contributions of South American tropical humid and subhumid forests to ecosystem services. *Reviews of Geophysics*, vol. 60, No. 4, DOI: 10.1029/2021RG000766

Brouwers, Kay, and others (2022). Lifelong learning through knowledge-sharing and digital collaboration. *Proceedings of the 23rd European Conference on Knowledge Management.* Reading: Academic Conferences International. DOI: 10.34190/eckm.23.1.748

Bruland, Gregory L. (2008). Coastal wetlands: function and role in reducing impact of land-based management. In *Coastal Watershed Management,* Ali Fares and Aly I. El-Kadi, eds. Southampton: WIT Press.

Burningham, Kate, Jane Fielding and Diana Thrush (2008). 'It'll never happen to me': Understanding public awareness of local flood risk. *Disasters*, vol. 32, No. 2, pp. 216–238. DOI: 10.1111/j.1467-7717.2007.01036.x

Castle, Sarah E., and others (2021). The impacts of agroforestry interventions on agricultural productivity, ecosystem services, and human well-being in low- and middle-income countries: a systematic review. *Campbell Systematic Reviews*, vol. 17, No. 2, e1167. DOI: 10.1002/cl2.1167

Celinah, Odeyale O., and Eseoghene B. Olawuyi (2018). Socio-economic impact of non-timber forest products in income generation for sustainable forest management in Gambari forest reserve, Oyo State, Nigeria. *Scientific Research Journal*, vol. VI, Issue X. DOI: 10.31364/scirj/v6.i10.2018.p1018573

Černohous, V., V. Švihla and F. Šach (2017). Contribution to assessment of forest stand impact on decrease of flood peakflow discharge. *Zprávy Lesnického Výzkumu*, vol. 62, No. 2, pp. 82–86.

Christopher, Nikita, and others (2024). Enhancing river floodplain management with nature-based solutions: overcoming barriers and harnessing enablers. *WIREs Water*, vol. 11, No. 4, e1723. DOI: 10.1002/wat2.1723

Climate Adapt (2023). Establishment and restoration of riparian buffers. Available at https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/establishment-and-restoration-of-riparian-buffer-s

Connective Cities (2022). *Water Sensitive Urban Planning in Times of Climate Change*. United Cities and Local Governments (UCLG) Peer Learning Note #33.

Creach, Axel, and others (2020). Vulnerability and costs of adaptation strategies for housing subjected to flood risks: application to La Guérinière France. *Marine Policy*, vol. 117, p. 103438. DOI: 10.1016/j.marpol.2019.02.010

CRED (2023). EM-DAT: The International Disaster Database. Centre for Research on the Epidemiology of Disasters. Available at https://emdat.be/. Accessed on 16 June 2025.

Cuenca-Cambronero, M., and others (2023). Challenges and opportunities in the use of ponds and pondscapes as nature-based solutions. *Hydrobiologia*, vol. 850, No. 15, pp. 3257–3271. DOI: 10.1007/s10750-023-05149-y

Das, Abhishek, and Priyanka H. Mallick (2023). The trend of forest ecosystem services assessment in eastern India: a review for future research insights. *Environmental Monitoring and Assessment*, vol. 195, No. 5, art. 615. DOI: 10.1007/s10661-023-11218-5

Davis, Marion, and Albert Salamanca (2013). Building and sharing knowledge for adaptation: lessons from the Regional Climate Change Adaptation Knowledge Platform for Asia (AKP). Stockholm Environment Institute and AKP policy brief.

den Boer, Jacomien, Carel Dieperink and Farhad Mukhtarov (2019). Social learning in multilevel flood risk governance: lessons from the Dutch Room for the River program. *Water*, vol. 11, No. 10, p. 2032. DOI: 10.3390/w11102032

Der Sarkissian, Rita, and others (2022). Land use planning to reduce flood risk: opportunities, challenges and uncertainties in developing countries. *Sensors*, vol. 22, No. 18, p. 6957. DOI: 10.3390/s22186957

de Ruig, Lars T., and others (2020). A micro-scale cost-benefit analysis of building-level flood risk adaptation measures in Los Angeles. *Water Resources and Economics*, vol. 32, p. 100147. DOI: 10.1016/j.wre.2019.100147

Desmiwati, Desmiwati, and others (2021). Contribution of agroforestry systems to farmer income in state forest areas: a case study of Parungpanjang, Indonesia. *Forest and Society,* vol. 5, No. 1, pp. 109–119. DOI: 10.24259/fs.v5i1.11223

De Zoysa, Mangala, and Makoto Inoue (2016). Farmers' woodlots management and sustainable livelihood development: a case study in southern Sri Lanka. *Environment and Ecology Research*, vol. 4, No. 2, pp. 85–95. DOI: 10.13189/eer.2016.040206

