MEKONG RIVER COMMISSION

THE COUNCIL STUDY
Cumulative Impact Assessment of Water Resource Development Scenarios

Cumulative Impact Assessment
Key Findings Report

Prepared by: The Council Study Core Team

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Executive summary

Introduction

Cumulative assessments provide a big picture understanding and become meaningful where disciplinary assessment indicators lead to conflicting recommendations. In these situations, some disciplines highlight development gains while others report losses, which triggers policy makers and planners to request a synthesising view. The Council Study included hydraulic and hydrological, ecological, socioeconomic and macroeconomic assessments, which are accompanied by a set of sector-focused assessments. Each disciplinary and thematic assessment comes with its own set of indicators, and some of these assessment indicators suggest that the development investments considered in 2020 and 2040 development plans are likely to lead to positive outcomes while other indicators highlight negative consequences. This cumulative assessment (CIA) aims to provide an additional integrating layer. It explicitly does not aim to replace the results provided by the other assessment reports. Many of the provided assessment reports include indicators that are critical to decision making. These should be considered side-by-side with the cumulative assessment indicators provided in this report.

This cumulative impact assessment combines ***three main concepts***. First, it applies a ***resilience and vulnerability*** perspective to derive the *combined effect* of positive and negative implications identified by the disciplinary and thematic reports. The resilience analysis combines core factors (e.g. food and income security) with both mitigating and amplifying dynamics from the natural, social, and macroeconomic environments. Second, a ***sustainability*** index was developed for the CIA based on the UN Sustainable Development Goals (SDGs). This implies testing indicators from the UN level in the Mekong context. This index combines the social, environmental and economic dimension of the MRC Indicator Framework. The founding principles for the MRC's water diplomacy emphasise sustainability as one of the two core values for Lower Mekong Basin (LMB) development. Therefore, it seems paramount to synthesise all assessment results through a sustainability lens. The third assessment perspective implemented by the CIA was focused on sectoral and transboundary ***trade-offs***, which the *Cooperation Dimension* in the *MRC indicator Framework*. This perspective addresses the MRC's second founding principle, the goal of *balanced development*, in the case of the CIA, balanced across sectors and countries.

The Council Study involved a prolonged design phase, which defined a set of four main development scenarios. The main scenarios define a combination of investments in multiple sectors, in particular in hydropower, agriculture and irrigation, flood protection, and navigation. Thus, assessments of these main scenarios highlight the *combined effect* of the proposed development plans. The first main scenario (M1) assumes the prevalence of the development situation of 2007. The second main scenario (M2) assumes investments as planned for 2020, and the third main scenario (M3) combines investment projects that are considered in plans for 2040. A fourth main scenario (M3CC) includes projected climate change applied to the 2040 development scenario.

The combined assessment of large investment bundles, as defined by the main scenarios, provides a variant of cumulative assessment, that although revealing synergetic effects, limits the attribution of impacts to sector-specific investments. In order to reveal sector-specific impacts, a set of sub-scenarios were introduced that assume the potential development situation of 2040 with climate change, but remove one-by-one sector-specific investments. For instance, sub-scenario H1a removes hydropower investment while all other sector developments remain as planned for 2040 (M3CC). Sub-scenario H1b removes only mainstream dams and realises all tributary dams. Sub-scenario A1 removes all land use change and agricultural expansion, sub-scenario Irr1 removes all irrigation projects, and F1 removes all flood protection projects. The sequential removal of sector investments from the 2040 development plan enabled a more precise quantification of sector-specific impacts. Additional sub-scenarios make other variations, which is explained further below. Two sub-scenarios acknowledge the high uncertainty of climate change projections and assume alternative climate change paths.

Vulnerability and resilience-related impacts

The main scenario results suggest a deterioration of resilience in several zones of the Lower Mekong Basin, particularly in Lao PDR and Cambodia, as food security declines and income security does not improve proportionately. This would disadvantage poor population segments without subsistence production, in particular the urban poor and landless people. Amelioration would require a range of investments to reduce undesirable social developments and promote distributional fairness. These household-level changes in food and income security are likely to be amplified by deteriorating ecosystems and sub-optimal macroeconomic processes. If climate change turns out to be drier than currently assumed, vulnerability is likely to increase substantially for the 2040 development plan.

