FINCAPES
Flood Impacts, Carbon Pricing, and Ecosystem Sustainability

Integrating Gender Equality and Socio-Economic Inclusion into Flood Risk Models and Analysis

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FINCAPES
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About FINCAPES
The Flood Impacts, Carbon Pricing, and Ecosystem Sustainability (FINCAPES) project is a collaborative, gender-responsive initiative funded by Global Affairs Canada. Over a 5.5-year period, jointly undertaken by the University of Waterloo's Faculty of Mathematics and Faculty of Environment, the project supports Indonesia in adapting to climate change, mitigating its impacts, and conserving biodiversity in a socially and economically sustainable manner. Aligned with Indonesia's priorities, FINCAPES enhances the nation's capacity in key areas: forecasting and mitigating financial impacts of climate-change-induced floods, promoting Nature-based Solutions for peatland and mangrove restoration, and strengthening climate finance policy frameworks with a focus on carbon financing mechanisms.

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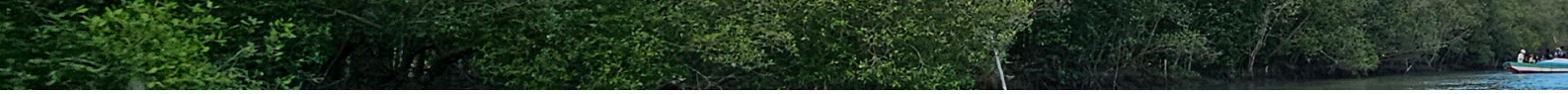

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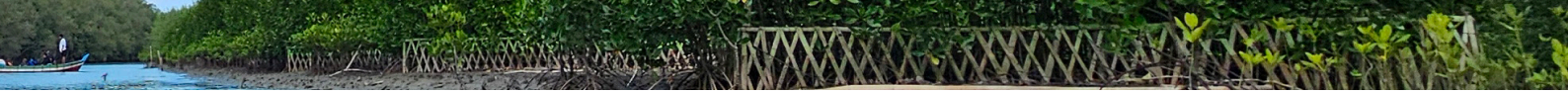
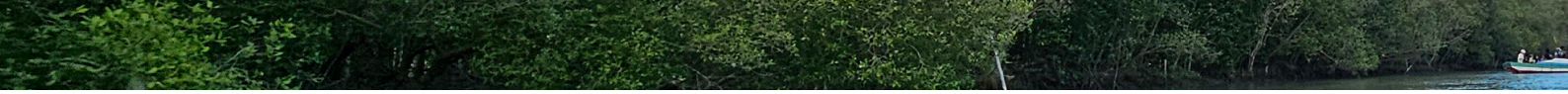


List of Acronyms and Abbreviations

CSOs	Civil Society Organizations
GBV	Gender-based Violence
GESEI	Gender Equality and Socio-Economic Inclusion
NFM	Natural Flood Management
NbS	Nature-based Solutions



Integrating Gender Equality and Socio-Economic Inclusion into Flood Risk Models and Analysis

1. Introduction

This report examines international best practices in flood risk modeling and vulnerability assessment, with a particular focus on integrating Gender Equality and Socio-Economic Inclusion (GESEI). Developed as a resource for the Flood Impacts, Carbon Pricing, and Ecosystem Sustainability (FINCAPES) project, this analysis explores how incorporating GESEI considerations enhances the effectiveness and success of flood risk models.

FINCAPES is a collaborative initiative supporting Indonesia's work to adapt to and mitigate climate change while conserving biodiversity. Funded by the Government of Canada, this 5.5-year project, jointly undertaken by the University of Waterloo and Indonesian partners (the Purnomo Yusgiantoro Center and IPB University), aims to develop capacity of Indonesian academics, practitioners and government on expertise related to nature-based solutions, and climate finance.

This report provides an overview of diverse flood risk models and illustrates how these models can be designed and implemented to address GESEI concerns. It is structured as follows:

- **Context:** Setting the stage with background information on flood risk modeling and the importance of GESEI.
- **Rationale for integrating GESEI within an NbS approach:** Explaining the benefits of integrating GESEI considerations in nature-based solutions for flood management.
- **Integrating GESEI into flood risk modelling:** Providing practical examples and strategies for incorporating GESEI into various flood risk models.

