Mekong River Commission
For Sustainable Development

A Gender and Social Vulnerability Assessment Approach

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Acronyms and abbreviations

AHP	Analytic hierarchy process
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
AR6	Sixth Assessment Report of the Intergovernmental Panel on Climate Change
DAGAP	Data Acquisition and Generation Action Plan
G&V	Gender and vulnerability
IPCC	Intergovernmental Panel on Climate Change
Lao PDR	People's Democratic Republic of Lao
LMB	Lower Mekong River Basin
MC	Member Country
MRC	Mekong River Commission
SIMVA	Social Impact Monitoring and Vulnerability Assessment
SoBR	State of the Basin Report
SP	Strategic Plan

1 Executive summary

In the Mekong River Commission (MRC) context, the key socio-economic issues that are repeatedly considered throughout the Basin Development Strategy (BDS) 2021–2030 are food security, gender and vulnerability (G&V), emergency management, and inequity of access and opportunities regarding water resources. In particular, the MRC Strategic Plan (SP) 2021–2025 (MRC, 2021c) emphasizes the importance of integrating a gender and vulnerability (G&V) approach, which includes gender equity and gender equality as an integral part of all MRC work and activities. In this regard, the MRC aims to develop a gender-disaggregated socio-economic data collection process for a more detailed gender perspective. This process can support the MRC's goal of improving equity for vulnerable groups, including recommended measures for regional and national plans such as the MRC Basin Development Strategies (BDSs) and Strategic Plans for decision-making and the sustainable development of the Mekong River Basin. A G&V assessment on water, food and energy security, and on the main water-related sectors in the Mekong River Basin can help to identify and develop these recommended measures.

In the current Mekong context, climate change is expected to have strong negative impacts on the Lower Mekong River Basin (LMB). Undertaking further analysis to understand the impacts of climate change on resource abundance, natural hazards and the inhabitants of the LMB can provide knowledge for the MRC to develop improved adaptation strategies and action plans. The MRC and Member Countries (MCs) are also interested in examining how gender equality and gender equity intersect with climate change impacts to understand social vulnerability.

The MRC is engaged in understanding and incorporating gender and other social vulnerability topics into their approach. Specifically, the Data Acquisition and Generation Action Plan (DAGAP) identifies priorities and mechanisms for collecting gender disaggregated data from MCs. In addition, the MRC recently commissioned a desk review (MRC, 2021a) to describe and map key social vulnerability metrics with a focus on gender, to identify additional gender data disaggregation requirements, and to recommend an engagement mechanism with partners. The desk review also recommended priorities for collecting additional data focused on food, water and energy security. This report draws on these recommendations and provides a detailed approach for conducting gender and social vulnerability assessments in the LMB.

The gender and vulnerability assessment approach

As described in the "Handbook on Mainstreaming Gender into the MRC's Core Functions and Activities: A guidebook for a gender-responsive and resilient Lower Mekong River Basin" (MRC, 2022), the dimensions of vulnerability include economic situation, education, disability, language abilities, access to means of communication, age and life stages. These factors and many others affect the resilience of Basin inhabitants. The MRC is committed to considering factors that affect social vulnerability and promote sustainable basin development.

Vulnerability is defined as "the propensity or predisposition to be adversely affected…[*which*] encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022). This report provides an explanation of different types of vulnerability assessments (physical or hazard-focused, social and integrated) and summarizes findings from three examples, which include details on the different types of assessment frameworks, methods and outputs. While slightly different approaches were used in each assessment, the most common vulnerability frameworks include components of exposure, sensitivity and adaptive capacity.

This report outlines <u>an integrated gender and social vulnerability approach focused on floods, droughts and extreme storm events for future application</u>. Steps for calculating exposure, sensitivity and adaptive capacity are described, followed by an explanation of the method for using these calculations to determine an overall vulnerability score at the provincial level for each of the MCs. The vulnerability assessments will be conducted at the provincial scale since it is the default scale of much of the data collected by the MRC. While the overall vulnerability framework described in this report could be applied to water resources development in the Mekong River Basin, the data needed for those applications would differ from the data for analyses focusing on floods, droughts and extreme storm events.

Exposure is defined as the extent and degree to which people and the resources on which they depend are exposed to a natural hazard. For the assessment proposed in this report, exposure data reflect high to low risk of a flood, storm or drought event, and are calculated individually for each exposure event. Potential data sources and equations for calculating exposure are presented here, illustrated by figures using randomly generated data.

Sensitivity is defined as the potential to which an area could be affected by a specific exposure event, regardless of capacity to respond to that event. Three sensitivity indicators are presented: the size of the population exposed to the hazard, land cover type and distance to the coast. Sensitivity could be calculated using a 1-km grid cell resolution, and at the sub-provincial level data required for the calculation, to account for a high level of spatial heterogeneity in the indicators. Data sources for these three indicators are suggested, and methods for calculating sensitivity are described. Since different land cover types experience sensitivity differentially , the experts can be consulted to rank land cover types from highly sensitive to not sensitive for each hazard type (flood, drought, storm event).

Adaptive capacity is the ability to change in response to a threat, and takes into consideration factors related to financial resources, knowledge to make informed decisions, and agency or power to carry them out. This report is based on the MRC Indicator Framework (MRC, 2019b), the Social Impact Monitoring and Vulnerability Assessments (MRC, 2018b, 2021b) and the desk review (MRC, 2021a), and suggest three edited strategic indicators from the MRC Indicator Framework: living conditions and wellbeing, livelihoods, and infrastructure and institutions. Thirty-three monitoring parameters for these indicators are presented, 12 of which relate to gender. The Delphi Method is proposed as a means for engaging experts to identify the most important elements of adaptive capacity in their situation and narrow down the number of indicators that may be used in a specific assessment. Using the Delphi Method, experts engage in an iterative process to reach consensus on specific topics, in this case, the indicators most relevant to adaptive capacity.

Two separate adaptive capacity calculations can be performed, one for males and one for females; the difference between these two can provide a measure of inequality in adaptive capacity. Similarly, the vulnerability scores can be calculated separately for males and females.

Challenges and limitations

Because MC data collection is not uniform for the adaptive capacity indicators, adaptive capacity is normalized for each country individually. The index presented here is relative and cannot be compared across countries. Overall, limits in data availability may constrain calculation of vulnerability. As highlighted by the MRC "disaggregated data are still difficult to obtain, and existing data are often not linked effectively and in a timely manner with decision-making processes and budget allocations. The basin community must therefore urgently address this multi-dimensional data gap" (MRC 2023, p. 2). However, comparisons can be made regionally if the original source of the data in each MC measures the exact same metric. In either case, useful comparisons between most and least vulnerable provinces can be made to inform decision-making and improve adaptive capacity.

Way forward

The authors identified actions that could promote progress in developing and using the results of G&V analyses in the LMB, as follows:

- Collect additional social and economic data, including gender-disaggregated data through the DAGAP and other processes, to facilitate vulnerability analyses and provide input for the 2023 State of the Basin Report (SoBR).
- Conduct an integrated gender and social vulnerability analysis focused on floods, droughts and extreme storm events to better understand how the LMB population may be affected by hazards such as droughts, floods and storm events, and how this differs by gender. Use the results of those analyses to inform policy.
- For provinces with different vulnerability scores, the MRC, MCs and stakeholders can examine each component of vulnerability (exposure, sensitivity and adaptive capacity) to understand the underlying causes of each component. This may help explain the contribution of each component, thereby shedding light on possible strategies to reduce vulnerability and achieve greater gender equality.

2 Introduction

2.1 Climate change in Southeast Asia

The Lower Mekong River Basin (LMB) in Southeast Asia covers a wide range of landscapes: the Mekong River flows through mountain ranges in Lao People's Democratic Republic (PDR) and Thailand and empties into the sea from the delta of Cambodia and Viet Nam. Potential impacts from climate change similarly vary over the extent of the LMB, with effects such as increased landslides a greater concern on steep hill sides (Tho, 2020) and saltwater intrusion changing agriculture in the delta (Loc et al., 2021). As the impacts from climate change become increasingly variable and widespread, the Mekong River Commission (MRC) and Member Countries (MCs) seek to better understand these impacts, including impacts on individuals, to help develop practical adaptation strategies. Climate change impacts are expected to become more widespread and extreme; therefore, there is an increasing need to understand how these changes impact individuals is increasing.

The MRC, in consultation with the MCs (Thailand, Lao PDR, Cambodia and Viet Nam), reported on predicted changes in climate trends in the State of the Basin Report 2018 (SoBR) (MRC, 2019c) based on the predictions of the Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5) in 2014. The report predicted increases in temperature and sea levels but did not predict significant changes in precipitation or tropical storm, drought or flood events. However, the SoBR reported that higher temperatures may lead to an increase in drought events, even with stable rainfall patterns. The report also predicted that flooded areas may increase over the next 40 years. Sea-level rise may exacerbate impacts from these events, especially in the Delta. Overall, the SoBR reported that the most marked impacts from climate change are predicted to come from rising temperatures and sea levels.

In 2021, the IPCC published the 6th Assessment Report (AR6) with new and updated predictions for Southeast Asia. The AR6 predicted medium confidence for an increase in mean precipitation, river flooding, landslides and tropical storms, and high confidence for an increase in mean temperature, extreme heat, heavy precipitation, pluvial flooding, coastal flooding and coastal erosion. These updated predictions from the AR6 show a marked difference from the former climate change predictions reported in the 2018 SoBR, and indicate the potential for increasingly negative impacts from climate change in the LMB. The AR6 also reports that increased floods and droughts combined with heat stress will have an adverse impact on food availability and prices.

2.2 Rationale for this report

In the context of a changing climate and an uncertain future, the MRC has been assessing climate change impacts and produced the Climate Change Report: Climate Change Impact for Council Study Sectors under the Council Study and the Study on the Sustainable Management and Development of the Mekong River Basin including Impacts of Mainstream Hydropower Projects (MRC, 2017). It has also developed an Adaptation Strategy and Action Plan (MRC, 2018a) and an Indicator Framework (MRC, 2019b) to assess multiple domains (e.g. economic, environmental). In addition to basin-wide approaches to addressing climate change effects, the MRC supports the MC's climate adaptation efforts by conducting studies, producing technical guidelines, and working with MCs to develop capacity for responding to climate change. In 2015, United Nations Educational, Scientific and Cultural Organization (UNESCO) Bangkok published a detailed report on mapping vulnerability to climate change in the Mekong region (Kuntiyawichai et al., 2015).

The MRC recognizes that gender equity and gender-inclusive development are critical to sustainable development and an integral part of economic growth, poverty reduction and of a successful LMB development strategy. As early as 2000, the MRC developed a Gender Policy with the goal to mainstream gender perspectives in all MRC development efforts, ensuring that all MRC development programmes benefit men and women equally (MRC, 2023). As a next step, the MRC is specifically interested in examining how gender intersects with climate change impacts to inform social vulnerability.

Various MRC reports and documents reference both gender equality and gender equity (MRC, 2015, 2018b, 2019b). The vulnerability assessment outlined here refers exclusively to gender equality. Since the two concepts are closely related, definitions for each are presented in order to clarify our use of gender equality, and not equity, in the vulnerability assessment.