The combination of sub-scenarios indicates that adjusting investments in hydropower and agriculture is likely to provide substantial resilience improvements if compared with M3CC. The erosion of mainstream river banks is likely to introduce substantial costs due to hydropower development, further increasing vulnerabilities. Flood peaks are projected to increase. However, flood protection plans are likely to mitigate damages from most floods. Extreme events (1:100 year flood events) would remain and, given the development gains and the increasing exposure of assets, damages were predicted to be extensive.

Sustainability effects

The design and quantification of sustainability indices has remained a research challenge for more than three decades. The fact that sustainability integrates a wide range of metrics and perspectives means that most stakeholders are disappointed with the final product, as highly critical dimensions are merged, crucial information is lost, and the results are often rendered as meaningless. Therefore, it is paramount to consider the results of the CIA sustainability assessment *in addition* to the critical outcomes highlighted by the disciplinary and thematic assessments. The sustainability index is *not intended to replace* these highly critical issues.

Another important issue is that the design of this sustainability index, explained in detail in the main text, involved a participatory process with the MRC Member Countries and is intended to operate in the future as a step towards implementing the SDGs in the Lower Mekong Basin. The selection of SDGs was largely constrained by the initial design of the Council Study. However, the combination of the first set of sub-indicators drawn from the socioeconomic, the BioRA, and the macroeconomic assessments shows that the main scenarios M2 (2020) and M3 (2040) are likely to result in sustainability losses. For most countries the main scenario M2 is likely to cause larger losses than M3.

The 2040 development scenario M3 would result in declining sustainability (Vietnam: -31%; Cambodia: -29%; Lao PDR: -27%; Thailand: -17%). Hydropower developments and operation cause most of this decline, followed by agricultural expansion.

The sub-scenario perspective reveals that selection of fewer, highly beneficial hydropower projects, and adding effective mitigation measures, could restore large parts of the sustainability losses and potentially lead to sustainability gains. The agricultural sub-scenarios emphasise that sustainability is not likely to be achieved by implementing extensive agricultural expansion plans as currently proposed.

Ideally, the sustainability index would be based on a larger number of indicators, which was not possible because of the implementation process of the council study. The most effective process would have defined the sustainability index upfront and then specified disciplinary assessment criteria. Therefore, the absolute values of the current sustainability index are secondary while the ordinal comparison between scenarios is more robust (and unlikely to change after adding more indicators).

Transboundary and sector trade-offs

The disciplinary assessment reports of this Council Study highlight a variety of policy-relevant transboundary impacts. These include the following:

- Substantial reduction of fish stocks due to hydropower dams, which involves
    - the elimination of white fish in large parts of the Mekong,
    - a surge of exotic and generalist fish species, and
    - an extensive deterioration of the overall ecosystem integrity;
- Substantial reductions of sediment, which is likely to cause extensive erosion in all zones in the lower Mekong basin, in particular the Mekong Delta;
- Considerable changes of hydrological flow;
- Food security reductions, increasing undernourishment in the poor population segments in multiple areas, which results from a combination of declining fish catch and increasing food prices;
- Substantial economic profit transfers due to foreign direct investment in hydropower projects.

This assessment highlights that the majority of transboundary impacts results from cross-sector trade-offs. Building on macroeconomic, socioeconomic and BioRA assessment results, the most critical cross-sector effects can be mapped into the transboundary context, involving the following:

- Hydropower would trigger the largest transboundary effects.
- Transboundary effects emerging from hydropower investments fall into three main categories:
    - Positive transboundary effects from Lao PDR to Thailand and from Cambodia to Vietnam, resulting from returns on investments in hydropower projects
    - Negative transboundary impacts due to fish losses (LMB-wide: $21.7 billion), which confronts Cambodia with the highest hydropower-fisheries trade-off (58% for M3CC)

- o Negative transboundary effects due to the erosion of river banks, which would require a combined investment of $6.8 billion
- Thailand shows substantial hydropower-fisheries trade-offs as most of its fisheries sector is likely to disappear under the 2040 development scenario.
- Cambodia would face substantial macroeconomic trade-offs (between agriculture and other sectors) due to workforce requirements in agriculture for 2020 and 2040 scenarios.

This study highlights the relevance of the trade-off between hydropower and fisheries. This underpinning assessment includes the expansion of fisheries due to reservoirs, but does not include expansion of aquaculture as a likely livelihood adaptation in response to increasing fish prices.