2. Context

Flood risks are rising in much of the world and projected to continue to do so, in part due to climate change. The people affected, and damages incurred are estimated to increase by two to five times by 2050.[1] Also of concern is that Guneralp et.al. calculate that nearly half of global urban development between 2015 and 2030 will occur in areas at risk of flooding, and that this will triple the total urban area exposed to flooding.[2] Riverine floods are the weather-related disaster that causes the most damage globally and are increasingly affecting heavily populated areas. Riverine floods currently average approximately US$ 115 billion of damage per year.[3]

Opperman and Galloway, observe that over the next 30 years, "Financial damages from river floods are projected to increase by 160–240% (with global losses rising up to nearly US$400 billion per year), and the number of people exposed to river flooding … projected to increase by 50–60%. [This] would affect approximately 90 million people globally, with low-income communities being particularly vulnerable.[4]

They also note these losses will increase even more dramatically with a warming of 2°C, with people exposed projected to double and damages increasing by up to 520% compared to today.[5]

1 Jeffrey J. Opperman and Gerald E. Galloway, "Nature-based solutions for managing rising flood risk and delivering multiple benefits", One Earth Volume 5, Issue 5, pp 451-465, May 20, 2022.

2 B. Guneralp, and Y. Liu, 2015. Changing global patterns of urban exposure to flood and drought hazards. Glob. Environ. Change 31, 217–225. https://doi.org/10.1016/ cited in Opperman et al., ibid.

3 Opperman and Galloway, op. cit.

4 Ibid.

5 Ibid.

Fig. 1: Areas Projected to be Affected by Increasing River Flood Hazards due to Climate Change[6]

3. Why Integrate Gender and Socio-Economic Inclusion in Flood Risk Models?

There are four core reasons:

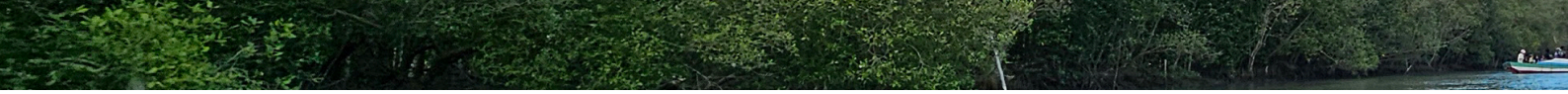
1. Flooding often has a disproportionately negative impact on diverse groups of women in both urban and rural contexts.
2. Women and men are affected differently by urban flooding due to the gender division of labour and underlying gender values found in all cultures to varying degrees.
3. Including the perspective, needs and knowledge of diverse groups of women and men in the development and implementation of flood prevention and response leads to better results and more effective and sustainable urban flood prevention and management.
4. Women have proven to be active contributors and agents of positive change in climate action and their contributions can add considerably to a community's resilience.

3.1 Gender Differentials in Flood Impacts

Urban flooding has a disproportionately negative impact on women and poor men. Theses occur at the economic, physical, and social levels. Often the challenges women face, their specific needs, and voices are either overlooked or given limited attention. This due to underlying societal gender norms that limit women's participation and access to or ownership of assets such as land, family businesses and the use and management of natural resources in an urban context. These same gender values and norms lead to women's economic and social contributions being under-valued, e.g., women-owned or operated informal sector businesses often represent a major source of income for poor women in the Global South. However, since informal sector businesses are not registered formally and are often under-capitalized and not insured, when these businesses are destroyed or damaged by flooding it leaves the women with little or no recourse. Men are more likely to work in the formal sector, have higher status jobs and have access to some level of government or employer protections and support.[7] Women's incomes are also lower than men's in all countries meaning women have fewer savings and personal resources with which to rebuild homes and businesses

6 The Nature Conservancy, February 16, 2024, Accelerating Adaptation https://www.nature.org/en-us/what-we-do/our-insights/perspectives/accelerating-adaptation-nature-based-solutions/

7 Women4Biodiversity Organization, 2021, Advancing Women's Rights, Gender Equality and the Future of Biodiversity in the post 2020 Global Biodiversity Framework, p.5



destroyed by flooding. All of these are factors that need to be considered in the development and implementation of flood risk models.