Di Falco, Salvatore, and others (2014). Crop insurance as a strategy for adapting to climate change. *Journal of Agricultural Economics*, vol. 65, No. 2, pp. 485–504. DOI: 10.1111/1477-9552.12053

Driessen, Peter P.J., and others (2016). Toward more resilient flood risk governance. *Ecology and Society*, vol. 21, No. 4. Available at https://jstor.org/stable/26269990

Drugge, Jordan, and Sharon L. Doty (2019). Riparian Buffers in Agricultural Areas. International Poplar Commission. Available at https://openknowledge.fao.org/server/api/core/bitstreams/aae3a349-0b36-4115-bfe4-c228313379af/content

Eleblu, John S., Eugene T. Darko and Eric Y. Danquah (2020). Case for climate smart agriculture in addressing the threat of climate change. In *African Handbook of Climate Change Adaptation,* W.L. Filho and others, eds. Cham: Springer International Publishing.

Fagerholm, Nora, and others (2016). A systematic map of ecosystem services assessments around European agroforestry. *Ecological Indicators*, vol. 62, pp. 47–65. DOI: 10.1016/j.ecolind.2015.11.016

FAO (2015). *Unasylva: Forest and Landscape Restoration*, vol. 66, No. 245. Food and Agriculture Organization of the United Nations. Available at https://openknowledge.fao.org/items/a1490678-9723-47cd-926d-a65ad88969dd

FAO (2025). Climate-Smart Agriculture. Food and Agriculture Organization of the United Nations. Available at https://fao.org/climate-smart-agriculture/en/

Farinaccio, F.M., E. Ceccon and D.R. Pérez (2024). Could agroforestry restore ecosystem services in arid lands? An analysis through the weight of the evidence approach. *Agroforestry Systems*, vol. 98, No. 2, pp. 507–521. DOI: 10.1007/s10457-023-00927-y

Filho, Walter L., and others (2022). Transformative adaptation as a sustainable response to climate change: insights from large-scale case studies. *Mitigation and Adaptation Strategies for Global Change*, vol. 27, No. 3, art. 20. DOI: 10.1007/s11027-022-09997-2

FloodAdaptVN (2025). FRAME: Flood Risk Information System for Adaptation Measures and Evaluation in Central Vietnam. Available at https://framefavn.org

Friess, Daniel A. (2016). Ecosystem services and disservices of mangrove forests: insights from historical colonial observations. *Forests*, vol. 7, No. 9, p. 183. DOI: 10.3390/f7090183

Gao, Yu-qin, and others (2020). Change of stream network connectivity and its impact on flood control. *Water Science and Engineering*, vol. 13, No. 4, pp. 253–264. DOI: 10.1016/j.wse.2020.12.004

Garcia, Juan A., and others (2021). Social marketing for flood risk management: a local communication campaign in Spain. In *Applied Social Marketing and Quality of Life,* M.M. Galan-Ladero and R.G. Rivera, eds. Cham: Springer International Publishing.

Gargaran, Jan P.S., and others (2024). Mangrove ecosystem in Asia: review and synthesis of ecosystem services and economic valuation methods. *Environmental and Experimental Biology*, vol. 22, No. 2, pp. 59–70. DOI: 10.22364/eeb.22.06

Gassner, Anja, and Philip Dobie, eds. (2022). *Agroforestry: A Primer. Design and Management Principles for People and the Environment.* Bogor, Indonesia: Center for International Forestry Research and World Agroforestry (CIFOR–ICRAF).

Glaus, Anik, and others (2020). How flood risks shape policies: flood exposure and risk perception in Swiss municipalities. *Regional Environmental Change*, vol. 20, No. 4, art. 120. DOI: 10.1007/s10113-020-01705-7

Handmer, John (1996). Policy design and local attributes for flood hazard management. *Journal of Contingencies and Crisis Management*, vol. 4, No. 4, pp. 189–197. DOI: 10.1111/j.1468-5973.1996.tb00093.x

Hidayati, Zakiah, Mafazah Noviana and Muhammad Fadzillah Rosyidi (2023). Interior modification of residential housing in flood prone areas. *International Journal of Disaster Management*, vol. 5, No. 3, pp. 159–180. DOI: 10.24815/ijdm.v5i3.28552

Hilmi, Endang, and others (2022). The potential of high tidal flooding disaster in North Jakarta using mapping and mangrove relationship approach. *IOP Conference Series: Earth and Environmental Science*, vol. 989, No. 1, p. 12001. DOI: 10.1088/1755-1315/989/1/012001

Hossain, Md. S. (2024). Assessing smallholder farmers' flood risk behavior and their willingness to pay for crop insurance as a risk coping strategy in northern Bangladesh. *Natural Hazards,* vol. 121, pp. 4191-4217. DOI: 10.1007/s11069-024-06958-7