These transboundary effects can be corrected by benefit-sharing and cost-sharing mechanisms. However, benefit-sharing schemes involve complex socioeconomic interactions (e.g. migration, price changes; see Section 3.4) experienced in many development situations after implementing incentive changes similar to benefit sharing. The reported effects highlight the need to employ more sophisticated analytical methods than used in this study.

Against the CIA backdrop, it is critical to emphasise that the results provided here should be considered cautiously and not interpreted as definitive single point predictions. The CIA is focused on the most critical trade-off between hydropower and fisheries and considers the aforementioned facets of the transboundary trade-off as a set of draft "in-principle" benefit sharing mechanisms. The mechanisms and instruments could be designed involving a levy on hydropower, which could be estimated at up to 18.9% on annual profits from mainstream hydropower and 8.6% for tributary hydropower. However, as explained in more detail in Section 3.4, the calculations require analysis of a variety of interaction dynamics; the development of sufficiently robust estimates will require application of appropriate socioeconomic simulation models. Most importantly, benefit sharing would need to be implemented as a cross-sector compensation between hydropower and fisheries, independent from national boundaries, and not necessarily as compensation between countries.

A benefit-sharing mechanism for hydropower-related erosion could be implemented as cross-country instruments as river embankments protection are typically funded by governments as public investments. A levy of 1.20% on annual profits from mainstream dams and 1.12% for tributary dams would compensate effects. This excludes erosion caused by hydropower in the Lancang (effect: $1.98 billion annually). Combining erosion and fisheries-focused levies results in 9.76% on annual profits from tributary dams and 20.1% on annual profits from mainstream dams.

Key messages and policy implications

The CIA integrated the results and insights from the other Council Study disciplinary and thematic assessments, but does not replace them. The integration echoes many issues raised by other assessments:

- Development plans include a few highly beneficial hydropower and agriculture projects.
- However, the combined development plans for 2020 and 2040 are likely to trigger a decline in resilience, vulnerability, and sustainability of communities in the Lower Mekong Basin.

- Poor households are likely to be most disadvantaged. The urban poor are likely to face considerable challenges as food prices are likely to increase.
- Overall sustainability effects of the development strategies as defined by the main scenarios would cause substantial sustainability losses, which could be avoided or even reversed by adjusting investment levels in hydropower and agriculture.
- Projected climate variation in several years of the 24-year projected time horizon, combined with the loss of fish-based protein, is likely to create conditions of acute levels of food insecurity in communities in Lao PDR and Cambodia.
- The emerging trade-offs between hydropower and fisheries are substantial and suggest a project-by-project assessment to identify the most harmful and the most beneficial projects.
- Transboundary effects would be significant, combining (a) positive effects for Thailand and Vietnam as return on investments from hydropower in Lao PDR and Cambodia, and (b) negative effects due to losses in fisheries and river sediments.
- Benefit-sharing mechanisms would need to be designed considering important socioeconomic interactions. A hydropower-fisheries focused levy would amount to 18.9% on annual profits from mainstream dams and 8.6% for tributary dams.
- Hydropower is predicted to cause erosion, requiring $6.8 billion for riverbank re-enforcements. A cost-sharing levy amounts to 1.20% of mainstream annual dam profits and 1.12% for tributary dams.

An emerging recommendation is that the large bundles of investment projects considered in this study need to be assessed on a project-by-project basis to identify sustainable development pathways. Sub-scenarios suggest that hydropower and agriculture investments are likely to have the largest impacts and appear to combine both highly beneficial and highly unsustainable projects. A disaggregated assessment would require more robust assessment methods that adequately integrate socioeconomic and biophysical interactions.