3.2 Flood Risks for Men

Gender-based risks for men that NbS need to consider include loss of businesses and income (particularly if they are the main breadwinner for their families). Poor men are also at considerable risk of losing their business assets. These assets are also less likely to be covered by insurance either because the businesses are based in the informal sector, the business owners are too poor to pay for insurance or are unaware of micro-insurance products they can access.

Health risks for men include placing themselves in situations that involve greater physical risk during actual flood situations. This is due to underlying gender values that place the onus on men to protect their families. Men are also more likely to own vehicles that would be in public spaces and roadways easily flooded during flash floods. Men are also prone to exposure from water borne diseases with infection rates exacerbated during flood situations due to water contamination from wastewater overflow. Men may be at greater risk of this exposure since being physically stronger than women they are called upon more to wade through flood waters to rescue family members or retrieve family belongings during and after the initial flood waters have receded.

3.3 Economic Issues

Globally women own less land than men. They thus, rely more on use of common land and resources shared by community members. Flood risk models and assessments, therefore, need to consider how shifting land and natural resource use due to economic development, climate change or flood prevention measures affect women's access to common land and resources even in an urban context.

In most countries **far fewer women also hold formal titles to land than men**. This is related, in part, to a perception that there is just one household head (predominantly perceived to be male) even when the land concerned belongs to the family. It also leaves women in a position where they may not have independent access to credit, they can access in a flood emergency. Without formal land title they do not have collateral to offer. In addition, UN Women estimates that 1 in every 10 women in the world lives in extreme poverty with climate change set to leave 236 million more women and girls hungry by 2030, twice as many as men (131 million).[8] Poor women are more likely to live in locations that are prone to flooding as they have fewer options regarding where they rent or build. This is particularly the case for women-headed households (as well as very poor families headed by men).

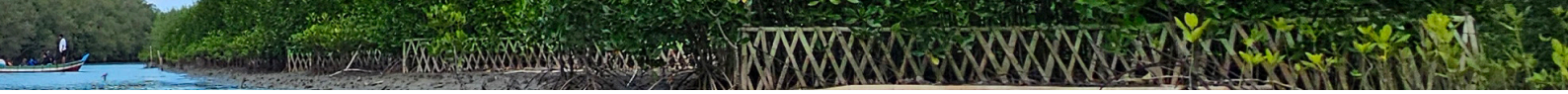
On average, women also earn less than men in all countries. This is, in part, due to patterns of occupational gender segregation in which women tend to be concentrated in work that pays less and have less status than those where men predominate. Women and children working in family businesses may not have direct control of the money earned through their labour. Women are also more likely to work part-time to accommodate family responsibilities. These patterns includes both professional women and those with less education or skills. In the event of a climate disaster this all means that women have less economic resilience to overcome the disaster.

3.4 Gender-Based Violence

Increased economic stress brought on by urban flooding has been linked to an increase in gender-based violence (GBV). This can take the form of verbal and psychological abuse, physical and/or sexual abuse and economic violence. The latter refers to "any action or omission aimed at economic abuse or abusive control of finances, monetary rewards, or punishments of women due to their social, economic, or political condition" and can occur in partner, family, work, or economic relationships. [9]

8 UN Women, 2024, 1 in 10 Women in the World Lives in Extreme Poverty. Press Release.

9 Women's World Banking, 2025, "What is Economic Violence Against Women and Why Does It Matter?", https://www.womensworldbanking.org/insights/what-is-economic-violence-against-women-and-why-does-it-matter/



International Monetary Fund research found that GBV also has an economic impact that can significantly lower a country's Gross National Product due to economic productivity losses arising from both physical and psychological injuries. Their research also showed that an increase in violence against women by 1% is associated with a 9% lower level of economic activity. Thus, any increase in GBV associated with urban flooding has both serious economic and rights implications.

Previous studies have found domestic violence costs a given economy between 1 and 2% of GDP.[10] Thus, any significant stress factors that contribute to increased GBV such as loss of income and property due to flooding contributes to a country's longer term economic losses. This, in addition to the related justice and health issues, make it imperative for flood risk models and assessments to track urban flooding impact on GBV and include GBV prevention components in related initiatives developed. In addition, increased GBV needs to be included in flood models as a potential risk category.