Hümann, Marco, and others (2011). Identification of runoff processes – the impact of different forest types and soil properties on runoff formation and floods. *Journal of Hydrology*, vol. 409, Nos. 3-4, pp. 637–649. DOI: 10.1016/j.jhydrol.2011.08.067

Huong, H.T.L., and A. Pathirana (2013). Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam. *Hydrology and Earth System Sciences*, vol. 17, No. 1, pp. 379–394. DOI: 10.5194/hess-17-379-2013

Idier, Déborah, and others (2020). Coastal flood: a composite method for past events characterisation providing insights in past, present and future hazards—joining historical, statistical and modelling approaches. *Natural Hazards*, vol. 101, No. 2, pp. 465–501. DOI: 10.1007/s11069-020-03882-4

Ionita, Anca D., Adriana Olteanu and Radu N. Pietraru (2020). Knowledge and decision support for hazard awareness. In *Knowledge Discovery, Knowledge Engineering, and Knowledge Management,* Ana Fred and others, eds. 11th International Joint Conference, IC3K 2019. Communications in Computer and Information Science, vol. 1297. Cham: Springer.

Islam, Mohammad A., and others (2024). Mangroves of Malaysia: a comprehensive review on ecosystem functions, services, restorations, and potential threats of climate change. *Hydrobiologia*, vol. 851, No. 8, pp. 1841–1871. DOI: 10.1007/s10750-023-05431-z

Janzen, S., and others (2024). Moving towards a comprehensive evaluation of ecosystem-based disaster risk reduction: the example of agroforestry for flood risk reduction. *Nature-Based Solutions*, vol. 5, p. 100104. DOI: 10.1016/j.nbsj.2023.100104

Judd, Neil, and others (2013). *The Sustainable Forestry Handbook: A Practical Guide for Tropical Forest Managers on Implementing New Standards*. London: Routledge.

Kaiser, Nina N., Christian K. Feld and Stefan Stoll (2020). Does river restoration increase ecosystem services? *Ecosystem Services*, vol. 46, p. 101206. DOI: 10.1016/j.ecoser.2020.101206

Karanja, Joseph M., and Osamu Saito (2018). Cost–benefit analysis of mangrove ecosystems in flood risk reduction: a case study of the Tana Delta, Kenya. *Sustainability Science*, vol. 13, No. 2, pp. 503516. DOI: 10.1007/s11625-017-0427-3

Kauppi, Pekka E., and others (2022). Managing existing forests can mitigate climate change. *Forest Ecology and Management*, vol. 513, p. 120186. DOI: 10.1016/j.foreco.2022.120186

Krauss, Ken W., and others (2014). How mangrove forests adjust to rising sea level. *New Phytologist*, vol. 202, No. 1, pp. 19–34. DOI: 10.1111/nph.12605

Kreibich, H., and others (2005). Flood loss reduction of private households due to building precautionary measures – lessons learned from the Elbe flood in August 2002. *Natural Hazards and Earth System Sciences*, vol. 5, No. 1, pp. 117–126. DOI: 10.5194/nhess-5-117-2005

Kurdyś-Kujawska, Agnieszka, and others (2021). Crop insurance, land productivity and the environment: a way forward to a better understanding. *Agriculture*, vol. 11, No. 11, p. 1108. DOI: 10.3390/agriculture11111108

Langan, Charlie, and others (2018). Tropical wetland ecosystem service assessments in East Africa: a review of approaches and challenges. *Environmental Modelling & Software*, vol. 102, pp. 260–273. DOI: 10.1016/j.envsoft.2018.01.022

Lee, Eunmi, and Haeyoung Lee (2019). Disaster awareness and coping: impact on stress, anxiety, and depression. *Perspectives in Psychiatric Care*, vol. 55, No. 2, pp. 311–318. DOI: 10.1111/ppc.12351

Lellyett, Stephen C., Robert N. Truelove and Abul K.S. Huda (2022). Improving early warning of drought in Australia. *Climate*, vol. 10, No. 7, p. 91. DOI: 10.3390/cli10070091

Li, Yuqi, and Chunlian Wang (2019). Yanweizhou ecological embankment strategy and its effects on flood control in the Jinhua River Basin. *Acta Ecologica Sinica*, vol. 39, No. 16, DOI: 10.5846/stxb201812052667

Lipper, Leslie, and others (2014). Climate-smart agriculture for food security. *Nature Climate Change*, vol. 4, No. 12, pp. 1068–1072. DOI: 10.1038/nclimate2437

Lovelock, Catherine E., Edward Barbier and Carlos M. Duarte (2022). Tackling the mangrove restoration challenge. *PLoS Biology*, vol. 20, No. 10, e3001836. DOI: 10.1371/journal.pbio.3001836

Lü, Yingshuo, Yaohan Wang and Xi Zheng (2021). Influence of forest landscape pattern on flood mitigation in Beijing Plain based on SWAT model. *Acta Ecologica Sinica*, vol. 41, No. 10. DOI: 10.5846/stxb202005281379