Contents

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Abbreviations and acronyms

AIP	:	Agriculture and Irrigation Programme (of the MRC)
BDP	:	Basin Development Plan
BDP2	:	BDP Programme, phase 2 (2006 –10)
BDS	:	(IWRM-based) Basin Development Strategy
BioRA	:	Biological resource assessment team (under Council Study)
CCAI	:	Climate Change and Adaptation Initiative (of the MRC)
DMP	:	Drought Management Programme (of the MRC)
EP	:	Environment Programme (of the MRC)
FMMP	:	Flood Mitigation and Management Programme (of the MRC)
FP	:	Fisheries Programme (of the MRC)
IKMP	:	Information and Knowledge Management Programme (of the MRC)
IWRM	:	Integrated Water Resources Management
ISH	:	Initiative for Sustainable Hydropower (of the MRC)
JC	:	Joint Committee (of the MRC)
LMB	:	Lower Mekong Basin
LNMC	:	Lao National Mekong Committee
M&E	:	Monitoring and evaluation
MIWRMP	:	Mekong Integrated Water Resources Management Project (of the MRC)
MRC	:	Mekong River Commission
MRCS	:	Mekong River Commission Secretariat
MRC-SP	:	MRC Strategic Plan
MWRAS	:	Mekong regional water resources assistance strategy (of the World Bank)
NIP	:	National Indicative Plan (C-NIP: Cambodia, L-NIP: Lao PDR, T-NIP: Thailand, V-NIP Viet Nam)
NMC	:	National Mekong Committee
NMCS	:	National Mekong Committee Secretariat
NAP	:	Navigation Programme (of the MRC)
PMFM	:	Procedures for Maintenance of Flow on the Mainstream
PWUM	:	Procedures for Water Use Monitoring
RDA	:	Regional distribution analysis
TCU	:	Technical Coordination Unit (of the MRCS)
TNMC	:	Thai National Mekong Committee
TRG	:	Technical Review Group (of the MRC)
UMB	:	Upper Mekong Basin
VNMC	:	Viet Nam National Mekong Committee

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1 Introduction

1.1 Purpose of this report

The purpose of this report is to present the key findings of the cumulative impact assessment (CIA). The CIA integrates the findings of the social, economic, and environmental assessments to identify the key impacts and benefits of selected water resources developments. Recommendations are made on measures or strategies to avoid or mitigate the most significant negative impacts.

The findings of the assessment are presented in three ways. First, as a qualitative assessment that structures the synthesis of all other assessments of the Council Study according to a resilience and vulnerability framework. The synthesis addressed the resilience and vulnerability of people and people's livelihoods. The synthesis also considered the Council Study economic and environmental assessment results. Second, a set of derived quantitative indicators, which provide the indices for three key concepts of the MRC: sustainability, cross-sector balance, and transboundary consequences. The indices combined scenario outcomes across six thematic domains: agriculture and land-use; irrigation; flood protection; hydropower; navigation; and industrial and urban water use. In all cases an effort was made to separate the effects of water resources development from other exogenous processes.

1.2 Report contents

The Council Study organisation, overall objectives, the responsibilities of other study components, and the overall scope of the CIA called for under the Council Study are described in Chapter 2. A definition of all the main development and sub-scenarios, and the background for the methodology developed for the cumulative impact assessment, are also detailed.

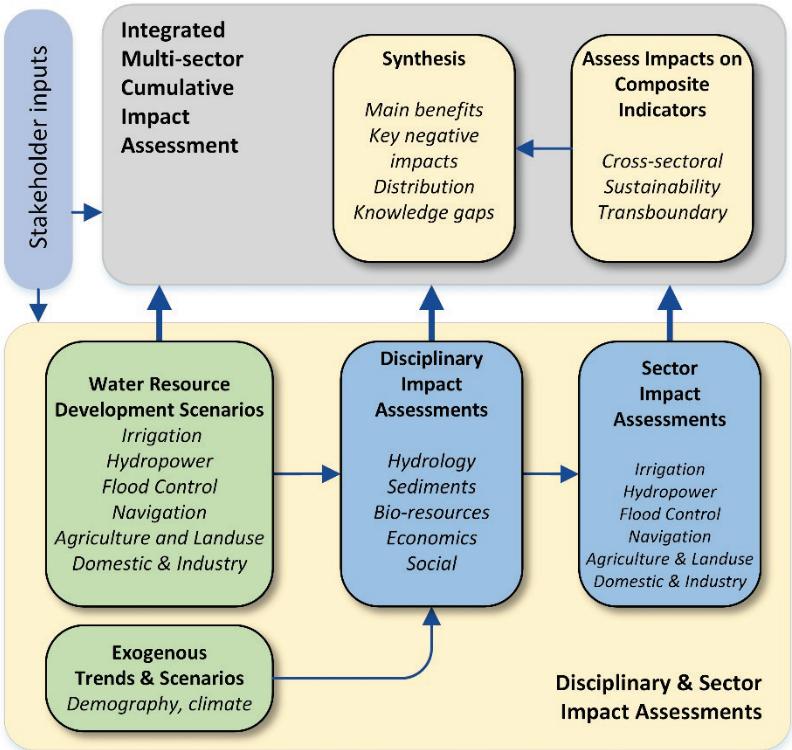
A description of the analyses and the main results for the three assessment dimensions, i.e. resilience and vulnerability, sustainability, and cross-sector and transboundary trade-offs, are detailed in Chapter 3. The results compare the main scenarios M2 (2020) and M3 (2040) with the M1 (2007) baseline to assess the combined impact of investments across hydropower, agriculture and irrigation, flood protection, and navigation. The results are also detailed for the combination of the main scenario M3CC (2040) with more seasonal climate change and all sub-scenarios, which includes the removal of sector investments from the M3CC development strategy and additional sector-focused investment variations. The sub-scenario–based assessment enables sector-specific contributions in the 2040 development outcome to be more accurately identified, which is a critical step towards designing a sustainable development pathway for the Lower Mekong Basin.