Flooding also often causes internal displacements of people from the areas affected. Women and children (both male and female) who are evacuated face increased risk of predatory sexual abuse and trafficking for the purposes of sexual exploitation. This especially affects poor women and children as they have fewer choices about where they evacuate to. Women may also be asked to provide sexual services to access humanitarian assistance by some unscrupulous officials in charge of its distribution.

3.5 Health Impacts

Other health impacts include that pregnant woman face increased risks of gestational hypertension and premature delivery when in high stress emergency situations such as flooding.[11] The contamination of drinking water and related spread of viruses and bacteria may pose a higher risk for women and girls due to their close interaction with water related with cooking and family care. The burden of caring for ill family members also generally falls to women. Consequently, urban flooding can, in some circumstances lead to an increase in women's workloads. This represents another potential risk category to include in flood risk models.

3.6 Gender Bias in Economic Recovery Initiatives and Flood Prevention Planning

In some countries government recovery and support programs for flood victims tend to focus on assistance to male household heads. This assumes this assistance will be equitably distributed within the family or that there is only a need to provide support to replace income derived from work traditionally done by men. Again, both women and men who work in the informal sector may not be eligible for government assistance following flooding since their businesses are not registered.

Due to pervasive gender values across many cultures and societies there is a global pattern in which most women hold more responsibility for family and household care than men. This contributes to "**women [being] radically under-represented in decision-making spaces related to conservation, climate action, land governance, and land administration at all levels".**[12] Despite strong evidence that increased gender equality has a significant positive effect on environmental outcomes, "the specific roles, behaviours and preferences of women and, women's knowledge and contributions" have not been adequately researched or considered in policy [and program] development".[13] Data still tends to be aggregated by community and by household and not by sex and gender and more men than women are consulted in related research processes. In some cultures, women are not encouraged to speak up in public, and partly as policy responses often assume that a one size fits all approach works for all demographic groups. Thus, many government agencies do not yet use an intersectional lens to assess

10 Ouedraogo, Rasmane and David Stenzel, 2021, How Domestic Violence is a Threat to Economic Development, IMF. https://www.imf.org/en/Blogs/Articles/2021/11/24/how-domestic-violence-is-a-threat-to-economic-development

11 Partash, Nasim, et al, "The impact of flood on pregnancy outcomes: A review article, Taiwanese Journal of Obstetrics and Gynecology", Volume 61, Issue1, January 2022, page 10-14.

12 Women4Biodiversity Organization, 2021, op.cit, p. 6

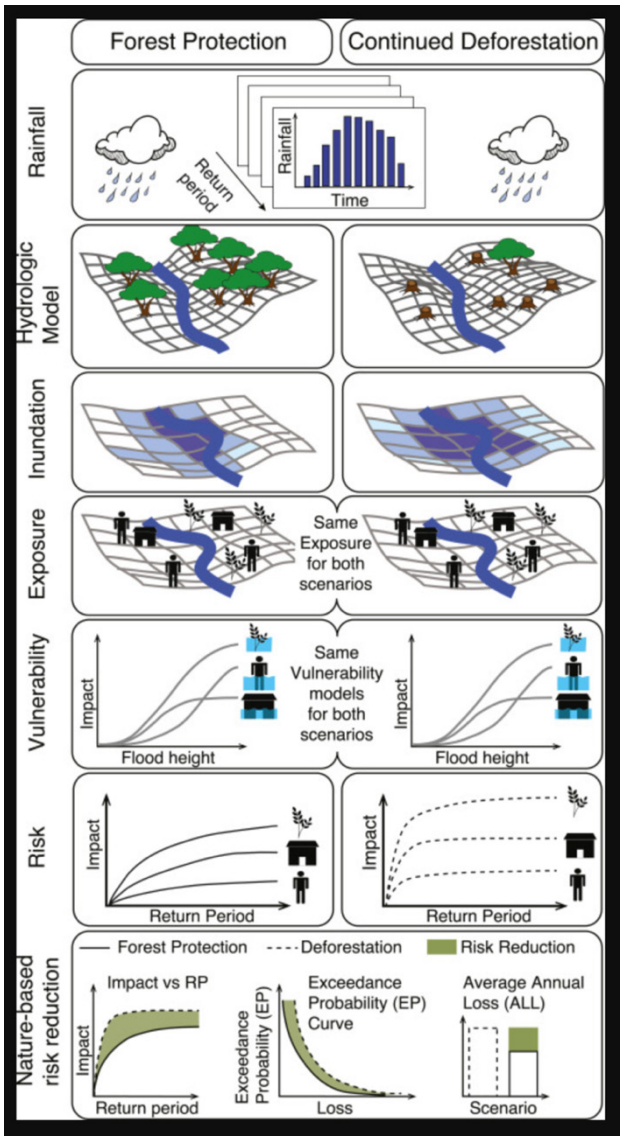
13 Women4Biodiversity Organization, op. cit., p. 5