'Gender equality' refers to a situation in which individuals are given the same access to services or benefits, regardless of gender (Minow, 2021). For example, if primary education is available to all, that promotes gender equality. It is the view of the MRCS and MCs that gender equality is a human right and that gender inequality negatively affects all members of a society.

'Gender equity' focuses on the underlying conditions and historical practices that favour one gender over another (ibid.). Gender equity focuses on treating people based on their needs, with an emphasis on fairness and justice, so that each person can reach the same outcome. For example, a policy may state that education is available to all (equality), but societal norms or customs discourage the education of girls. Therefore, the policy may promote equality, but the practice might create inequity. Figure 1 shows the difference between equality and equity.

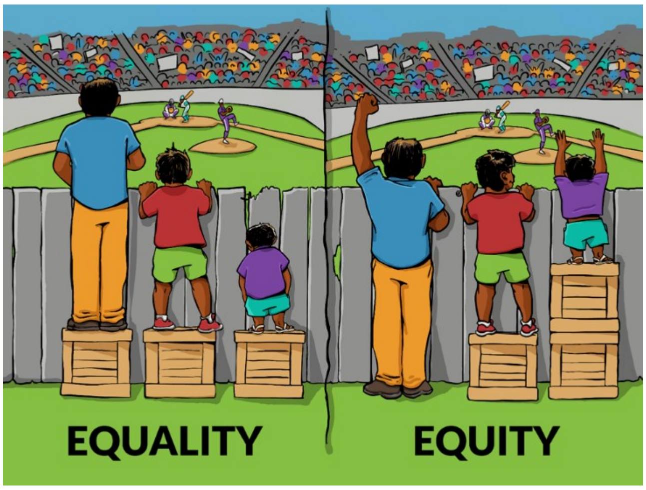

Figure 1. Illustration of the difference between equality and equity

Source: Interaction Institute for Social Change; Artist: Angus Maguire (interactioninstitute.org and madewithangus.com).

Gender equality and gender equity are included in the MRC Gender Handbook (2022). The MRC Indicator Framework (2019b) includes gender equality as a component, and the Council Study (MRC, 2015) acknowledges the importance of assessing gender equity and social vulnerability. However, neither the Council Study nor the Social Impact Monitoring and Vulnerability Assessments (SIMVA) assess gender equality (MRC, 2015, 2018b), even though G&V are mainstreamed in planned work outlined in the MRC Strategic Plan 2021–2025. This omission may be due to the fact that the objectives of the Council Study and SIMVA were related to overall social conditions, and while some gender data were collected, this was not the primary focus of those analyses. One of the primary recommendations of the Council Study's Social-Economic Impact Assessment (MRC, 2015) was to complete an investigation into gender equality and vulnerability in the LMB, which could be included in the 2023 SoBR.

Toward this goal, the MRC developed the Data Acquisition and Generation Action Plan (DAGAP; 2019a), which outlines strategic priorities and mechanisms for ensuring the collection and delivery of gender-disaggregated data from the MCs. The MCs are identifying data sources and availability to this end. Most recently, the MRC commissioned a desk review (MRC, 2021a) of G&V indicators, available data, data gaps, examples of vulnerability maps and recommendations. One of the objectives of the desk review was to identify current efforts to address the intersection of G&V in the Mekong region. Another objective was to suggest priorities for collecting gender-disaggregated data focused on food, water and energy security. This report draws on the desk review recommendations and incorporates many of its suggestions for additional gender-disaggregated data for use in the vulnerability assessment. This report also elaborates on the desk review discussion of a vulnerability assessment by proposing a detailed assessment approach that can be used when the MRC acquires additional gender-disaggregated data. One of the desk review's (2021) recommendations for the MRC is to finalize an approach to measuring social vulnerability with a focus on gender, and to detail the methodology using currently available data or socio-economic data that were submitted by the MCs within the DAGAP. This report seeks to address this recommendation.

3 Vulnerability assessments

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the propensity or predisposition to be adversely affected… [which] encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022). Vulnerability assessments are used to understand the degree to which a population will be affected, and can be used to compare impacts across multiple populations or to forecast potential future impacts. As discussed in Mohanty and Wadhawan (2021), there are five common types of vulnerability assessments, summarized here into three categories – physical or hazard-focused vulnerability assessments, social vulnerability assessments, and integrated vulnerability assessments.

Physical or hazard-focused vulnerability assessments mainly focus on environmental, biophysical or climate factors driving vulnerability in an area. They often aim to measure the impact of an event by focusing on the frequency, intensity and scale of the event, and the landscape characteristics that can exacerbate impacts.

Social vulnerability assessments mainly focus on the resources, services and other socio-demographic characteristics of a population to understand how sensitive a population will be to a hazard or other system shock. These assessments are generally more generic (e.g. not measuring a specific threat) and may reflect how a population will be able to respond to a change.

Integrated vulnerability assessments aim to bring together both physical and social vulnerability assessments to illustrate a more holistic depiction of vulnerability. These assessments often include three main components – exposure, sensitivity and adaptive capacity.[1] In integrated vulnerability assessments, exposure is used to define the severity of a specific hazard or threat that a population will experience; sensitivity is used to reflect the degree to which the population may be affected by the threat; and adaptive capacity reflects the population's ability to respond and change in response to the threat.

A framework for a gender and vulnerability assessment

The framework **for a G&V assessment** combines exposure to natural hazards, sensitivity and adaptive capacity. The G&V assessment outlined in this report takes an integrated approach, which is illustrated in Figure 2 including (A) the Vulnerability Index and (B) men's and women's vulnerability. By using data disaggregated by gender to calculate adaptive capacity as well as gender-specific adaptive capacity metrics, the vulnerability index can be calculated for men and women (provincial level data commonly only disaggregated by gender) to

[1] **IPCC 2022: Exposure** is the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. **Sensitivity** is the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise). **Adaptation**, in human systems, is the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities. In natural systems, adaptation is the process of adjustment to actual climate and its effects; human intervention may facilitate this.

examine differences and similarities. This framework is described in detail starting from *section 4*.

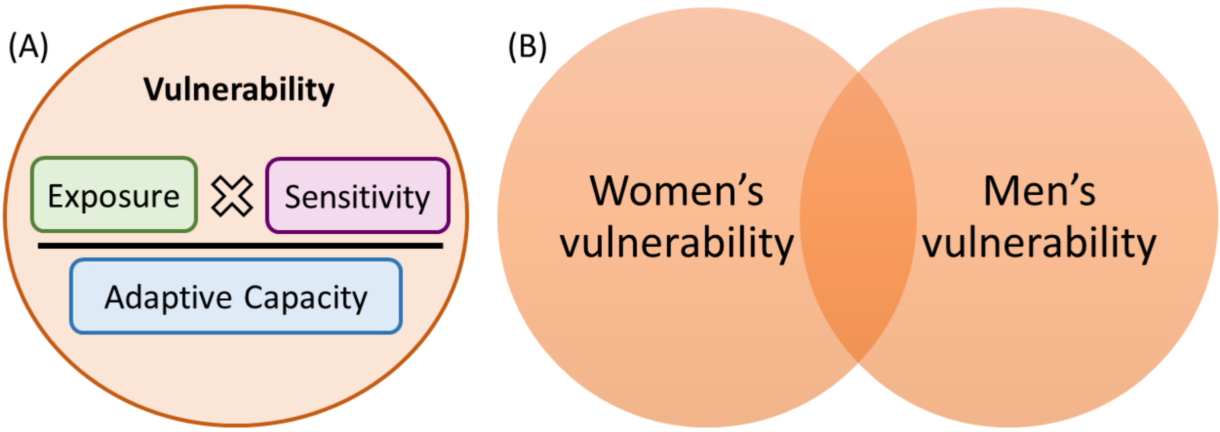

Figure 2. Conceptual diagram of the gender and vulnerability assessment methodology

Note: (A) shows that the vulnerability index calculated by multiplying exposure and sensitivity, and then dividing by adaptive capacity, where adaptive capacity differs by gender. (B) shows that some types of vulnerability will overlap between men and women, and other types will be distinct. Ideally, vulnerability would be calculated for all types of gender identities. However, national and regional data (e.g. census data) often only report data for men and women, which explains why these two are presented here.

3.1 Examples of vulnerability assessments

This section summarizes three vulnerability assessments and their respective vulnerability frameworks, discusses the methods used to assess vulnerability, and demonstrates what the results of a vulnerability assessment may look like. The examples of the assessments summarized here are: (i) an assessment examining vulnerability to typhoons in Viet Nam; (ii) an assessment examining vulnerability to multi-hazards in India; and (iii) an assessment examining flood vulnerability in An Giang Province,Viet Nam. Each study uses a spatial approach to demonstrate the variability in the levels of vulnerability across a study area, and uses multiple indicators to calculate a multi-component vulnerability index. The collection of examples demonstrates how vulnerability assessments can be conducted at multiple scales. It also demonstrates how the main components of vulnerability assessments can vary slightly across studies. Table 1 summarizes the main components of the vulnerability framework used in each example. Annex Table I provides more details on the specific indicators used in each example and how they compare to the approach presented in this report.

Table 1. Main components of the vulnerability frameworks used in the vulnerability assessment examples

Main components of the vulnerability framework		
Example 1	**Example 2**	**Example 3**
Hazard	Exposure	Sensitivity
Exposure	Sensitivity	Response capacity
Sensitivity	Adaptive capacity	Prevention capacity
Adaptive capacity		Benefits

3.1.1 Example 1: Vulnerability to typhoons

Nguyen et al. (2019) examine vulnerability to typhoons across Viet Nam using 21 variables compiled into a four-component vulnerability framework consisting of hazard, exposure, sensitivity and adaptive capacity. Multiple indicators are combined to create a value for each of the four components. This assessment examines historic typhoon pressure and frequency over 66 years combined with indicators such as precipitation, slope and elevation to calculate the hazard component. Exposure and sensitivity are combined to represent potential impacts and are calculated using variables such as land use, land cover, proximity to coastline, proximity to power stations and population density. Adaptive capacity includes indicators such as mangrove protection, education level, income and housing conditions. The indicators used are drawn from a variety of sources resulting in data at different scales, ranging from high spatial resolutions to the provincial level.

To calculate a vulnerability index from the 21 indicators, Nguyen et al. (2019) normalized and weighted indicator values. The authors used an analytic hierarchy process (AHP) (see Jagoda et al. [2020] for an overview of how to conduct this technique) to calculate weights for all indicators in each component, which was then reviewed and verified by local experts. The AHP results in individual weights for each indicator, ultimately ranking indicators by degrees of importance. The values for each indicator were then compiled into a single index value for each of the four components and used to calculate a single vulnerability index value shown in Figure 3 using Equation 1. This vulnerability equation is not intended to be interpreted as a mathematical function, but is used to illustrate the relationship between vulnerability indicators to estimate relative vulnerability levels between different geographical areas or provinces.