Maidl, E., and M. Buchecker (2015). Raising risk preparedness by flood risk communication. *Natural Hazards and Earth System Sciences*, vol. 15, No. 7, pp. 1577–1595. DOI: 10.5194/nhess-15-1577-2015

Mannucci, Simona, and others (2022). Flood resilience and adaptation in the built environment: how far along are we? *Sustainability*, vol. 14, No. 7, p. 4096. DOI: 10.3390/su14074096

MARD (2020). Announcement of the current status of the national forest in 2019 (Decision No. 1423/QD-BNN-TCLN dated 15 April 2020) Ministry of Agriculture and Rural Development, Viet Nam.

Matczak, Piotr, and Dries L.T. Hegger (2020). Flood risk governance for more resilience—reviewing the special issue's contribution to existing insights. *Water*, vol. 12, No. 8, p. 2122. DOI: 10.3390/w12082122

Mazviona, Batsirai, Simon Sølvsten and Rana I. Palwishah (2024). Quantifying the Impact of Rainfall and Temperature Stress on Index Crop Insurance. DOI: 10.2139/ssrn.5018747

Mbow, Cheikh, and others (2014). Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability*, vol. 6, pp. 61–67. DOI: 10.1016/j.cosust.2013.10.014

McIvor, Anna L., and others, eds. (2013). Mangroves as a sustainable coastal defence. In *Proceedings of the 7th International Conference on Asian and Pacific Coasts (APAC 2013).* Bali, Indonesia: The Nature Conservancy.

Mcleman, Robert, and Barry Smit (2006). Vulnerability to climate change hazards and risks: crop and flood insurance. *Canadian Geographies/Geographies canadiennes*, vol. 50, No. 2, pp. 217–226. DOI: 10.1111/j.0008-3658.2006.00136.x

Mehryar, Sara, and Swenja Surminski (2021). *Investigating flood resilience perceptions and supporting collective decision-making through fuzzy cognitive mapping.* Centre for Climate Change Economics and Policy Working Paper 400/ Grantham Research Institute on Climate Change and the Environment Working Paper 373. London, UK: London School of Economics and Political Science. Available at https://eprints.lse.ac.uk/115529/1/CCCEP_investigating_flood_resilience_perceptions.pdf

Menéndez, Pelayo, and others (2020). The global flood protection benefits of mangroves. *Scientific Reports*, vol. 10, No. 1, p. 4404. DOI: 10.1038/s41598-020-61136-6

Menoni, Scira, and others (2024). Cross-sectoral and multilevel dimensions of risk and resilience management in urban areas enabled by geospatial data processing. *Sustainability*, vol. 16, No. 19, p. 8712. DOI: 10.3390/su16198712

Mitheu, Faith, and others (2023). Impact-based flood early warning for rural livelihoods in Uganda. *Weather, Climate, and Society*, vol. 15, No. 3, pp. 525–539. DOI: 10.1175/WCAS-D-22-0089.1

Mizik, Tamás (2021). Climate-smart agriculture on small-scale farms: a systematic literature review. *Agronomy*, vol. 11, No. 6, p. 1096. DOI: 10.3390/agronomy11061096

MONRE (2020). Climate Change Scenarios for Vietnam. Ministry of Natural Resources and Environment, Viet Nam: Department of Climate Change.

Munji, Cecilia A., and others (2013). Vulnerability to coastal flooding and response strategies: the case of settlements in Cameroon mangrove forests. *Environmental Development*, vol. 5, pp. 54–72. DOI: 10.1016/j.envdev.2012.10.002

Najafi, Husain, and others (2024). High-resolution impact-based early warning system for riverine flooding. *Nature Communications*, vol. 15, No. 1, art. 3726. DOI: 10.1038/s41467-024-48065-y

Nelson, H.P., and others (2020). A review of tropical dry forest ecosystem service research in the Caribbean – gaps and policy-implications. *Ecosystem Services*, vol. 43, p. 101095. DOI: 10.1016/j.ecoser.2020.101095

Ngo-Duc, Thanh (2014). Climate change in the coastal regions of Vietnam. In *Coastal Disasters and Climate Change in Vietnam: Engineering and Planning Perspectives*, Nguyen Danh Thao, Hiroshi Takagi and Miguel Esteban, eds. Elsevier.