the differential impacts of environment management and disaster response policies and related programming, including urban flood risk assessment.

4. Integrating a GESEI Perspective into Flood Risk Modeling

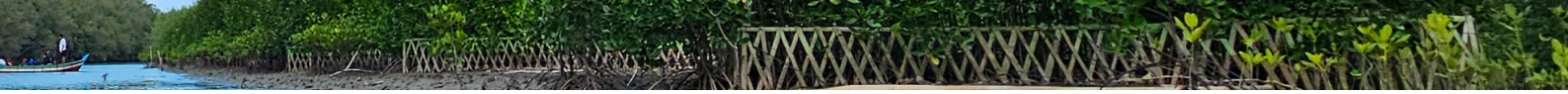
Lallemant et al. note that one of the main analytical challenges in the flood risk modelling area is to find effective ways to couple models that link flood hazard, which is a function of the climate and landscape to the exposed population and assets, and the respective population's vulnerability.[14] They conducted a review of existing flood risk models and concluded that most did not make this link well or only used a narrow definition of what could be counted in vulnerability assessments such as limiting the risk assessment to cover only built agricultural structures. Our own review of their assessment also found that **none of the flood risk models presented included an explicit GESEI analysis in the vulnerability components of the models** and some did not include even generic demographic or sociological vulnerability assessments. The flood risk models Lallemant et al. reviewed are depicted in Fig. 3 below.

Fig. 2. Flood Risk Models



Source: Lallemant et al., op. cit.

14 David Lallemant, Perrine Hamel, Mariano Balbi, Tian Ning Lim, Rafael Schmitt, and Shelly Win, "Nature-based solutions for flood risk reduction: A probabilistic modeling framework", One Earth Volume 4, Issue 9, 17 September 2021, pp. 1310-1321.

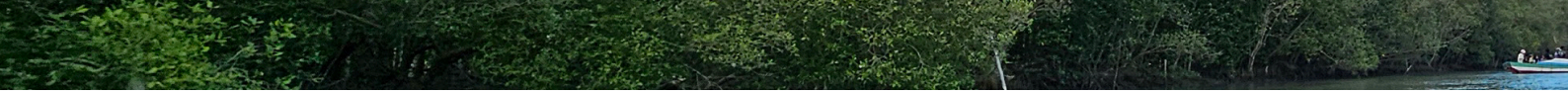


We have summarized Lallemant et al.'s analysis of four flood risk models in Table 1 below and added observations regarding what is either missing related to GESEI and vulnerability assessments or where there is a need for a more explicit definition of what constitutes vulnerability.

Table 1: Summary of Flood Risk Models and Links to Demographic/Economic Vulnerability[15]