Equation 1:

$$Vulnerability = \frac{(Hazard \times Exposure \times Sensitivity)}{Adaptive\ Capacity}$$

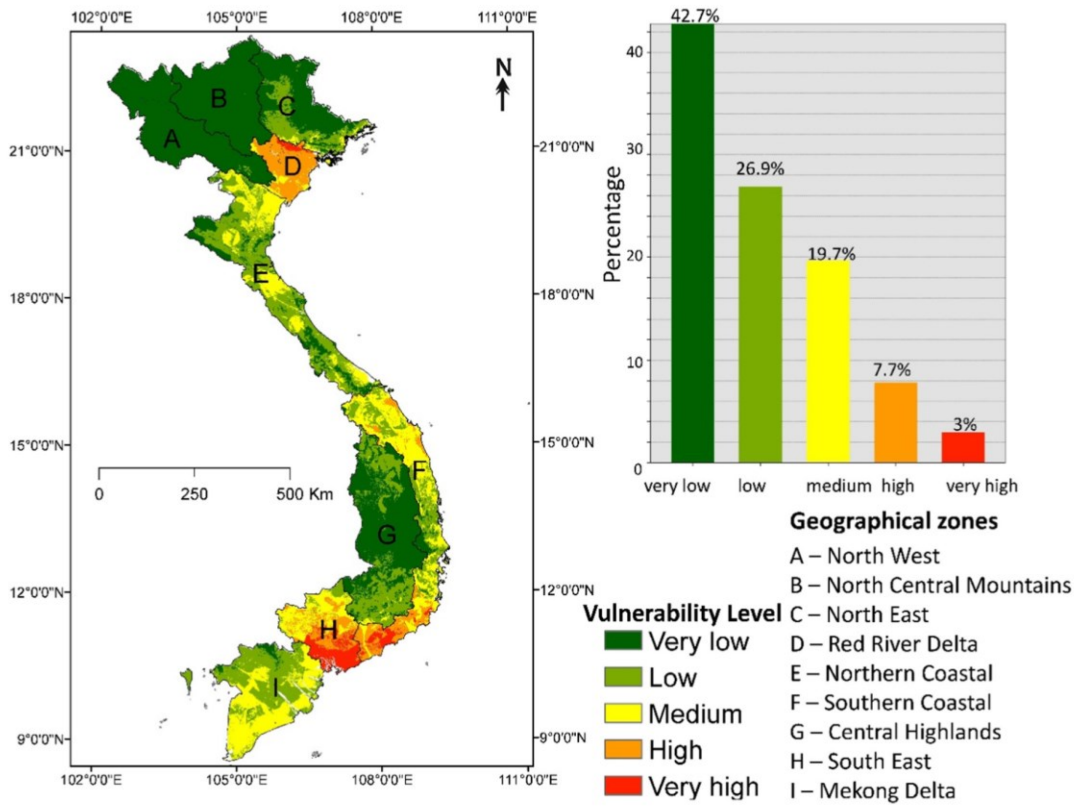

Figure 3. Results of the typhoon vulnerability assessment, Viet Nam

Source: Nguyen et al. (2019), Figure 8.

3.1.2 Example 2: Multi-hazard vulnerability in India

Mohanty and Wadhawan (2021) take a similar approach to examine vulnerability to floods, droughts and cyclones in India. The authors use a three-component vulnerability framework which includes exposure, sensitivity and adaptive capacity. Mohanty and Wadhawan define exposure as the frequency and intensity of the three extreme events – floods, droughts and cyclones – using 50 years of observed data (1970–2019). Indicators used to calculate sensitivity are elevation, slope, land use, land cover, soil moisture and groundwater. Similar to example 1, this example uses an AHP method to calculate weights for each sensitivity indicator. Different weights were calculated for the sensitivity indicators for each of the three types of extreme events. The authors used Equation 2 to calculate the sensitivity index with weighted indicators.

Equation 2:

$$Sensitivity\ Index = W_{ELV} \times Elevation + W_{SL} \times Slope + W_{LULC} \times Land\ Use\ Land\ Cover + W_{SM} \times Soil\ Moisture + W_{GW} \times Groundwater$$

Where:

W_{ELV} is the calculated weight for elevation, W_{SL} is the calculated weight for slope, W_{LULC} is the calculated weight for land use/land cover, W_{SM} is the calculated weight for soil moisture, and WGW is the calculated weight for groundwater.

The authors then used the Delphi Method to select seven adaptive capacity indicators, which represent four dimensions of adaptive capacity, i.e. economic, social, governance and infrastructure. Examples of the adaptive capacity indicators include population density, literacy rate and critical infrastructure.

The data used in the assessment were drawn from different sources and were collected at different scales. To adjust for this, the authors used a downscaling method so that the data were matched on the finer scale. For example, data collected for the sensitivity component were rescaled from 25 km x 25 km resolution to 30 m x 30 m resolution.

To calculate vulnerability, all indicators were normalized and then calculated for the component indices, i.e. exposure, sensitivity and adaptive capacity. Finally, the exposure index was then multiplied by the sensitivity index and then divided by the adaptive capacity index to calculate a value for vulnerability, as shown in Equation 3.

Equation 3:

$$Vulnerability = \frac{Exposure \ \times Sensitivity}{Adaptive\ Capacity}$$

These calculations were performed separately for floods, droughts and cyclones to calculate three different vulnerability values (Figure 4). The authors also combined the vulnerability indices to examine multi-hazard vulnerability or identify areas at risk of more than one type of extreme event.

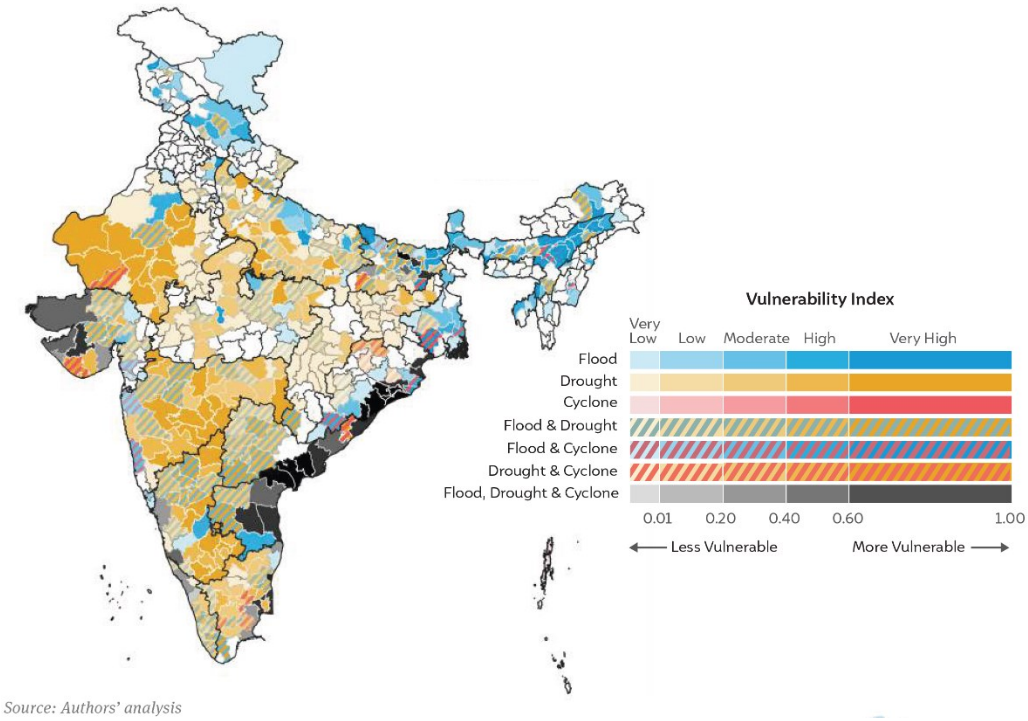

Figure 4. Results of the multi-hazard vulnerability assessment, India

Source: Mohanty and Wadhawan (2021), Figure 18.

3.1.3 Example 3: Assessment of vulnerability to high floods in An Giang Province, Viet Nam

In the final example, Can et al. (2019) examined flood risk in An Giang Province in Viet Nam, showing a finer scale at which vulnerability can be assessed. This example uses survey data collected at the commune level. In addition to the smaller study area, this example does not calculate exposure or integrate a hazard component as the other examples do; rather, the authors estimated flood risk by calculating sensitivity, adaptive capacity and benefits from floods. Sensitivity is divided into social sensitivity and environmental sensitivity. Social sensitivity includes variables such as total population, literacy rate and income; environmental sensitivity includes variables such as stability of the riverbank and ecosystem. Adaptive capacity is divided into the response capacity and prevention capacity. Response capacity includes indicators such as flood forecast and government support; prevention capacity includes indicators such as transportation access, public works and communication opportunities. Finally, the benefits component, which is a component that other examples did not consider, recognizes that low severity floods can bring some benefits. For instance, floods can lower salinity, thus improving productivity in crop fields and aquaculture production.

Similar to examples 1 and 2, an AHP technique was used to weight all the indictors, and experts were consulted to review and verify the weights. The flood vulnerability index (Figure 5) was then calculated using a set of equations described in detail in Can et al. (2019).

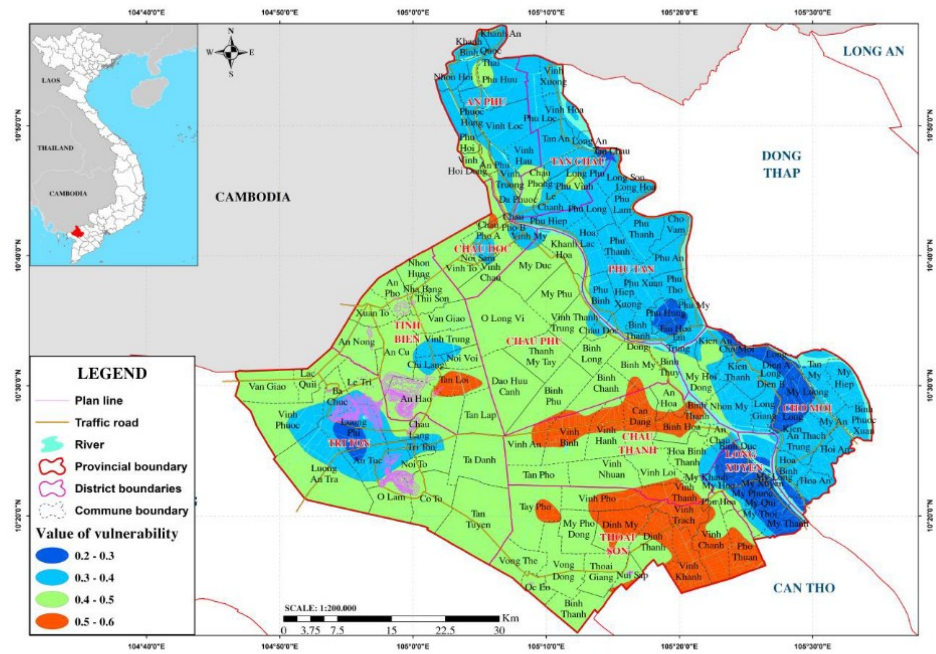

Figure 5. Results of the flood vulnerability assessment, An Giang Province, Viet Nam

Source: Can et al. (2019), Figure 3.