Nguyen, Cong D., and others (2021a). Long-term improvement in precautions for flood risk mitigation: a case study in the low-lying area of central Vietnam. *International Journal of Disaster Risk Science*, vol. 12, No. 2, pp. 250–266. DOI: 10.1007/s13753-020-00326-2

Nguyen, Minh T., and others (2021b). Understanding and assessing flood risk in Vietnam: current status, persisting gaps, and future directions. *Journal of Flood Risk Management*, vol. 14, No. 2, DOI: 10.1111/jfr3.12689

Noble, Ian R., and others (2014). Adaptation needs and options. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, C.B. Field and others, eds. Cambridge and New York: Cambridge University Press, pp. 833–868. Available at https://ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap14_FINAL.pdf

Nordbeck, Ralf, and others (2023). Conflicting and complementary policy goals as sectoral integration challenge: an analysis of sectoral interplay in flood risk management. *Policy Sciences*, vol. 56, No. 3, pp. 595–612. DOI: 10.1007/s11077-023-09503-8

Obaitor, Olabisi S., and others (2025a). Modelling Future Urban Growth Scenarios in the Context of SSPs and Ecosystem-Based Adaptation to Address Flood Risk in Huế Vietnam. Under review.

Obaitor, Olabisi S., and others (2025b). Spatial dynamics and drivers of urban growth in Thua Thien Hue province, Vietnam: insights for urban sustainability in the Global South. *ISPRS International Journal of Geo-Information*, vol. 14, No. 2, p. 44. DOI: 10.3390/ijgi14020044

Opitz-Stapleton, Sarah, and others (2019). Risk-informed development: from crisis to resilience. Research Report. Overseas Development Institute, United Nations Development Programme and Swiss Agency for Development and Cooperation. DOI: 10.13140/RG.2.2.24990.28480

Ortiz Vargas, A., and others (2025). Bridging ecosystem services and disaster risk management: entry points for integrating ecosystem information into policy frameworks, the study case of Thua Thien-Hue province in central Vietnam. EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-19937. DOI: 10.5194/egusphere-egu25-19937

Osberghaus, Daniel, and Hendrik Hinrichs (2021). The effectiveness of a large-scale flood risk awareness campaign: evidence from two panel data sets. *Risk analysis*, vol. 41, No. 6, pp. 944–957. DOI: 10.1111/risa.13601

PANORAMA (2025). Panorama: Solutions for a Healthy Planet. Available at https://panorama.solutions. Accessed on 16 June 2025.

Pegoraro, Camila, and others (2019). Climate smart crops: flood and drought-tolerant crops. In *Sustainable Solutions for Food Security,* Atanu Sarkar, Suman R. Sensarma and Gary W. vanLoon, eds. Cham: Springer International Publishing.

Peskett, Leo M., and others (2021). Tracers reveal limited influence of plantation forests on surface runoff in a UK natural flood management catchment. *Journal of Hydrology: Regional Studies*, vol. 36, p. 100834. DOI: 10.1016/j.ejrh.2021.100834

Pham, T.T., and others (2018). Local perspectives on drivers of deforestation and degradation and effectiveness of financial incentive mechanisms in Bach Ma National Park. Working Paper 240. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Pham, T.T., (2021). Mangrove environmental services and local livelihoods in Vietnam. Info Brief No. 339. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Pham, Thi D.M., and others (2024). Community-based early warning systems in a changing climate: an empirical evaluation from coastal central Vietnam. *Climate and Development*, vol. 16, No. 8, pp. 673684. DOI: 10.1080/17565529.2024.2307398

Potter, Sally, Sara Harrison and Peter Kreft (2021). The benefits and challenges of implementing impact-based severe weather warning systems: perspectives of weather, flood, and emergency management personnel. *Weather, Climate, and Society*, vol. 13, No. 2, pp. 303–314. DOI: 10.1175/WCAS-D-20-0110.1

Prokić, Marija, Stevan Savic and Dragoslav Pavic (2019). Pluvial flooding in urban areas across the European continent. *Geographica Pannonica*, vol. 23, No. 4, pp. 216–232. DOI: 10.5937/gp23-23508

Quandt, Amy, and others (2017). The role of agroforestry in building livelihood resilience to floods and drought in semiarid Kenya. *Ecology and Society*, vol. 22, No. 3, DOI: 10.5751/ES-09461-220310

Quijas, Sandra, and others (2019). Linking biodiversity, ecosystem services, and beneficiaries of tropical dry forests of Latin America: review and new perspectives. *Ecosystem Services*, vol. 36, p. 100909. DOI: 10.1016/j.ecoser.2019.100909

Rackelmann, Fabian, Zita Sebesvari and Rainer Bell (2023). Synergies and trade-offs in the management objectives forest health and flood risk reduction. *Frontiers in Forests and Global Change*, vol. 6, DOI: 10.3389/ffgc.2023.1208032

Rahman, Khandkar-Siddikur, and others (2024). Nypa-based land uses and ecosystem services in the tropics: a review. *Ecological Indicators*, vol. 159, p. 111613. DOI: 10.1016/j.ecolind.2024.111613

Ramachandran Nair, P.K., and others (2010). Carbon sequestration in agroforestry systems. *Advances in Agronomy*, vol. 108, pp. 237-307. DOI: 10.1016/S0065-2113(10)08005-3

Ramm, Gaby, and others (2018). Integrating insurance into climate risk management: conceptual framework, tools and guiding questions: examples from the agricultural sector. Report No. 24. Bonn: United Nations University – Institute for Environment and Human Security (UNU-EHS).