2 Design of the assessment

2.1 Assessment components & process

The Council Study consists of six thematic teams and five disciplinary teams. The thematic teams were mainly responsible to guide the design of the scenarios (see Section 2.2). Disciplinary teams applied their assessment methodologies to the scenarios to develop projections across a 24-year horizon to quantify the impacts of the defined development interventions on their respective indicators. Disciplinary impact assessment results were then handed over to the thematic teams to combine disciplinary results into a sector-specific synthesis. Disciplinary results were concurrently provided to the CIA. The components and connections of the Council Study are summarized in Figure 1.

Figure 1 Overview of the cumulative impact assessment process and its relationship to disciplinary and thematic sector assessments



Several steps involved a truly participatory approach that gave MRC Member Countries the opportunity to specify detailed indicators and assumptions. For instance, during the CIA, Member Countries selected from the generic list of indicators for SDGs a subset that they felt are the most meaningful in the context of water-related infrastructure investments. Similarly, Member Countries specified weights in the livelihoods and well-being indicator, which is a core element of the socioeconomic assessment. Another aspect of the participatory process was a series of regular workshops, which provided Member Countries the opportunity to understand, criticise, and approve assessment methodologies and input data. They also specified the list of assessment indicators the various teams need to report on as well as the scenarios during the design phase of the Council Study. The details and comparisons of the Council Study Development Scenarios are described in the next Section.

2.2 Scenarios

2.2.1 Main development scenarios

The macroeconomic assessment focused on the three main water resources development scenarios:

(i) Early Development Scenario (2007);
(ii) Definite Future Scenario (2020); and
(iii) Planned Development Scenario (2040).

Each formulated scenario has a basin-wide scope and is composed of developments in each of the six thematic areas. These developments were introduced as composite changes to an assumed *reference period*, which is defined by a 24-year time series from 1985–2008 of hydro-meteorological data (rainfall, evaporation, boundary water levels, etc.) broadly representative of historic natural flow conditions of the Mekong River. The historical period was calibrated using a range of *exogenous drivers* that are not directly linked to the water infrastructure investments in the scenarios, but have substantial influence on livelihoods, sustainability, and social, economic and ecological conditions. Trends were statistically estimated for these exogenous drivers, which include population growth for each of the Member Countries at the level of the LMB. The combination of past hydro-meteorological data (or patterns) and predicted trends of exogenous drivers define the M1 2020 *baseline*.

→ Early Development Scenario (2007) – Scenario M1

The main purpose of the scenario is to assess the distribution of the benefits, costs, impacts, and risks of water resources development in the Mekong Basin as of 2007. The scenario defines the state of water infrastructure development as it was in the year 2007 when the flow regime of the Mekong mainstream was considered to be still in a natural state, except the influence of Chinese dam impoundments in the Upper Mekong or Lancang River. The scenario includes the infrastructure and land use/cover changes in in the six thematic areas as of 2007. In addition to modelling with the Decision Support Framework (DSF), the impact assessment of the early development scenario was based on existing observations, studies, and assessments of historical changes in land use, development of (irrigated) agriculture, flood control structures, wetland areas and biodiversity, capture fisheries, livelihood and well-being indicators. The assessment results allowed the Member Countries to consider whether the benefits, impacts, and risks of new water resources development are reasonable and equitable.

→ Definite Future Scenario (2020) – Scenario M2

The main purpose of this scenario was to assess the distribution of the benefits, costs, impacts, and risks of water resources development in the Mekong Basin as predicted in 2020. The scenario includes all existing (before and after 2007), under-construction, and firmly committed development in the six thematic areas which are expected to be in place by 2020. The impacts (positive and negative) of this scenario are inevitable (but negative impacts can be mitigated).