3.1.4 Summary of vulnerability examples

The examples above show how different approaches can be taken to assess vulnerability at different scales and to different threats. The following are key considerations drawn from these examples for assessing vulnerability:

- **Developing a vulnerability framework:** While different frameworks can be used to assess vulnerability, the most common frameworks consist of three main components, i.e. exposure, sensitivity and adaptive capacity.
- **Selecting indicators:** Variables that make a population sensitive will vary by hazard or type of threat that it is exposed to, as well as those indicators that help populations adapt to a threat. Therefore, it is important to adjust the indicators used to calculate sensitivity and adaptive capacity, or adjust the weights for these indicators when assessing different threats.
- **Collecting data at different scales:** Data for each indicator are often collected at different scales. Different methods can be used to downscale or scale up indicators to compare vulnerability components.
- **Normalizing data:** Indicators are often normalized in order to be combined into a single index due to indicators being measured on different scales.
- **Calculating weights:** While there are commonly used techniques to calculate weights for vulnerability indicators, such as AHP, expert opinion on weights can be important to validate weights and ranking results.
- **Calculating vulnerability:** In vulnerability assessments, often a single value for each component of the framework (e.g. sensitivity, adaptive capacity) is calculated in order to combine into a single vulnerability index. Exposure and sensitivity are known to have a positive relationship with vulnerability (i.e. greater exposure leads to greater vulnerability), while adaptive capacity is expected to reduce vulnerability. Therefore, most frameworks will add or multiply exposure and sensitivity, and subtract or divide the result by adaptive capacity to produce a vulnerability index value.

4 The integrated gender and social vulnerability assessment approach

This report describes an approach that can be used to conduct an integrated vulnerability assessment to examine gender and social vulnerability to floods, droughts and extreme storm events in the LMB. It outlines specific steps to calculate exposure, sensitivity, adaptive capacity and an overall vulnerability score at the provincial level for each of the MCs. A conceptual diagram of this G&V approach is shown in Figure 2. This report also expands on current efforts by the MRC to assess vulnerability with an emphasis on gender equality and gender equity, as per previous MRC supported reports, which have highlighted this intersection, such the SIMVAs (MRC, 2018b, 2021b), the Council Study (MRC, 2015) and the desk review (MRC, 2021a]. These reports found diverging impacts of specific hazards across gender as well as inequities in access to adaptation or coping mechanisms by gender. For instance, the desk review (MRC, 2021a) found that gender can influence vulnerability through: the unbalanced distribution of non-paid labour (e.g. household responsibilities such as cooking, cleaning, caring for family members); established gender norms determining where and how women participate in specific industries (e.g. riverbank gardening, paddy rice, domestic fish retail trade and/or subsistence fishing); and the disruption of gender norms through forced migration for labour or as a result of impacts or losses from natural hazards. Additionally, the desk review identified gender-specific tasks that are more at risk due to climate hazards, such as water and fuel gathering, and maintaining riverbank gardens.

The approach outlined in this report integrates indicator recommendations from the desk review and other MRC reports to better account for gender equality and recognize how gender intersects with climate change impacts to define social vulnerability.

The following sections outline the specific steps that can be taken to assess vulnerability to floods, droughts and extreme storm events. Steps for the three components of the integrated vulnerability assessment – exposure, sensitivity and adaptive capacity – are outlined separately, followed by steps that can be used to calculate a single vulnerability index. Moreover, to help illustrate the methods used to calculate the vulnerability index described in this report, an example data set has been created by using randomly generated numbers. The examples are demonstration purposes only and do not represent real data. Prior to outlining the steps for each component, the spatial and temporal scales of analysis are discussed.

4.1 Scale and study area

Selecting an appropriate spatial scale (national, provincial or sub-provincial) depends on the objective of the assessment and availability of input data. A vulnerability assessment conducted at a fine scale (gridded, district or commune level) would provide the highest level of detail and allow for a more complete hotspot analysis to help direct mitigation efforts. Vulnerability can vary greatly across areas within the same province, such as between urban and rural, coastal and inland, or high- and low-income sub-regions. However, obtaining social indicators or monitoring parameters at the sub-provincial level requires either extensive survey methods or disaggregated census data from each MC. Therefore, a vulnerability assessment conducted at the provincial scale may be the most efficient way forward, because it can be completed without extensive additional data collection and within a relatively short time frame.

The MRC established in the DAGAP that the default spatial scale for social and economic data will be the provincial level. DAGAP acknowledges that data and assessments conducted at the national level are too broad to investigate and illustrate geographic differences in the MRC corridor. Sub-province data (such as at the district or commune level) are at too fine a scale for coordination over the entirety of the LMB. Sub-provincial data might be useful for case studies targeted at specific locations. While these types of studies could provide valuable information, they will not be aggregated over the whole of the LMB because it is unlikely that every case study will use the same data sources and analysis methods. These case studies and other areas with community-level data are useful and could be used for local policy decisions or adaptation strategies.

Environmental data sets are frequently produced on orthogonal grids (e.g. land use and land cover). Therefore, the first two vulnerability assessment components, exposure and sensitivity, are expected to be calculated on a grid. These data will need to be aggregated to the provincial scale and combined with data from the adaptive capacity component (collected at the provincial level) to calculate vulnerability. Data are aggregated by calculating the mean of exposure and mean of sensitivity for all grid cells within each province. An example is provided in Figure 13.

Transnational comparisons of vulnerability are challenging given that social indicators (monitoring parameters) are often from census data that are collected differently across the MCs. For instance, a monitoring parameter such as access to credit could reference a census question on “percent of households with a bank account” in one MC but reference “percent of communities with a bank or credit fund” in a different MC. Although both are measures of access to credit, they are quantifiably different and estimate different metrics. Therefore, these two estimates are not directly comparable. To compare monitoring parameters across more than one nation, the original source of the data must measure the same metric. In this case, regional (i.e. trans-national) comparisons could be made.

The default temporal scale for MRC assessments is annual, but data for the sensitivity and adaptive capacity may not be available on an annual basis. Additionally, years of collected data may not match among all MCs. For the vulnerability assessment outlined here, the aim is to use data collected in same year to the extent possible.

4.2 Exposure

Exposure is defined as the extent and degree to which people and the resources they depend on are exposed to a natural hazard. The MRC has prioritized floods, droughts and storm events as priority hazards of concern, which are used as monitoring parameters in the MRC Indicator Framework. However, vulnerability to floods, droughts and storm events has yet to be examined in available reports, such as the 2018 SoBR, due to a lack of data. The desk review notes this deficiency and recommends the creation of GIS layers indicating areas of the LMB most at risk of impacts from these events to assist in vulnerability analyses.

The approach outlined in this report relies on exposure data that are spatially referenced and on a continuous or categorical scale, reflecting high to low frequency or risk of an event taking place and its potential severity. Exposure to each hazard – i.e. floods, droughts and storms – would be indicated on separate data layers due to the geographical variation in the occurrence of such events.

There are two potential data sources to use for the exposure calculation outlined in this report. The MRC technical team is currently developing maps of flood and drought hazards. It is expected these maps will spatially indicate where each hazard will occur and the degree of severity of the hazard.

Exposure data inputs for the MRC Technical Division

- Natural hazard geospatial data indicating the severity of exposure to a flood, drought, or storm event
- Spatial resolution of the hazard data gridded on a sub-provincial scale and covering the entirety of the study area (LMB).

An alternative data source is SERVIR-Mekong, which has developed tools to monitor floods and droughts, such as the Mekong Drought and Crop Watch (MDCW) and the Historical Flood Analysis Tool (HFAT):

- **MDCW** data sets summarize current drought conditions in single day, 8-day, 16-day and 24-day summaries, classifying risk from no drought to extremely dry. The tool also calculates a drought outlook warning forecasting risk up to three months into the future. The natural hazard map in Figure 6 shows an example of a one-month drought outlook
- **HFAT** uses satellite imagery to detect the presence of surface water and tracks the temporal changes to identify areas with high, medium and low flood occurrence between 1984 and 2018.

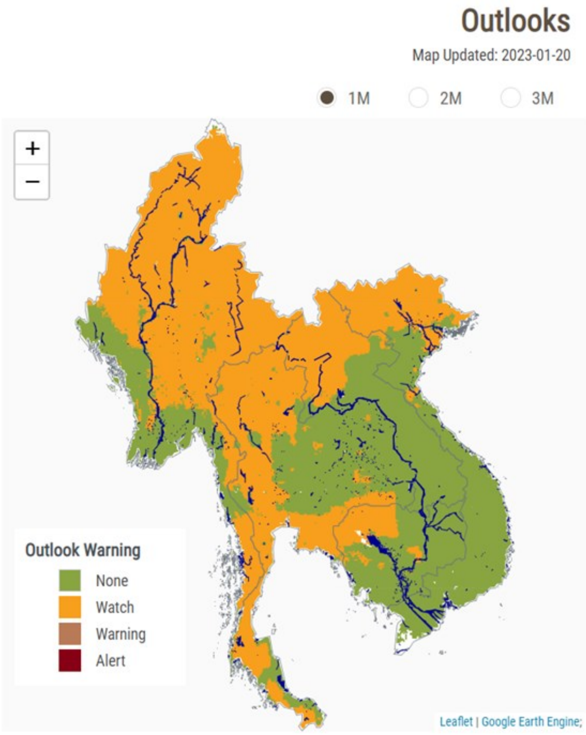

Figure 6. A snapshot of the Mekong Drought and Crop Watch Outlooks

Note: The degree of the hazard is described in four levels of increasing severity (none, watch, warning, alert).
Source: The Mekong Drought and Crop Watch. https://mdcw-servir.adpc.net/home

Whatever data source is used as a measurement of exposure, it will need to be normalized using Equation 4, which converts the score to a scale of 0–1. Normalizing the data values allows exposure to be combined, in a later step, with sensitivity and adaptive capacity in the overall vulnerability score.

Equation 4: $$x_{normalized} = \frac{(x - x_{min})}{(x_{max} - x_{min})}$$

Equation 4 shows how to transform each data point, where x_{min} and x_{max} are the minimum and maximum values, respectively, of the indicator over all values (x) within the study area. Then $x_{normalized}$ is the new indicator value used for exposure.

4.2.1 Exposure

Figure 7 is an example of drought exposure scores using the randomly generated example data set. The example demonstrates possible values for a drought hazard on a 3 x 3 grid, with severity of the drought indicated on a scale of 1–5. Figure 7(A) shows the raw exposure scores, whereas Figure 7(B) shows the normalized values using Equation 4, on a scale of 0–1.

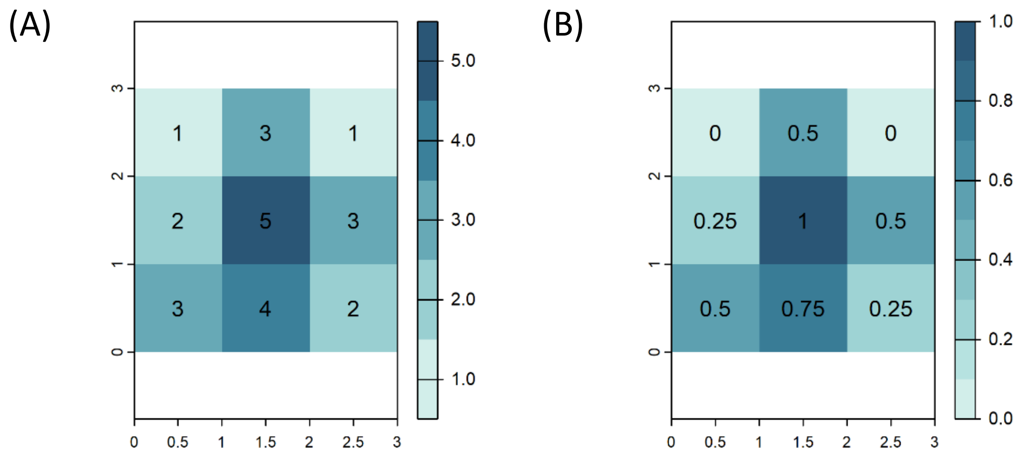

Figure 7. Drought exposure generated using random numbers

Note: Higher values represent increased severity of drought. (A) shows raw exposure scores on a scale of 1-5; (B) shows normalized exposure scores, which were transformed from raw values using Equation 4.