Raskin, Ben, and Simone Osborn (2019). *The Agroforestry Handbook: Agroforestry for the UK*. Bristol: The Soil Association. Available at https://soilassociation.org/media/19141/the-agroforestry-handbook.pdf

Redmond, Grace, and others (2015). Projected changes in tropical cyclones over Vietnam and the South China Sea using a 25 km regional climate model perturbed physics ensemble. *Climate Dynamics*, vol. 45, 7-8, pp. 1983–2000. DOI: 10.1007/s00382-014-2450-8

Reinhardt-Imjela, Christian, and others (2018). The impact of late medieval deforestation and 20th century forest decline on extreme flood magnitudes in the Ore Mountains (southeastern Germany). *Quaternary International*, vol. 475, pp. 42–53. DOI: 10.1016/j.quaint.2017.12.010

Renaud, Fabrice, and Radhika Murti, eds. (2014). *Ecosystems and Disaster Risk Reduction in the Context of the Great East Japan Earthquake and Tsunami: A Scoping Study.* Report to the Keidanren Nature Conservation Fund. Bonn: United Nations University – Institute for Environment and Human Security (UNU-EHS). Available at https://collections.unu.edu/eserv/unu:1899/pdf11102.pdf

Rivest, David, and others (2013). Soil biochemical properties and microbial resilience in agroforestry systems: effects on wheat growth under controlled drought and flooding conditions. *Science of the Total Environment*, vol. 463-464, pp. 51–60. DOI: 10.1016/j.scitotenv.2013.05.071

Rojas, Octavio, and others (2022). Assessment of the flood mitigation ecosystem service in a coastal wetland and potential impact of future urban development in Chile. *Habitat International*, vol. 123, p. 102554. DOI: 10.1016/j.habitatint.2022.102554

Ruby, Emily (2005). How urbanization affects the water cycle. California Water and Land Use Partnership. Available at https://oehha.ca.gov/media/downloads/ecotoxicology/fact-sheet/watercyclefacts_0.pdf

Santoro, Antonio, and others (2022). From flood control system to agroforestry heritage system: past, present and future of the mulberry-dykes and fishponds system of Huzhou city, China. *Land*, vol. 11, No. 11, p. 1920. DOI: 10.3390/land11111920

Schaefer, Laura, and Eleanor Waters (2016). Climate Risk Insurance for the Poor & Vulnerable: How to Effectively Implement the Pro-Poor Focus in InsuResilience. United Nations University – Institute for Environment and Human Security: Munich Climate Risk Insurance Initiative (MCII). Available at https://collections.unu.edu/eserv/UNU:5956/MCII_CRI_for_the_Poor_and_Vulnerable_meta.pdf

Schipper, E. Lisa F. (2020). Maladaptation: when adaptation to climate change goes very wrong. *One Earth*, vol. 3, No. 4, pp. 409–414. DOI: 10.1016/j.oneear.2020.09.014

Schultz, Richard, and others (2019). Agroforestry practices: riparian forest buffers and filter strips. In *Agroforestry for Sustainable Agriculture,* Maria Rosa Mosquera-Losada and Ravi Prabhu, eds. London: Burleigh Dodds Science Publishing.

Sett, Dominic, and others (2024). Advancing understanding of the complex nature of flood risks to inform comprehensive risk management: findings from an urban region in Central Vietnam. *International Journal of Disaster Risk Reduction*, vol. 110, art. 104652. DOI: 10.1016/j.ijdrr.2024.104652

Sett, Dominic, and others (2025). Flood risks in Hue, Central Viet Nam: an assessment of current flood hazard, exposures, vulnerabilities, root causes and impacts. United Nations University – Institute for Environment and Human Security (UNU-EHS). DOI: 10.53324/QZLT4709.

Shao, Wanyun, Kairui Feng and Ning Lin (2019). Predicting support for flood mitigation based on flood insurance purchase behavior. *Environmental Research Letters*, vol. 14, No. 5, p. 54014. DOI: 10.1088/1748-9326/ab195a

Sheergojri, Ishfaq A., Irfan Rashid and Ishfaq ul Rehman (2024). Systematic review of wetland ecosystem services valuation in India: assessing economic approaches, knowledge gaps, and management implications. *Journal of Environmental Studies and Sciences*, vol. 14, No. 1, pp. 167–179. DOI: 10.1007/s13412-023-00866-1

Singh, Rinku, and G.S. Singh (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology & Environment*, vol. 2, No. 5, pp. 296–316. DOI: 10.1007/s40974-017-0074-7