→ Planned Development Scenario (2040) – Scenario M3

The main purpose of the scenario was to assess the distribution of the benefits, costs, impacts, and risks of water resources development in the Mekong Basin as of 2040. In addition to the development in the Definite Future Scenario, the Planned Development Scenario includes all water resources development that is planned in the six thematic areas in the Mekong Basin. On a timescale, the scenario covers the water resources development that would be in place by 2040 if these plans were fully implemented.

2.2.2 Development sub-scenarios

In order to respond rigorously to key policy questions arising from the stated objectives and assessment requirements of the Inception Report additional sub-scenarios have been developed.

Impacts of climate change

Three sub-scenarios for 2040 were developed to explore the interactions between water resource development and changes in climate (Table 1). Comparisons between scenarios M3 and C2 for instance measure the effect of water resources development at the level of 2040 under a climate that is even wetter than mean projections. The sub-scenarios which assume climate changes (M3CC, C2, and C3) are derived from statistical downscaling of the outputs of a set of global circulation models driven with assumptions of intermediate levels of greenhouse gas emissions (RCP4.5) and using these estimates to adjust the reference 1985–2008 climate.

Table 1 Climate change sub-scenarios for analysis CIA

	Sub-scenarios	Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3	Planned Development Scenario 2040 No climate change	2040	2040	2040	2040	2040	2040	1985-2008	2040
M3CC	Planned Development 2040	2040	2040	2040	2040	2040	2040	Mean warmer & wetter	2040
C2	Planned Development 2040 + Wetter Climate	2040	2040	2040	2040	2040	2040	Wetter	2040
C3	Planned Development 2040 + Drier Climate	2040	2040	2040	2040	2040	2040	Drier	2040

Impacts of individual sectors

To evaluate and report on the impacts and benefits of water resources development in each sector as requested in the Inception Report it was necessary to analyse the contributions made by each sector. The best study design for doing this was to compare the main scenario with all sectors developed with a sub-scenario having the entire set of developments minus those in the target sector. In the following sections these comparisons are tabled for each sector.

→ Agricultural land-use sub-scenarios

To address the key policy goal in the Inception Report of reporting on the impacts and benefits of agriculture and land-use development, comparisons were made between main scenario M3CC and sub-scenario A1 (Table 2). An alternative scenario with more land-use changes (A2) was also compared with M3/C1 or A1.

Table 2 Sub-scenario to better understand impacts of different assumptions about future agricultural land use

Scenario		Level of Development for water-related sectors[1]						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	Mean warmer & wetter	2040
A1	Planned Development 2040 without ALU	**2007**	2040	2040	2040	2040	2040	Mean warmer & wetter	2040
A2	High level ALU implementation	**HIGH**	2040	2040	2040	2040	2040	Mean warmer & wetter	2040

→ Flood protection sub-scenarios

To assess the positive and negative impacts of flood protection infrastructure, comparisons will be made between main scenario M3CC and sub-scenario F1 (Table 3). Two other alternative flood protection strategies (F2 and F3) will also be compared with F1 or M3/C1.

Table 3 Sub-scenarios to better understand impacts of different assumptions about future flood protection investments

Scenario and sub-scenarios		Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3 CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	Mean warmer & wetter	2040
F1	Planned Development 2040 without FPF	2040	2040	**2007**	2040	2040	2040	Mean warmer & wetter	2040
F2	Planned Development 2040 with FP2	2040	2040	FPF2	2040	2040	2040	Mean warmer & wetter	2040
F3	Planned Development 2040 with FPF3	2040	2040	FPF3	2040	2040	2040	Mean warmer & wetter	2040

→ Irrigation sub-scenarios

To assess the positive and negative impacts of irrigation infrastructure overall, comparisons were made between main scenario M3CC and sub-scenario I1 (Table 4). Another sub-scenario with even more irrigation infrastructure (I2) was also compared with I1 or M3.

Table 4 Sub-scenarios to test the effects of water resources development in the irrigation sector

Scenario and sub-scenarios		Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3 CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	Mean warmer wetter	2040
I1	Planned Development 2040 without IRR	2040	2040	2040	2040	**2007**	2040	Mean warmer wetter	2040
I2	Planned Development 2040 with IRR HIGH	2040	2040	2040	2040	**HIGH**	2040	Mean warmer wetter	2040

→ Hydropower sub-scenarios

To assess the positive and negative impacts of hydropower development, comparisons were made between main scenario M3CC and sub-scenario H1 (Table 5). Two other alternative flood protection strategies (H2 and H3) were also be compared with H1 or M3/C1.