Flood Risk Model	Characteristics	Links to Vulnerability	GESEI Gaps
Comparison of the "Supply" and "Demand" for Flood Mitigation Services	Often uses indices when the units of supply and demand are different, e.g., a flood mitigation service supply ranking can be derived from land cover and soil data, while demand ranking can be derived from topographic, land cover, and historical flood events data. To compare supply and demand, some authors propose calculating supply as the available flood storage capacity in upstream areas of selected cities, and demand as the accumulated modeled runoff entering these cities.	Although the supply-demand framework provides insights to the scarcity of flood mitigation service in an area, it does not allow for quantitative assessment of flood exposure and losses, or cost-benefit analysis of various mitigation options *nor does it include any assessment of vulnerabilities of specific demographic groups.*	*Questions/analytical tools regarding which m/f demographic groups have a need for flood mitigation services and what it will cost to provide flood mitigation services to these demographic groups.*
Hydrological and Hydraulic Modeling	Provides explicit flood hazard information (e.g., inundation maps) under various scenarios and uses data intensive modeling which focuses on topographical data. Sometimes adapted to include monetary valuation.	There are few examples of a complete flood risk chain," where the impact of different natural infrastructure scenarios is propagated to a hydrologic model, an inundation model, and an exposure and vulnerability model, to finally output expected losses and impacts.	*Typically, there is no inclusion of either an exposure and vulnerability model or GESEI related vulnerabilities.*
Flood Risk Simulation	For each land-use scenario, it is possible to model peak discharge for different recurrence interval rainfall events, and use the resulting hydrographs as inputs to a hydraulic model that simulates flood inundation extent & depth. The workflow provides probabilistic loss curves corresponding to baseline and alternative scenarios. The difference between these represents the decreased flood risk due to natural infrastructure.	By identifying exposed assets such as built infrastructure, agriculture, and people, and categorizing them according to a taxonomy of vulnerability and value it is possible to calculate expected damage and associated losses, which are aggregated for each flood simulation.	*The taxonomy of vulnerability in this model would need to explicitly include categories related to GESEI and include identification of built assets belonging to both women and men as opposed to solely focus on built infrastructure.*
Probalistic Risk Analysis	A systematic method to explicitly quantify potential adverse consequences of hazard events on a system, and the likelihood of such consequences. Tradition- ally used to assess the reliability of complex engineering systems, this method can also be used to assess the risks from natural hazards to entire cities or regions.	For probabilistic flood risk analysis, the approach reviews natural variability in rainfall, through hydrologic, hydraulic, exposure, and vulnerability models to develop loss-recurrence curves measured in terms of direct impacts to communities (i.e., people affected, damage, losses).	*The direct impacts of communities would need to consider gender and sex disaggregated data and take diverse GESEI issues and categories of analysis into consideration to be gender inclusive.*

15 Content based on summary of from the article by Lallemant et al, op. cit. Gender analysis column content with italicized phrases are added.



Based on their own review of these flood risk models, Lallemant et al. suggest that by combining natural infrastructure hydrologic modeling with a probabilistic flood risk analysis model it is possible to integrate ecosystem services within traditional risk-decision, engineering, and financial risk management practices. This approach would:

1. Explicitly represent natural infrastructure through distributed, spatially explicit hydrologic and hydraulic models.
2. Account for the entire probabilistic flood hazard curve rather than single-scenario events.
3. Express risk mitigation in terms of economic and human benefits.
4. Address key model uncertainties and provide a quantitative assessment of their impact on risk and losses.
5. Rely on a relatively small amount of data (mostly global datasets).
6. Be underpinned through statistical calibration against observed floods (and hence can be adapted to ungauged basins).[16]

As with the other flood risk models outlined, Lallemant et al.'s proposed model would need to include explicit GESEI-related criteria in its risk analysis of economic and human benefits. Lallemant et al. themselves note that in the sample case study their research team presented related to flood risk linked with deforestation that,

> **"The values of average annualized losses [in their analysis] only account[ed] for direct impact on buildings and agriculture; they [did] not account for the indirect impacts of disruption to businesses, services (e.g., education), supply chains, and more. Likewise, the human cost in terms of people affected [did] not account for fatalities and injuries, long-term impacts on well-being, and more."**[17]

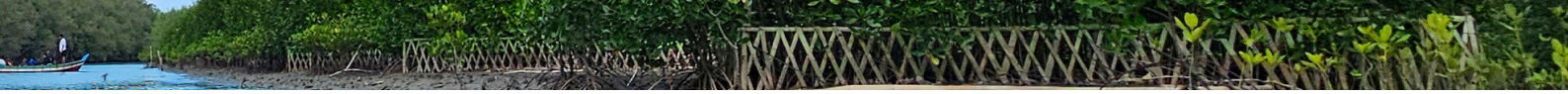
Their proposed model does, however, provide a framework which opens the opportunity to build in these additional categories of analysis and vulnerability in the future while also considering different ways of including factors related to nature-based solutions.