4.3 Sensitivity

For the approach outlined in this report, sensitivity is defined as the degree to which an area could be impacted or affected by a natural hazard (i.e. exposure). For example, a mangrove forest is less sensitive to coastal flooding than an urban area when both are exposed to the same degree and duration of flooding. Due to low to zero population estimates and a lack of agriculture in the mangrove forest, even with high exposure to coastal flooding, the social impact is low. Three indicators are used to calculate social sensitivity in this approach: the size of the population exposed to the hazard, land cover type, and distance to coast.

The sensitivity components are normalized using Equation 4 before they are combined into an overall sensitivity score. Normalizing the indicators transforms the values into a 0 to 1 linear scale such that all indicators are on the same relative scale and can be combined easily. On a normalized scale, a value of 1 indicates the highest observed value for that indicator, and a value of 0 indicates the lowest possible value of that indicator. Rescaling allows to compare between indicators that are on different scales – for example, population numbers, which range into the millions, with land cover sensitivity scores, which range in the single digits.

The approach outlined here describes a calculation of sensitivity using a 1-km grid cell resolution, and not at the provincial level. Calculating sensitivity at the provincial level would overlook a high degree of spatial heterogeneity in indicators that determine potential impact. For example, if the population of a province is very large (highly sensitive), but the majority of the population is concentrated in a part of the province that is not at risk of flooding (low exposure), the potential impact would be low. Alternatively, if most of a province is not at risk of flooding (low exposure) except for a small area (high exposure) where the population is concentrated (highly sensitive), the impact on the province would be high. Therefore, sensitivity must be on smaller spatial scale than the provincial one to capture this variation within the province itself. Additionally, distance to coast, an important determinant of potential impact from storm events, is not a meaningful indicator at the provincial scale.

Sensitivity data inputs for the MRC Technical Division

- Population size in a geospatial data layer on a gridded scale
- Land cover or land use geospatial data layer and associated sensitivity scores for each land cover type, for each type of hazard (flood, drought, storm). The MRC land cover maps can be used for this input
- Coastline of the Member Countries as a polyline feature layer from which distance to coast can be calculated.

4.3.1 Population size

Population size is a sensitivity indicator regardless of the type of hazard exposure. A spatially referenced population count data set can be sourced from the WorldPop.org data set (https://hub.worldpop.org) and the methodology used can be found at Lloyd et al. (2019). WorldPop provides annual population estimates on a 1-km resolution; they are currently available for 2000–2020 and are regularly updated. To combine with land cover type and integrate into the overall sensitivity component, population size is normalized using Equation 4, which transforms population size to a scale of 0–1.

4.3.1.1 Population size example

Figure 8 is an example of population size, generated using random numbers. Figure 8(A) shows the raw population values, ranging within the 100s. Figure 8(B) shows the normalized population numbers, transformed from the raw values using Equation 4 and ranging on a scale of 0–1, where 1 represents the largest population count and 0 represents the smallest population count.

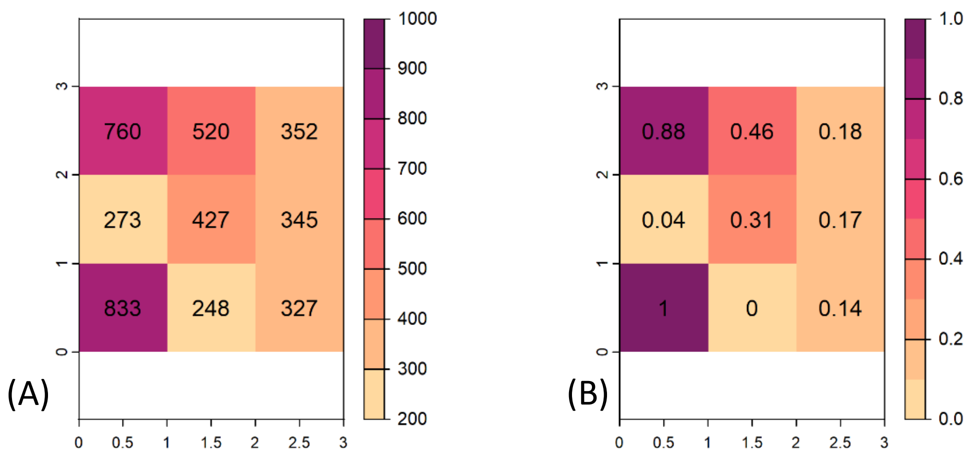

Figure 8. Example of population size generated using random numbers.

Note: (A) shows raw population counts; (B) shows normalized population counts

4.3.2 Land cover

Land cover is a sensitivity indicator for all types of hazard exposure, but the impact of the hazard changes depending on the land cover type. The land cover data set developed by the MRC can be used for this indicator. The MRC Land Use and Land Cover Map has a spatial resolution of 10 m, covers the entirety of the LMB, and has been classified for three years, i.e. 2003, 2010 and 2020. The classifications are provided in Table 2.

Using expert consultations and Table 2, land cover types can be ranked from highly sensitive to not sensitive for each hazard type. For example, the land cover type "marsh or swamp" ranks not sensitive to flood exposure, whereas an "industrial plantation" may be somewhat sensitive, and an "urban" is highly sensitive. These rankings can then be used to reclassify the land cover map to numerical values as follows: not sensitive (value = 0), somewhat sensitive (value = 1), or highly sensitive (value = 2), for each hazard type.

Table 2. Land cover sensitivities

Land cover type	Flood	Drought	Storm event
Annual crop			
Aquaculture			
Bamboo			
Bare soil			
Deciduous forest			
Evergreen forest			
Flooded forest			
Land cover type	**Flood**	**Drought**	**Storm event**
Forest plantation			
Grassland			
Industrial plantation	*Somewhat sensitive*		
Mangrove			
Orchard			
Paddy rice			
Urban	*Highly sensitive*		
Water body			
Coniferous forest			
Marsh or Swamp	*Not sensitive*		
Shrubland			
Others			

Note: Table 2 shows land cover types from the MRC's land use and land cover map, which can be filled in by domain experts and representatives from the Member Countries to indicate the degree of sensitivity for each land cover type. Some examples have been provided, in light grey.

Source: Based on MRC's Land Use and Land Cover Map.

After determining sensitivity levels and reclassifying the land cover geospatial layer, land cover type is then rescaled to the 1-km resolution so that it can be combined with the other sensitivity metrics. Within each WorldPop 1-km grid cell, the land cover sensitivity values (either 0, 1 or 2) are summed together for a total score. Last, these values are normalized using Equation 4 to range on a scale of 0–1.

4.3.2.1 Land cover example

Table 3 provides random sensitivity scores for an example of land cover types. All sensitivity scores are for drought and are random; they do not indicate true sensitivity for each land cover type. These sensitivity scores are shown in Figure 9(A), where each cell represents a different land cover type. Because land cover type often has a higher spatial resolution than other spatial data such as population size, the land cover grid is 6 x 6 in Figure 9(A) and is aggregated to match the other example data sets (population size and drought) in Figure 9(B). Each of these larger cells were calculated taking the sum of the underlying cells from (A). Finally, Figure 9(C) shows the drought sensitivity scores normalized on a scale of 0–1 using Equation 4.

Table 3. Randomly generated sensitivity scores for three land cover types experiencing drought conditions

Land cover type	Drought sensitivity score
Forest	Not sensitive (0)
Paddy rice	Highly sensitive (2)
Urban	Somewhat sensitive (1)

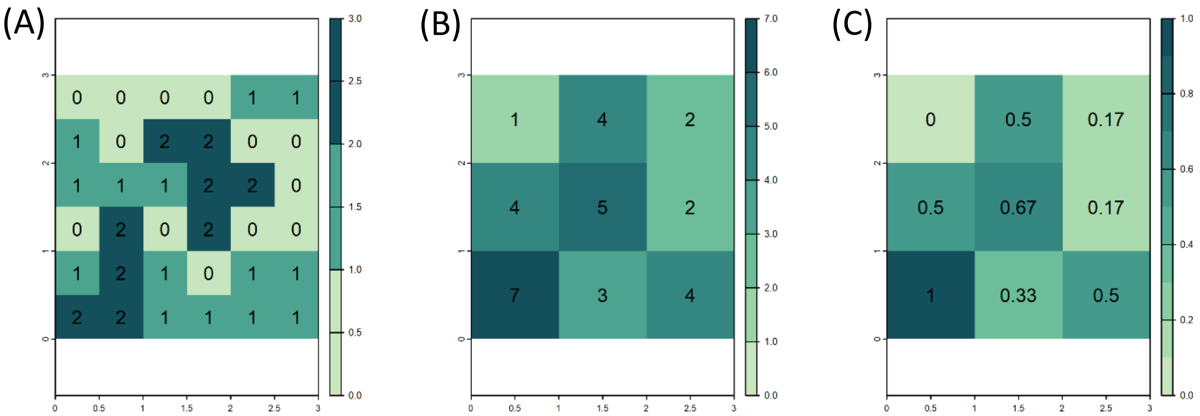

Figure 9. Example of land cover sensitivity scores using randomly generated data

Note: (A) shows the raw sensitivity scores, where each cell represents a cell in a land cover map; (B) aggregates the land cover types to a lower spatial resolution by calculating the sum of the underlying cells; (C) shows the normalized sensitivity scores

4.3.3 Distance to coast

Areas close to ocean coastline are more sensitive to tropical cyclones, sea-level rise and coastal flooding than in-land areas. MCs with areas that experience these impacts can include distance to coast in the sensitivity index. If proximity to the coast does not impact the MC, it can be excluded from the sensitivity calculation.

Distance from the coastline impacts sensitivity to storm events and coastal flooding. Using a polyline feature layer, Euclidean distance to the coast can be calculated in a GIS on the same 1km raster grid as the WorldPop population size raster layer. Using Equation 4, distance to coast is normalized on a 0 to 1 scale. Because increased distance from the coast indicates a decrease in sensitivity, the normalized value is then subtracted from 1 before combining in the overall sensitivity score; hence, areas closest to the coast have the highest sensitivity values.

4.3.3.1 Distance to coast example

Figure 10 is an example of the distance to coast spatial layer. The blue line represents an example coastline, and each cell represents a measurement of the Euclidian distance to coast. If each cell is 1 km x 1 km, then the values in Figure 10(A) show 1 km, 2 km and 3 km from the coastline. Figure 10(B) normalizes the distance to coast using Equation 4 and subtracts the resulting value from 1.