Smith, Ben, and others (2013). Learning across locales, organizations and networks: the weADAPT experience. weADAPT briefing note. Stockholm Environment Institute. Available at https://weadapt.org/wp-content/uploads/2023/05/learning_across_locales_weadapt_2014.pdf

Song, Shanshan, and others (2023). Mangrove reforestation provides greater blue carbon benefit than afforestation for mitigating global climate change. *Nature Communications*, vol. 14, No. 1, art. 756. DOI: 10.1038/s41467-023-36477-1

Su, Jie, and Alexandros Gasparatos (2023). Perceptions about mangrove restoration and ecosystem services to inform ecosystem-based restoration in Large Xiamen Bay, China. *Landscape and Urban Planning*, vol. 235, p. 104763. DOI: 10.1016/j.landurbplan.2023.104763

Sudmeier-Rieux, K., and others (2015). Opportunities, incentives and challenges to risk sensitive land use planning: lessons from Nepal, Spain and Vietnam. *International Journal of Disaster Risk Reduction*, vol. 14, pp. 205–224. DOI: 10.1016/j.ijdrr.2014.09.009

Sudmeier-Rieux, K., and others (2021). Scientific evidence for ecosystem-based disaster risk reduction. *Nature Sustainability*, vol. 4, No. 9, pp. 803–810. DOI: 10.1038/s41893-021-00732-4

Sun, S.A., S. Djordjević and S.T. Khu (2011). Decision making in flood risk based storm sewer network design. *Water Science & Technology*, vol. 64, No. 1, pp. 247–254. DOI: 10.2166/wst.2011.179

Surminski, Swenja (2014). The role of insurance in reducing direct risk – The case of flood insurance. *International Review of Environmental and Resource Economics*, vol. 7, 3-4, pp. 241–278. DOI: 10.1561/101.00000062

Taillandier, Chloé, Ron Cörvers and Lindsay C. Stringer (2023). Growing resilient futures: agroforestry as a pathway towards climate resilient development for smallholder farmers. *Frontiers in Sustainable Food Systems*, vol. 7, DOI: 10.3389/fsufs.2023.1260291

Tarchiani, Vieri, and others (2020). Community and impact based early warning system for flood risk preparedness: the experience of the Sirba River in Niger. *Sustainability*, vol. 12, No. 5, p. 1802. DOI: 10.3390/su12051802

Thanh Tu, Tran, and Vilas Nitivattananon (2011). Adaptation to flood risks in Ho Chi Minh City, Vietnam. *International Journal of Climate Change Strategies and Management*, vol. 3, No. 1, pp. 61–73. DOI: 10.1108/17568691111107943

Thistlethwaite, Jason, and Daniel Henstra (2019). The Governance of Flood Risk Management. In *Oxford Research Encyclopedia of Natural Hazard Science*. DOI: 10.1093/acrefore/9780199389407.013.335

Tuan, Le Xuan (2012). Preliminary assessment of sea level rise impacts to coastal ecosystems in Thua Thien - Hue. *VNU Journal of Science, Earth Sciences*, vol. 28, No. 2, pp. 140–151. Available at https://js.vnu.edu.vn/EES/article/view/1165

Udawatta, Ranjith P. (2021). Flood control and air cleaning regulatory ecosystem services of agroforestry. In *Agroforestry and Ecosystem Services*, Ranjith P. Udawatta and Shibu Jose, eds. Cham: Springer International Publishing.

UFCOP (2017). Land use planning for urban flood risk management. UFCOP knowledge notes. Working Paper 114816. Urban Floods Community of Practice. Washington D.C.: World Bank Group.

USDA. Riparian Forest Buffers. United States Department of Agriculture. Available at https://www.fs.usda.gov/nac/practices/riparian-forest-buffers.php. Accessed on 16 June 2025.

van Berchum, E.C., and others (2014). The framework for integrated water management in the Thua Thien-Hue Province. Student Report. TU Delft: Department of Hydraulic Engineering

van Dau, Quan, Kittiwet Kuntiyawichai and Vichian Plermkamon (2017). Quantification of flood damage under potential climate change impacts in central Vietnam. *Irrigation and Drainage*, vol. 66, No. 5, pp. 842–853. DOI: 10.1002/ird.2160

van Hensbergen, Hubertus J., Kenichi Shono and Jonas Cedergren (2023). A guide to multiple-use forest management planning for small and medium forest enterprises. Forestry Working Paper No. 39. Rome: Food and Agriculture Organization of the United Nations. DOI: 10.4060/cc6780en van Tuyen, Truong (1997). Management of biological resources in Tam Giang Lagoon: issues, participatory research application, and challenges. Ottawa: International Development Research Centre. Available at https://academia.edu/67134527/Management_of_biological_resources_in_Tam_Giang_Lagoon_issues_participatory_research_application_and_challenges

van Tuyen, Truong, and others (2023). Community-based tourism as social entrepreneurship promoting sustainable development in coastal communities: a study in Thua Thien Hue province, Central Vietnam. *Maritime Studies*, vol. 22, art. 8. DOI: 10.1007/s40152-023-00293-6