What none of the flood risk models presented did, however, was to include resilience analysis as a part of the overall approach to assessing the vulnerability of diverse demographic groups. This is critical. An example from a Bangladesh post-flood impact study found that while fragile housing conditions, unequal access to land, and uneven household capital made it more difficult for women to recover from flood damage, women also acted as key recovery agents during floods. This was since the men in their households pressured the women to sell their household belongings, such as utensils, sewing machines, and ornaments to support their families. This study also found that poor women in the area affected by the flood studied had a high level of resilience. This was, in part, due to their experiences overcoming adversity in the past. These are also factors that can and should play into flood risk analysis and vulnerability assessments.[18]

16 Lallemant et al, op. cit.

17 Lallemant et al, op. cit.

18 Tasnim Jerin, M. Abul Kalam Azad, Mohammad N. Khan, International Journal of Disaster Risk Reduction, 95 (2023) 103851. www.elsevier.com/locate/ijdrr



5. Opportunities for and Constraints to Consider in Flood Risk Models in Urban Areas

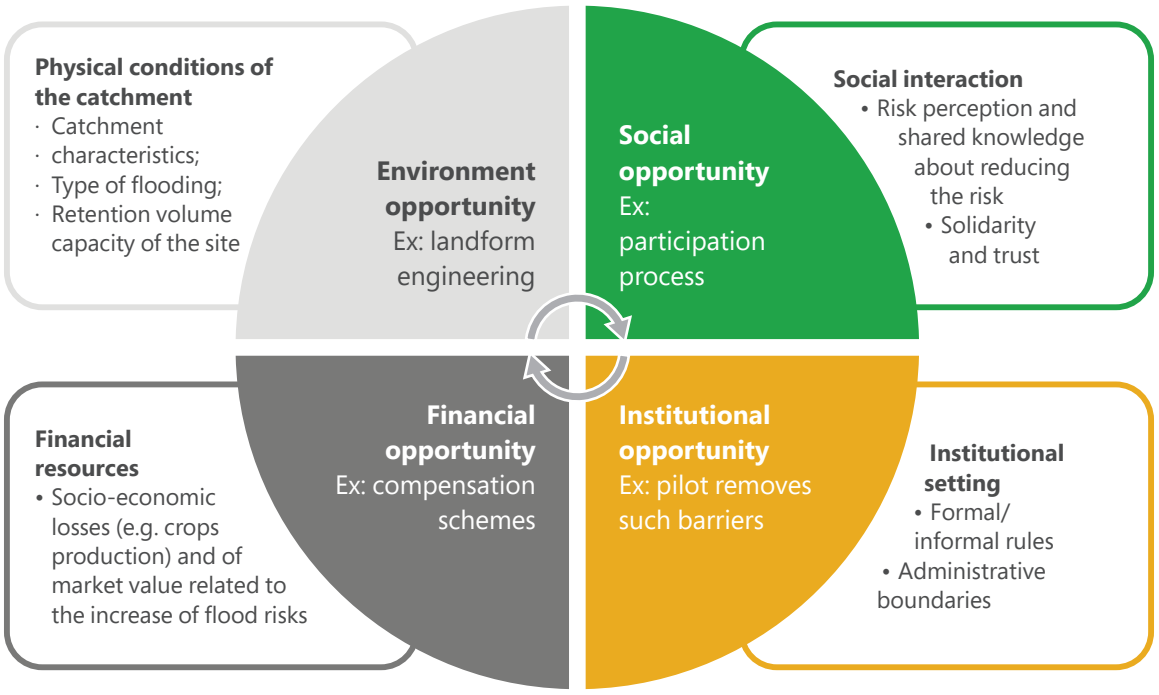
To reduce and manage flood risk requires a multi-pronged approach which touches on four main areas of interaction:

1. The physical conditions of the catchment
2. Social interaction
3. Financial resources
4. Institutional settings.

Often, however, it is mainly physical loss of property, injury and loss of life that are considered in flood risk models – along with the different geographical and meteorological factors that contribute to flooding. which fosters the interaction among the four areas of opportunities outlined in Fig. 4 on the next page. All these opportunities can contribute to increased community resilience as well as potential additional risk categories to consider for inclusion.