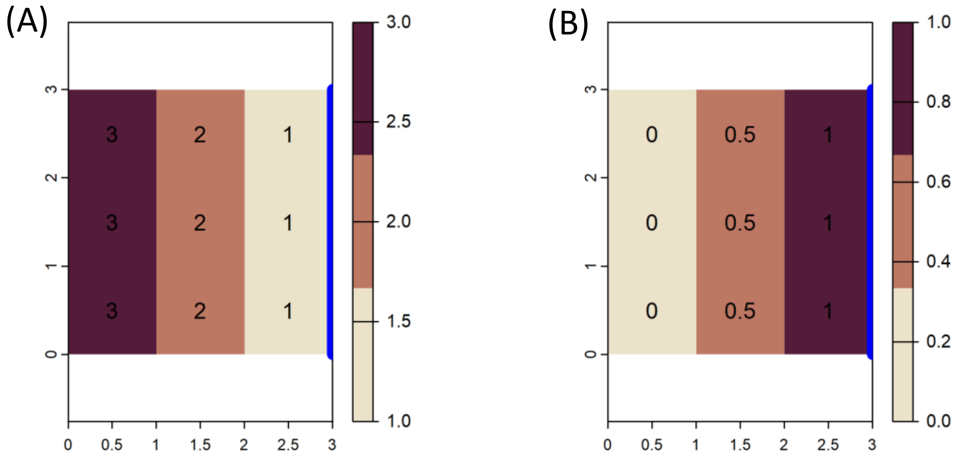

Figure 10. A distance-to-coast spatial layer where the blue line represents the coast

Note: (A) shows the raw measurement of the Euclidean distance to the coast and (B) shows the normalized value (on a scale of 0–1), subtracted from 1 such that areas closest to the coast have the highest sensitivity values.

4.3.4 Calculating sensitivity

For the sensitivity component, equal weights are given to population size, land cover and distance to coast to calculate the arithmetic mean across the three normalized indicators. For calculating sensitivity to floods, the distance to coast indicator is excluded, and sensitivity is calculated using only population size and land cover type. Taking the mean of the indicators results in a sensitivity value ranging from 0 to 1 on the 1-km orthogonal grid.

4.3.4.1 Sensitivity example

For an example of the overall sensitivity to drought, the mean of the three components was calculated: the normalized population count in Figure 8(B), the normalized land cover sensitivity in Figure 9(C) and the normalized distance to coast subtracted from 1 in Figure 10(B). This overall sensitivity score is shown in Figure 11.

Figure 11. An overall sensitivity score

Note: The overall sensitivity score is calculated by taking the mean of the normalized population size, normalized land cover type sensitivity, and normalized distance to coast subtracted from 1. All input layers are derived from randomly generated data

4.4 Adaptive capacity

Adaptive capacity, or the ability to change in response to a threat, is determined by many diverse factors, including financial resources, knowledge to make informed decisions, and agency to leverage resources and carry out decisions related to coping or adaptation. This report presents an adaptive capacity framework with an extensive list of factors influencing adaptive capacity, and outlines an approach to further narrow these factors to those that are most important through expert consultations. Specifically, this report walks through the steps of a Delphi Method, which aims to build consensus among a group of experts through multiple rounds of surveys and feedback.

Through a review of the MRC Indicator Framework, suggestions from the desk review (MRC, 2021a), and findings from SIMVA (MRC, 2018b; MRC, 2021b) and the Council Study (MRC, 2015), a framework for adaptive capacity was developed, which includes three edited strategic indicators from the existing MRC Indicator Framework: living conditions and wellbeing; livelihoods, employment, and education; and infrastructure and institutions (Figure 12). Each strategic indicator comprises multiple assessment indicators which include a total of 33 monitoring parameters. Table 4 provides a list of all monitoring parameters in the adaptive capacity framework. A list of only the additional data needs for the G&V assessment can be found in Table 5. It is consistent with the data acquisition framework within the DAGAP, and the spatial scale refers to national and provincial data.

Full descriptions of how to calculate the monitoring parameters are not provided here, but can be found in the Mekong Basin Indicator Framework: Technical Guidelines for Implementing the Mekong Basin Indicator Framework (MRC, 2019b). Twelve out of the 33 monitoring parameters, relate to gender. Because of these gender parameters, adaptive capacity can be calculated separately for men and women, resulting in two adaptive capacity measurements. The male and female adaptive capacity indices can then be compared to each other, and the difference between the two can be evaluated as a measure of inequality in adaptive capacity. This difference can be carried over into the vulnerability score by calculating it separately for men and women.

The comprehensive list in Table 4 provides a foundation for calculating the adaptive capacity assessment, which could be further narrowed through expert consultations using methods such as the Delphi Method. Items that are not currently included in the Indicator Framework are underlined. Some of the monitoring parameters were, however, included in earlier documents (Stephens, 1998), as noted in the desk review (MRC, 2021a). These parameters include literacy by gender, gender income equality, and some measures of political participation.

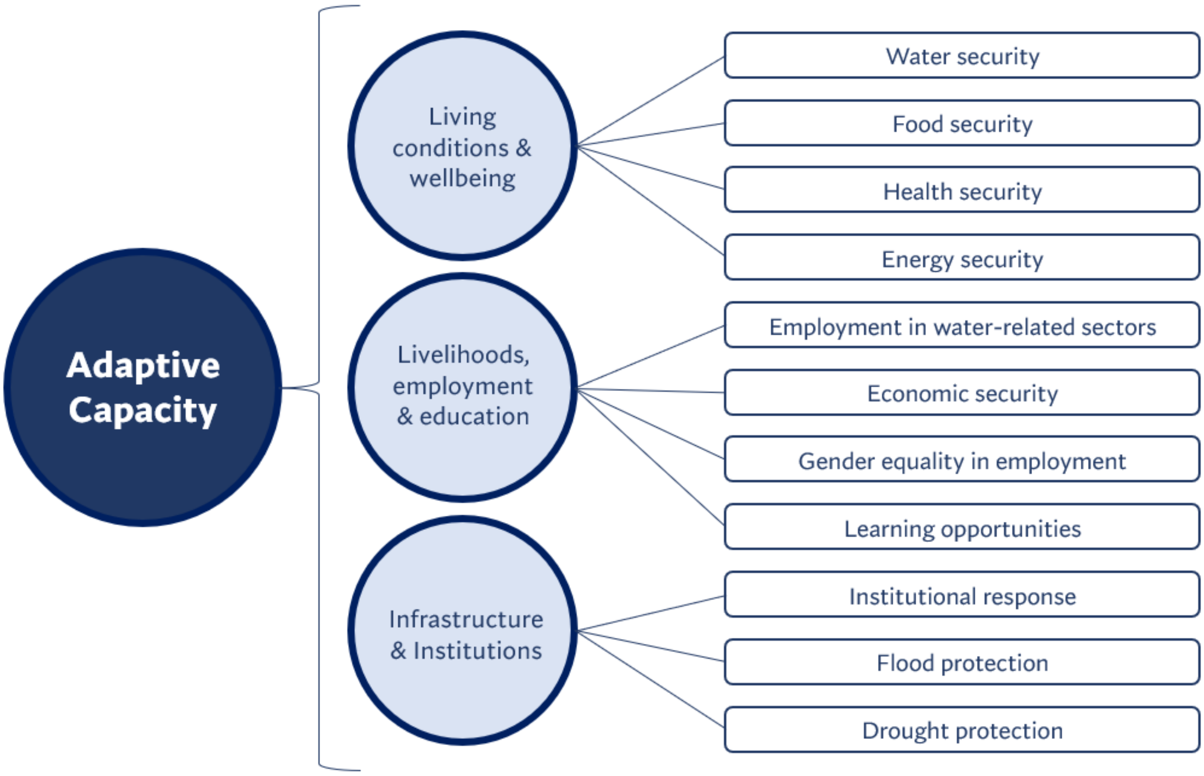

Figure 12. The Adaptive Capacity Framework

Table 4. Adaptive capacity monitoring parameters

Strategic	Assessment Indicator	Monitoring Parameter
Living Conditions and Wellbeing	Food security	Adequacy of dietary energy supply
		Prevalence of undernourishment
		Prevalence of infant malnutrition
	Water security	Adequacy of domestic water supply
		Sufficiency of water for farming
	Health security	Access to safe water supplies
		Prevalence of malnutrition
		Access to sanitation
		Incidence of water-borne disease
		Maternal mortality
	Energy security (Access to electricity)	Urban household electrification rate
		Rural household electrification rate
Livelihoods, employment and education	Employment in LMB water-related sectors	Proportion of working age population employed in LMB water-related sectors
	Economic security	Sufficiency of household income
		Sufficiency of household assets
		Gender income equality
		Access to credit and bank account by gender
	Gender equality in employment, economic, and political engagement	Female-male ratio of water-related sector employment
		Political participation by gender
		Distribution of non-paid vs paid labour by gender
		Gender equality in ownership of land
	Learning opportunities	Literacy rate by gender
		Occupational training by gender
		Primary education enrolment by gender
		Secondary education enrolment by gender
Infrastructure and Institutions (adaptation to climate change)	Institutional response to the effects of climate change	Policies and strategies for climate change response
		Budget for climate change response
		Number of awareness-raising activities
		Access to climate finance
	Flood protection measures	Area of urban land protected by embankments/levees
		Area of agricultural land protected by embankments
	Drought protection measures	Proportion of irrigable land that is irrigated
		Volume of available water storage

Table 5. Additional data requirements for the gender and vulnerability (G&V) assessment

Assessment indicators	Monitoring parameters	Data items	Spatial scale	Temporal scale	Subdivision
Health security	Maternal mortality	Deaths per 1,000 live births (no.)	National Provincial	Annual	Total Urban Rural
Economic security	Gender income equality	Average income in LMB water-related sectors (USD/year) - Average income of total population in each water-related sector - Average income of males in each water-related sector - Average income of females in each water-related sector	National Provincial	Annual	Hydropower Agriculture Navigation Forestry Fisheries Tourism Sand mining
		Average income in non-water-related sectors (USD/year) - Average income of total population in each water-related sector - Average income of males in each water-related sector - Average income of females in each water-related sector	National Provincial	Annual	Industry Handicraft Hospitality, etc.
	Access to credit and bank account by gender	Total population with a bank account (no.) - Total number - Number of males with a bank account - Number of females with a bank account	National Provincial	Annual	Total Urban Rural
		Total population with access to credit (no.) - Total number - Number of males with access to credit - Number of females with access to credit	National Provincial	Annual	Total Urban Rural
Gender equality in employment, economic, and political engagement	Female-male ratio of water-related sector employment	Number of jobs in each LMB water-related sector (no.) - Total number of jobs in each water-related sector - Number of jobs in each LMB water-related sector occupied by males - Number of jobs in each LMB water-related sector occupied by females	National Provincial	Annual	Hydropower Agriculture Navigation Forestry Fisheries Tourism Sand mining
	Political part-icipation by gender	Total number of political positions or government decision makers (no.) - Total number of political positions - Total number of male political positions	National Provincial	Annual	National Provincial District Village