Table 5 Sub-scenarios to test the effects of water resources development in the hydropower thematic sector

Scenario and sub-scenarios		Level of Development for water-related sectors						Climate	Flood-plain
		ALU	DIW	FPF	HPP	IRR	NAV		
M3 CC	Planned Development Scenario 2040 with climate change	2040	2040	2040	2040	2040	2040	Mean warmer & wetter	2040
H1a	Planned Development 2040 without HPP	2040	2040	2040	**2007**	2040	2040	Mean warmer & wetter	2040
H1b	Planned Development 2040 without mainstream HPP	2040	2040	2040	**Only tributary 2040**	2040	2040	Mean warmer & wetter	2040
H3	Planned Development 2040 with HPP mitigation investments	2040	2040	2040	**2040**	2040	2040	Mean warmer & wetter	2040

2.3 Assessment methods & strategic indicators

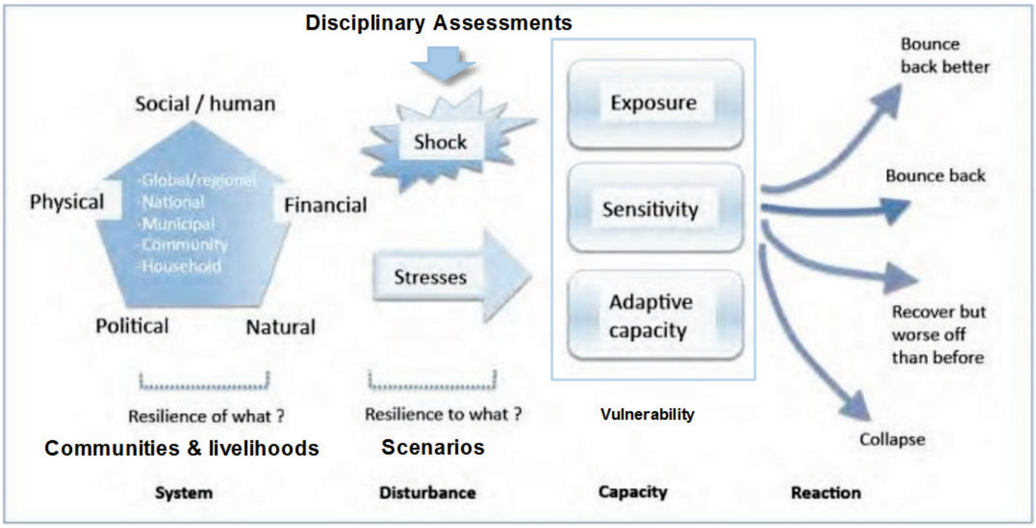
The cumulative assessment is divided into two parts. The first part aims to synthesise all findings across disciplines and sectors in the context of the resilience of the people living in the Mekong Basin. Impacts on their livelihoods will be a critical dimension, which involves economic and environmental changes. The second part aims to quantify impacts in form of three indicators that are at the core of MRC agreements and, therefore, part of the Inception Report of the Council Study .

2.3.1 Resilience and vulnerability-focused synthesis

This step provides a qualitative synthesis that combines all disciplinary and sectoral findings and interprets their combined effect on the resilience and the vulnerability of people in the Mekong Basin. provides a framework for the resilience concept. This step focused on communities and their livelihoods. However, the analysis included the broader systems perspective of how communities and livelihoods depend on and are being influenced by social, natural, financial, physical, and political factors. Shocks to the system were defined by the scenarios, and the disciplinary assessments project the various facets of change that households would have to face and to cope with in the various parts of the Lower Mekong Basin. Changes across the comparison of the development scenarios translate into different levels of exposure, sensitivity, and adaptive capacity. As a consequence of a qualitative interpretation, Mekong communities were assigned to four resilience categories:

- Communities bounce back and are better off than before, often a positive transformation of the social-ecological system;
- Communities will bounce back and recover from the shock to a situation with similar characteristics as before the shock;
- Communities will recover but they will be worse off than before;
- Communities will collapse, which could involve substantial segments of the communities moving away and a loss of the majority of existing livelihoods.