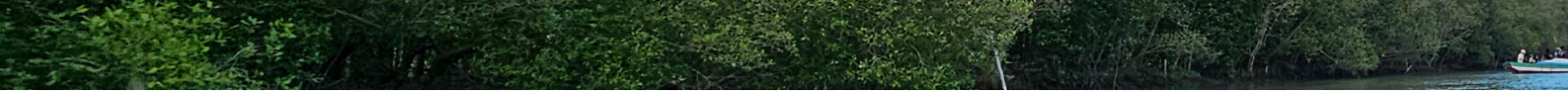
1. *Physical conditions of the catchment*:
   Catchment characteristics influence the range of potential natural flood management and other flood prevention measure and their location as well as the expected outcomes such measures can generate across the relevant objectives.[19] *N.B., another factor to consider are how women and men use the land and water in the identified areas and who owns the land and controls water use – both formally and informally.*

Fig. 3: Additional Resilience and Risk Factors to Consider



Source: Thomas Thaler, Paul Hudson, Christope Viavattene, Colin Green, "Natural flood management: Opportunities to implement nature-based solutions on privately owned land", Wires Water 01 Feb 2023
https://doi.org/10.1002/wat2.1637

19 Thaler et al., op. cit.



2. *Social interaction:*
   Natural flood management and other flood risk reduction measures, are sensitive to the social context in which they operate. These interventions must have either an existing stock of social capital and trust that creates a suitable environment for the required social interaction and negotiation or must be able to generate sufficient levels of trust and social capital during the project development and to maintain this trust and social capital stock afterward.[20] *To maximize the effectiveness of these social interactions there needs to be an intersectional gender analysis of how underlying gender values and differing gender roles affect these interactions and who will benefit directly and indirectly from the flood risk prevention measures.*

2. *Financial resources*:
   Natural flood management and other flood risk reduction measures require investment and securing of public and private funding to manage them in the short and long term and ensure their financial viability. Governments need to establish a compensation mechanism for land converted to natural retention areas if the flood risk prevention measures will alter productivity temporarily (or in the long term (opportunity costs associated with a change in production). There also needs to be consideration of how increased biodiversity and carbon sequestration may support landowners' businesses and increase their profitability and viability in the long run if they comply with the flood prevention measures and other policies.[21] *These compensation mechanisms also need to accurately assess who (m/f) owns the businesses affected and to include consideration and compensation for businesses in the informal sector.*

2. *Institutional setting*:
   The institutional setting and related planning analysis need to assess what are the formal or informal rules regarding each stakeholder group needs to be engaged and what roles and responsibilities they will take as well as to determine the different organizations that will be involved in the flood risk prevention measures. The institutional context may need to be supported to create an enabling environment for flood risk prevention measures.[22] *Typically, it is also governments that have overall responsibility for ensuring that any green infrastructure initiatives also meet their official equity and equality policies.*

6. Integrating GESEI into Flood Risk Models and Assessment Processes: Summary

Flood risk models generally need to consider finding ways include the following factors in their risk assessment categories:

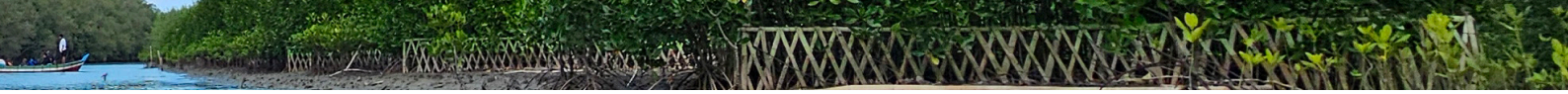
1. Which specific demographic groups will be affected by potential flooding?
   Disaggregated by sex, gender, age, location, income, education, ethnicity, etc.

2. How are these demographic groups likely to be impacted from the perspective of injury, loss of life, loss of property, and loss of income in both the formal and informal sectors?

3. Is it possible to disaggregate data within the household by male and female to look at the different levels of risk women and men face at the physical, social, and economic levels even within the household?

4. Is there any significant difference in the potential impact of flooding between and among these demographic groups and between women and men from the perspective of injury, loss of life, loss of property, loss of income, etc.?

20 Thaler et al., op. cit.
21 Thaler et al., ibid.
22 Ibid.



5. Which institutional, government assistance programs, economic, social networks, and cultural factors are likely to contribute to women and men's/girls and boys' resilience if faced with a flood situation?

6. How can existing flood risk vulnerability models be adapted to include significant gender differences at the individual, household, community, and decision-making levels as well as gender-based resilience factors?

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