Assessment indicators	Monitoring parameters	Data items	Spatial scale	Temporal scale	Subdivision
		- Total number of female political positions			
	Distribution of non-paid vs. paid labour by gender	Average hours a day spent on non-paid labour tasks (unpaid care work or household duties) - Average hours spent by males - Average hours spent by females	National Provincial	Annual	Total Urban Rural
		Average hours a day spent on paid labour tasks in water-related sectors - Average hours spent by males in each water-related sector - Average hours spent by females in each water-related sector	National Provincial	Annual	Hydropower Agriculture Navigation Forestry Fisheries Tourism Sand mining
	Gender equality in ownership of land	Number of households headed by males and females	National Provincial	Annual	Total Urban Rural
		Number of households that own land by males and females	National Provincial	Annual	Total Urban Rural
Learning opportunities	Literacy rate by gender	Literacy rate for total population of 15 years or older (%) - Literacy rate for males above 15 years (%) - Literacy rate for females above 15 years (%)	National Provincial	Annual	Total Urban Rural
	Occupational training by gender	No. of students enrolled in occupational training in water-related sector - No. of total students enrolled - No. of male students enrolled - No. of female students enrolled Number of total students who completed occupational training in water-related sectors - No. of male students who completed occupational training in water-related sectors - No. of female students who occupational training in water-related sectors	National Provincial	Annual	Hydropower Agriculture Navigation Forestry Fisheries Tourism Sand mining
	Secondary education enrolment by gender	Number of girls and boys attending secondary education	National Provincial	Annual	Total Urban Rural

Note: Underlined text indicates a new monitoring parameter or an adjustment to the existing MRC Indicator Framework. Shaded boxes highlight monitoring parameters important for gender equality

4.4.1 The Delphi Method

The Delphi Method is an approach used to build informed group consensus by experts. Input is gathered from expert group discussions on specific topics. The experts then present a summary from these discussions, allowing themselves time to reflect and gather additional feedback until an agreement on an issue is reached. It is well-suited for complex problems where uncertainty is high and available analytical techniques are not useful. Hence, a systematic gathering of subjective opinions and allowing a group of experts to reach consensus may be the most effective method (Hanafin et al., 2007). This method was used in previous vulnerability research to understand adaptive capacity and the factors that lead to higher sensitivity to hazards across India (Mohanty and Wadhawan, 2021) in Example 2. To build consensus across indicators using the Delphi Method, the following steps can be taken:

1. Compile a list of expert participants from the MCs. Experts must meet specified minimum qualifications that are determined in advance in order to be included. Often, experts have professional knowledge in the selected topic or are stakeholders in the topic because they live and/or work in the affected area (Melnyk et al., 2009), and have on-the-ground knowledge of the effects of the specified hazards or events.
2. Gather participants in a virtual setting to conduct the exercise. A virtual research space is conducive to maintaining the anonymity of participants. It may also encourage participation, because experts do not need to travel to a specific site, and they may complete the Delphi exercise questions within a specified time frame (often a week). Additionally, a larger number of experts may be queried if travel is not required (Donohoe, Stellefson and Tennant, 2012).
3. Clearly explain the purpose of the exercise (i.e. to select indicators needed to represent adaptive capacity in a vulnerability assessment to floods, droughts and storm events) and how the exercise will be completed (i.e. through multiple rounds of priority ranking and feedback solicitation).
4. Present the list of indicators in Table 4 and ask MCs to anonymously and individually rank variables by level of importance for adaptation to each of the three hazards.
5. Compile and summarize the results. If data are collected in a virtual research space, summarizing and reporting the results are relatively straightforward (Donahoe, Stellefson and Tennant, 2012).
6. Present the results to the group and provide an opportunity for participants to reflect on the results of the first round.
7. After presenting the ranked results, ask the group to anonymously and individually rank variables again.
8. Compile and summarize the results from the second round of ranking.
9. Present the results from the second round of ranking to the group and provide another opportunity for individual reflection.
10. Continue until there is progress made towards reaching a consensus on the most important monitoring parameters for each hazard.
11. When possible, narrow variables down to the top five parameters in each strategic indicator category and conduct the final round of ranking where instead of ranking the variables, participants will be asked to respond to each variable with one of three choices: include, exclude or unsure.
12. Compile the results and present the final framework, with at least one monitoring parameter from each strategic indicator represented.

4.4.2 Adaptive capacity calculation

After finalizing the adaptive capacity framework for each hazard, the data for each of the monitoring parameters can be gathered at the provincial level, even if a country has data at the district level. These monitoring parameter values are normalized using Equation 4 on a scale of 0–1, using the values for both men and women for the 12 gender-disaggregated parameters (i.e. normalization is not calculated separately for data associated with women and men). Normalization is performed for each MCindividually (i.e. within each country, there is a maximum value of 1 and minimum value of 0) if the underlying data differ. Parameters that negatively influence adaptive capacity are subtracted from 1 to obtain the correct relationship. To calculate a single score for each strategic and assessment indicator and the adaptive capacity index, each indicator can be normalized by all province values for that indicator. If there are national differences in the measurements of the monitoring parameters, each country is normalized separately. Equation 4 can be used to normalize each monitoring parameter.

After normalizing all indicators, a single score for each of the assessment indicators is calculated using the arithmetic mean shown in Equation 5, where n is the number of values and a_i is the data set value for the i^{th} province. The same equation can be used to calculate a value for each of the strategic indicators, by taking the mean of the assessment indicators within each group, and to calculate a single adaptive capacity score.

Equation 5: $$A_{mean} = \frac{1}{n}\sum_{i=1}^{n} a_i$$

This approach results in an equally weighted adaptive capacity index. Alternatively, weights could be added to specific monitoring parameters to indicate greater importance for adaptive capacity. Weights could be determined during the expert consultation ranking exercise but are not required.

Adaptive capacity data inputs for the MRC Technical Division

- National statistics data from the Member Countries, as specified in Table 5
- DAGAP data for the monitoring parameters that require gender disaggregated values
- All adaptive capacity data is at the province level.

4.4.3 Adaptive capacity example

Here, an example shows how to calculate adaptive capacity for one province. All of the monitoring parameters are listed in Table 4, although conducting the Delphi Method activity would narrow down this list. Ann example of the Delphi Method is not provided since it is an interactive activity involving participant discussion. Table 6 shows random numbers for the monitoring parameters and how they are used to calculate the assessment indicators. Each monitoring parameter value is normalized according to Equation 4 across all provinces within the same country, using data for both men and women, which results in values between 0 and 1. Table 7 shows how the normalized assessment indicators are in turn used to calculate the strategic indicators and adaptive capacity score. Calculating the strategic indicators and adaptive capacity scores is repeated for each MC and performed separately for both women and men. All numbers are random and do not represent values taken from national statistics.

Table 6. Monitoring parameter values for one province using randomly generated numbers

Assessment indicator	Monitoring parameter	A normalized monitoring parameter value	Calculation	Assessment indicator
Food security	Adequacy of dietary energy supply	0.87	(0.87 + (1 - 0.10) + (1 - 0.03)) / 3	0.91
	Prevalence of undernourishment	0.10		
	Prevalence of infant malnutrition	0.03		
Water security	Adequacy of domestic water supply	0.87	(0.87 + 0.73) / 2	0.80
	Sufficiency of water for farming	0.73		
Health security	Access to safe water supplies	0.68	(0.68 + (1 – 0.08) + 0.89 + (1 – 0.21) + (1 – 0.04)) / 5	0.85
	Prevalence of malnutrition	0.08		
	Access to sanitation	0.89		
	Incidence of water-borne disease	0.21		
	Maternal mortality	0.04		
Energy security (access to electricity)	Urban household electrification rate	0.95	(0.95 + 0.68) / 2	0.82
	Rural household electrification rate	0.68		
Employment in LMB water-related sectors	Proportion of working age population employed in LMB water-related sectors	0.44	NA	0.44
Economic security	Sufficiency of household income	0.71	(0.71 + 0.62 + 0.37 + 0.59) / 4	0.57
	Sufficiency of household assets	0.62		
	Gender income equality	0.37		
	Access to credit and bank account by gender	0.59		
Gender equality in employment, economic, and political engagement	Female-male ratio of water-related sector employment	0.38	(0.38 + 0.17 + (1 - 0.42) + 0.21) / 4	0.33
	Political participation by gender	0.17		
	Distribution of non-paid vs. paid labour by gender	0.42		
	Gender equality in ownership of land	0.21		
Learning opportunities	Literacy rate by gender	0.69	(0.69 + 0.75 + 0.91 + 0.77) / 4	0.78
	Occupational training by gender	0.75		
	Primary education enrolment by gender	0.91		
	Secondary education enrolment by gender	0.77		
Institutional response to the effects of climate change	Policies and strategies for climate change response	0.51	(0.51 + 0.34 + 0.19 + 0.22) / 4	0.31
	Budget for climate change response	0.34		
	Number of awareness-raising activities	0.19		
	Access to climate finance	0.22		

Assessment indicator	Monitoring parameter	A normalized monitoring parameter value	Calculation	Assessment indicator
Flood protection measures	Area of urban land protected by embankments/levees	0.87	(0.87 + 0.57) / 2	0.72
	Area of agricultural land protected by embankments	0.57		
Drought protection measures	Proportion of irrigable land that is irrigated	0.74	(0.74 + 0.24) / 2	0.49
	Volume of available water storage	0.24		

Notes: In this example, the values have already been normalized, using Equation 4, across all province values for that measurement in the same nation, but using data for both men and women. Monitoring parameters that negatively affect adaptive capacity are subtracted from one before calculating the assessment indicator. Calculations of assessment indicators are shown. These numbers do not represent national statistics but used for illustrative purposes only.
NA = Not applicable.

Table 7. A calculation of adaptive capacity and strategic indicator values

Strategic indicator	Assessment indicator	Assessment indicator	Calculation	Strategic indicator	Adaptive capacity
Living conditions and wellbeing	Food security	0.91	(0.91 + 0.80 + 0.85 + 0.82) / 4	0.84	(0.84 + 0.53 + 0.51) / 3 = 0.63
	Water security	0.80			
	Health security	0.85			
	Energy security (access to electricity)	0.82			
Strategic indicator	**Assessment indicator**	**Assessment indicator**	**Calculation**	**Strategic indicator**	**Adaptive capacity**
Livelihoods, employment and education	Employment in LMB water-related sectors	0.44	(0.44 + 0.57 + 0.33 + 0.78) / 4	0.53	
	Economic security	0.57			
	Gender equality in employment, economic, and political engagement	0.33			
	Learning opportunities	0.78			
Infrastructure and institutions (adaptation to climate change)	Institutional response to the effects of climate change	0.31	(0.31 + 0.72 + 0.49) / 3	0.51	
	Flood protection measures	0.72			
	Drought protection measures	0.49			

Notes: The strategic indicator is the arithmetic mean of the assessment indicators. Weights can be given to the assessment indicators during the Delphi Method activity. Adaptive capacity is the arithmetic mean of the strategic indicators. The strategic indicator values were drawn from the assessment indicator values in Table 6.

4.5 Vulnerability

Vulnerability is specific to the type of natural hazard and is calculated from exposure, sensitivity and adaptive capacity using Equation 6. Exposure and sensitivity must first be rescaled from the 1-km grid to the provincial level before they can be combined with adaptive capacity. To rescale, the mean exposure or sensitivity score is calculated for all grid cells that fall within a province (also known as a zonal statistics operation). Finding the mean score per province for exposure and sensitivity will result in polygon feature classes with values ranging from 0 to 1. Using Equation 6, they can be combined with the adaptive capacity score to calculate vulnerability.