Vasileiou, Konstantina, Julie Barnett and Danaë Stanton Fraser (2022). Integrating local and scientific knowledge in disaster risk reduction: a systematic review of motivations, processes, and outcomes. *International Journal of Disaster Risk Reduction*, vol. 81, p. 103255. DOI: 10.1016/j.ijdrr.2022.103255

Vidal-Abarca Gutiérrez, María R., and others (2023). Ecosystem services provided by dry river socio-ecological systems and their drivers of change. *Hydrobiologia*, vol. 850, pp. 2585–2607. DOI: 10.1007/s10750-022-04915-8

Vu, Bien T., and others (2025a). Enablers and barriers to implementing effective disaster risk management according to good governance principles: lessons from Central Vietnam. *International Journal of Disaster Risk Reduction*, vol. 120, p. 105344. DOI: 10.1016/j.ijdrr.2025.105344

Vu, Bien T., and others (2025b). A Novel Approach to Developing Local Flood Vulnerability Scenarios Based on the Shared Socioeconomic Pathways Framework: Sectoral Risks and Policy Implications. Submitted.

Wang, Mao, and others (2010). Maintenance of estuarine water quality by mangroves occurs during flood periods: a case study of a subtropical mangrove wetland. *Marine Pollution Bulletin*, vol. 60, No. 11, pp. 2154–2160. DOI: 10.1016/j.marpolbul.2010.07.025

Wang, Xin, and others (2022). Flood mitigation effects of lake-reservoir group on the Poyang Lake watershed based on runoff-weighted model from multi-satellite weekly observation. *Journal of Hydrology: Regional Studies*, vol. 44, No. 4, p. 101265. DOI: 10.1016/j.ejrh.2022.101265

Wei, Xiaohua, and Juan A. Blanco (2014). Significant increase in ecosystem C can be achieved with sustainable forest management in subtropical plantation forests. *PLoS ONE*, vol. 9, No. 2, e89688. DOI: 10.1371/journal.pone.0089688

Weichselgartner, Juergen, and Patrick Pigeon (2015). The role of knowledge in disaster risk reduction. *International Journal of Disaster Risk Science*, vol. 6, No. 2, pp. 107–116. DOI: 10.1007/s13753-015-0052-7

Wilson, Matthew H., and Sarah T. Lovell (2016). Agroforestry—The next step in sustainable and resilient agriculture. *Sustainability*, vol. 8, No. 6, p. 574. DOI: 10.3390/su8060574

Wu, Guangdong, and others (2024). Adding sectors or strengthening ties? Adaptive strategies for cross-sector collaboration in disaster governance. *Public Management Review,* pp. 1–23. DOI: 10.1080/14719037.2024.2315563

Wyrwoll, Paul R., and R. Quentin Grafton (2022). Reforming for resilience: delivering ‘multipurpose hydropower’ under water and energy risks. *International Journal of Water Resources Development*, vol. 38, No. 6, pp. 1032–1061. DOI: 10.1080/07900627.2021.1944844

Yoder, Landon, and others (2025). Cover crops as climate insurance: exploring the role of crop insurance discounts to promote climate adaptation and mitigate risk. *Journal of Environmental Management*, vol. 373, p. 123506. DOI: 10.1016/j.jenvman.2024.123506

Yousefi Mohammadi, Maryam, and others (2024). Mitigating the flood disaster effects through the implementation of knowledge management: a systematic literature review. *Environmental and Sustainability Indicators*, vol. 23, p. 100431. DOI: 10.1016/j.indic.2024.100431

Zhou, Kejing, and others (2024). Urban flood risk management needs nature-based solutions: a coupled social-ecological system perspective. *npj Urban Sustainability*, vol. 4, art. 25, DOI: 10.1038/s42949-024-00162-z

Ziana, and others (2020). The effect of diameter and distance between vegetation in the riverbank to flood discharge by eco-hydraulic in the Lawe Alas River, Southeast Aceh, Indonesia. *IOP Conference Series: Materials Science and Engineering*, vol. 933, No. 1, p. 12051. DOI: 10.1088/1757-899X/933/1/012051

Zougmoré, Robert B., and others (2018). Facing climate variability in sub-Saharan Africa: analysis of climate-smart agriculture opportunities to manage climate-related risks. *Cahiers Agricultures*, vol. 27, No. 3, p. 34001. DOI: 10.1051/cagri/2018019

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Annexes
Annex 1: Annex to the UNU-EHS Research Report: Opportunities for improved flood risk management and adaptation in Hue, Central Viet Nam: Addressing current and future flood risks

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