Equation 6:

$$Vulnerability = \frac{\text{Exposure x Sensitivity}}{\text{Adaptive Capacity}}$$

Finally, quantiles are used to develop qualitative breaks for the vulnerability score (i.e. low, medium or high vulnerability). The vulnerability score and its components can be calculated for multiple years to examine trends over time. However, if it is desired to compare scores between years, the indicator maximum and minimum values used to normalize each indicator (e.g. maternal mortality, population size) must be taken from the entire period of record. Therefore, the x_{min} and x_{max} values from Equation 4 are not calculated individually per year, but over all the years that are used to calculate vulnerability and measure the trend. If x_{min} and x_{max} are taken from single years, then the vulnerability scores (as well as exposure, sensitivity and adaptive capacity scores), can only be compared within that year.

4.5.1 Vulnerability example

Building on the exposure, sensitivity and adaptive capacity examples, we created an example of vulnerability to drought for two provinces. Figure 13 uses the same 3 x 3 grid as the previous examples but calculates each component at the provincial level by taking the average of the cells within the province polygon. For adaptive capacity, the example values calculated in Table 7 are used for the upper polygon, and a random value is used for the lower one. Equation 6 is used to calculate the vulnerability to drought scores in Figure 13(D). Here, only one set of scores for each province is shown, which indicates they only represent values for one gender. However, to measure gender equality, adaptive capacity scores are calculated for men and women separately and then compared.

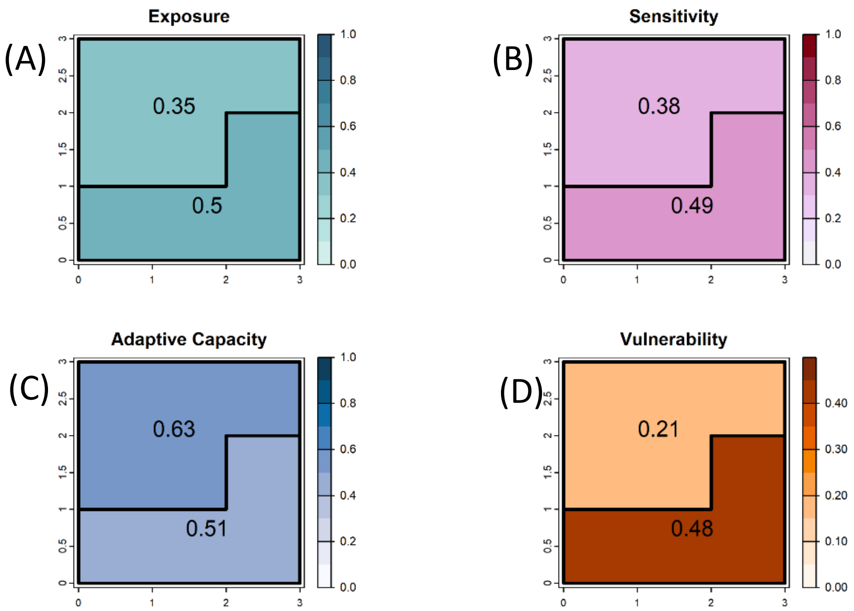

Figure 13. Example of vulnerability to drought for one gender

Note: Calculations use an example of two provinces in the same country within the 3 x 3 grid. For each province, the mean is calculated from the cells within the polygon for both drought exposure (A) and sensitivity (B). See Figures 7 and 11 for examples of how these components were calculated. For adaptive capacity in (C), the value of 0.63, which is calculated in Table 7, is used in the upper polygon. The lower polygon represents another province within the same country and shows a random number for illustrative purposes only. Finally, vulnerability to drought (D) is calculated using Equation 6.

5 Challenges and limitations

Because most currently available MC data for the adaptive capacity indicators are not uniform (e.g. each country may measure access to sanitation using different metrics appropriate to the national context), the assessment outlined here normalizes adaptive capacity within each country individually. As a result, the vulnerability index cannot be directly compared across countries. If both Kampot, Cambodia, and An Giang, Viet Nam have a vulnerability score of 1.25, these provinces cannot be interpreted as equally vulnerable. Instead, the province vulnerability scores can be compared directly to other provinces in the same nation. If there is a need to compare the vulnerability index regionally across provinces in different countries in the LMB, the parameters must be derived from the exact same metric collected in each nation (e.g. the metrics in the "Data Items" column in Table 5 would need to be the same across all the MCs).

Additionally, because the index is relative, a province with a vulnerability score of 2.0 cannot be said to be twice as vulnerable as a province with a score of 1.0. Instead, it can be interpreted in relative terms. For example, in Figure 13, although the vulnerability score is around 2.3 times higher in the lower province than the upper province, this does not signify that the province is 2.3 times more vulnerable; rather, relative terms can be used, and lower province may be more vulnerable than the upper province due to higher exposure and lower adaptive capacity. Relative indices still provide useful and actionable information. Summary statements about vulnerability across the LMB region could briefly discuss the five most vulnerable provinces within each country and compare them to each other and to the five least vulnerable provinces within each country. Similarities and differences in the exposure, sensitivity and adaptive capacity indices comprising these scores could be examined and used for decision-making.

6 Moving forward and conclusions

The MRC SoBRs rely on the Mekong River Basin Indicator Framework structured around five dimensions (environment, social, economic, climate change and cooperation) to assess performance across the 15 strategic indicators related to development and management conditions within the Mekong Basin. Underpinning these strategic indicators are 55 assessment indicators and 120 monitoring parameters, which will be addressed in the 2023 SoBR. The 2018 SoBR noted many gaps in data availability, especially in the social and economic dimensions. These gaps made it impossible to analyse key questions as part of the SoBR process. The DAGAP was approved by the MCs in 2021 as a means to identify data gaps and set up a process for data acquisition.

Currently, each MC is collecting social and economic data to meet the DAGAP requirements. Data are expected to be disaggregated by gender and by urban and rural households in the social dimension. The socio-economic data requirements were collected and transmitted to MRCS in the first quarter of 2023, with subsequent delivery to the MRC every five years. This is an ambitious undertaking, and the MRC recognizes that this is a long-term process; data gaps are likely to remain despite these efforts.

As acknowledged by the MRCS and the MCs, data availability for the draft 2023 SoBR improved over the 2018 SoBR, which had insufficient socio-economic data. This improvement was a result of the data collection within the DAGAP. However, there are remaining data gaps identified for social and economic dimensions for the SoBR 2023, including gender-disaggregated data. This reflects the need to make some changes to the current national survey data collection and processing mechanisms in the MCs to incorporate the additional disaggregated data requirements in their routine data collection. These will be critical inputs for the MRC's socio-economic data collection every five years, including the next round of data collection in 2027 in preparation for the 2028 SoBR.

In reference to the socio-economic data gaps identified and the proposed list of G&V data requirements for the G&V Assessment, the MRCS plans to work with the MCs to collect additional socio economic and G&V data. After the socio-economic and G&V data requirements are collected by the MRC, the next step is to compile the input data necessary for the exposure, sensitivity and adaptive capacity components described in this report. Text boxes are inserted through this report stating the data requirements from the MRC Technical Division for each component. Moreover, there are two exercises to be conducted through virtual meetings with representatives from the MRC MCs. The first is described in section *4.3.1. Land cover* and in Table 2; the second is the Delphi Method outlined in section *4.4.1. The Delphi Method*. Once these data have been compiled and the exercises conducted, the vulnerability assessment can be calculated. Examples were provided for each calculation, outlining and demonstrating the methods described for calculating each vulnerability component.

The provincial-scale vulnerability index outlined here could assist the MRC in understanding the degree to which the LMB population could be affected by hazards such as droughts, floods, and storm events, and how these effects could differ across gender. The MRC MCs can use the index values to examine which provinces may be more vulnerable to hazards and to inform policy recommendations. Each component of the vulnerability framework (exposure, sensitivity and adaptive capacity) can be examined to understand vulnerability at a finer scale.

For provinces with different vulnerability scores, MRC stakeholders can examine each vulnerability component to find causes of high vs. low vulnerability, and can ask the following questions:

- Is high vulnerability for a given province caused by high exposure (e.g. spatially extensive or severe flooding) or by high sensitivity (high population numbers where many people are affected by the hazard)? Are there ways to help reduce vulnerability?
- Is low vulnerability for a given province caused by high values of the adaptive capacity component, and if so, which values? Is it caused by high economic security, high gender equality and/or gender equity, high flood/drought protection measures, or something else? Do the low vulnerability scores suggest effective mitigation or adaptation strategies for more vulnerable provinces?
- Are coastal regions more vulnerable than inland regions, as might be expected with a changing climate and rising sea levels?
- How do gender equality and gender equity vary across provinces, and which monitoring parameters contribute to the variation? Do the data suggest ways that greater equality and gender equity could be achieved?

Conducting the gender and vulnerability assessment described in this report can help MRC achieve their goal of assessing vulnerability and gender equality across the LMB. If time and budget allow, the MRC could conduct and prepare the gender and social vulnerability assessment in 2024, which aims to outline how G&V considerations including equity for vulnerable groups, may be incorporated into the MRC's regional plans, procedures, guidelines and reports such as the MRC SP 2025–2030, SoBR 2028 and other MRC key documents, which will be developed and designed for sensitivity and the inclusion of women and socially vulnerable populations.

This report describes how vulnerability specifically to floods, droughts and extreme storm events are calculated. In addition, the elements of the vulnerability framework (exposure, sensitivity and adaptive capacity) could be applied to other situations in the Mekong River Basin, such as for the development of water resources. Because vulnerability analyses are specific to a threat or exposure, additional data collection would be required.

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Annex

Table I. Comparison of indicators used in three reference vulnerability assessments and example assessment in this report

Component	Nguyen et al., 2019 Indicators	Mohanty and Wadhawan, 2021 Indicators	Can et al., 2019 Indicators	Example assessments in this report*
Hazard/ exposure	Typhoon pressure Typhoon frequency Precipitation Coastal flood risk Proximity to typhoon tracks Slope Elevation	Floods Drought Storms surges and convective storms	N/A (considers flood risk)	Floods Drought Storms
Sensitivity/ Potential impacts	Land use/land cover Proximity to coastline Proximity to airports Proximity to tourist sites Proximity to hotels Proximity to power stations Proximity to a transportation network Population density	Land use/land cover Elevation Slope Groundwater Soil moisture	Population Female ratio Children ratio Elderly ratio Poverty rate Literacy rate Income Environmental state Stability of riverbank Domestic water Disease outbreak Ecosystem	Land use/land cover Population density Proximity to coastline
Adaptive capacity/ response and prevention capacity	Mangrove protection Proximity to a health centre Local response ability Education level Income Housing condition	District disaster management plans Gross district domestic product Literacy rate Sex ratio Availability and accessibility to critical infrastructure Availability of disaster-ready shelters Population density	Experience of flood prevention Ability of flood prevention Rescue ability Flood forecast Government support Communication Public works Transportation Irrigation Disease prevention	Water security Food security Health security Energy security Employment in water-related sectors Economic security Gender equality in employment Learning opportunities Institutional response Flood protection

	Education recovery Self-cleaning environment	Drought protection
Benefits	Increased seafood quantity Increased alum cleaning Increased silt quantity Freshwater supplementary	

Note: See Table 4 for more details about indicators for this report.

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