- **Figure 2 Resilience framework and vulnerability concept with outcome categories**



In addition to the categorisation of possible community outcomes, the assessment qualified how the resilience of the overall system changes and how vulnerabilities change. The qualitative assessment considered exposure, sensitivity, and adaptive capacity for each zone in the Mekong corridor and added for each Member Country the remaining area in the Mekong Basin. Critical factors for the qualitative assessment are

- Exposure: Level of loss/gain and its gravity
- Sensitivity: Livelihood dependency (e.g. fisheries) based on household survey data
- Adaptive capacity: Income to allow for a substitution of the loss (excl. migration)

2.3.2 Indices: Sustainability, cross-sector impacts, and transboundary impacts

Three composite, integrated indicators were proposed (Table 7). The first, *sustainability*, quantified sustainability effects as defined by the UN-led SDG process that all Mekong riparian countries are committed to. The second, *cross-sectoral synergies*, measured the extent of synergies or trade-offs among sectors including capture fisheries. The third, *transboundary influence*, measured the contribution to sustainability and cross-sector changes due to investments in any of the other LMB countries, derived from the basic assessment indicators.

→ Sustainability

Sustainability is a core concept of the Council Study and the overall MRC indicator framework. The following sustainability index helps interpret the differences between scenario results from an integrated assessment perspective.

The sustainability index was based on the subset of SDG indicators, as listed in Table 6. Methodologically, the index was calculated by normalising each indicator. In a first step, the selection of SDG indicators was completed with Member Countries. In a second step, the range of possible outcomes was specified for each indicator, also implemented with Member Countries. The starting values for the worst and the best situation – lower and upper bound – of each indicator were derived from global data. Once complete, disciplinary assessment results were used to calculate the state of each indicator for each scenario and then normalised within the agreed value range of possible outcomes.

Each assessment indicator was assigned a sustainability value between zero (unsustainable) and one (highly sustainable). The sum over all sustainability indicators could then be compared across scenarios and the index analysed to identify which scenarios lead to sustainability improvements or to sustainability losses.

Table 6 Sustainability indicators selected and prioritised by Member Countries

Economic Indicators	Lower bound	Upper bound	Priority
Economic loss due to disasters *& shocks* in % of GDP	10%	0%	High
Average farming household income	$3,000	$30,000	High
Energy intensity (primary energy MJ per $ GDP)	10	2	Medium
Annual growth rate of real GDP per capita	-5%	+7%	Medium
Proportion of domestic budget funded by domestic taxes	10%	90%	Low
Foreign direct investments in % of total domestic budget	1%	5%	Low
Tourism as a proportion of total GDP	5%	20%	Low
Social Indicators			
% of population below national poverty line	50%	0%	High
% of population with low food security	50%	0%	High
Loss of human life due to disasters	1,000	0	Medium
% of population undernourished	75%	0%	Medium
% of population with access to electricity	30%	100%	Medium
% of people living below 50 per cent of median income	50%	5%	Medium
% of children under 5 with malnutrition	50%	0%	Medium
Under-five mortality rate	50	0	Medium
% of Government spending on education	5%	25%	Low
Mortality rate attributed to unsafe water	10	0	Low
% of population using safely managed drinking water services	0%	100%	Low
% of wastewater safely treated	0%	100%	Low
% of youth (age 15-24 years) not in education or employment	80%	5%	Low
Number of agencies that have integrated mitigation, adaptation, impact reduction and early warning	0	20	Low
Environmental indicators			
Change in water-use efficiency over time	-5%	+5%	High
% of important biodiversity sites covered by protected areas	0%	100%	High
Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	80%	20%	Medium
Change in the extent of water-related ecosystems over time	-5%	+1%	Medium
Renewable energy share in total final energy consumption	0%	50%	Medium
Proportion of fish stocks within biologically sustainable levels	0%	100%	Medium
% of land that is degraded over total land area	20%	0%	Medium
Sustainable fisheries as a percentage of GDP	0%	5%	Medium
Investments under an enforced disaster risk management strategy	$0	$100m	Low
Degree of IWRM implementation (0-100)	0	100	Low
Proportion of transboundary basin area with an operational arrangement for water cooperation	0%	100%	Low
Coverage of protected areas in relation to coastal areas	0%	100%	Low
Forest area as a proportion of total land area	10%	70%	Low

→ Cross-sector impacts

Many MRC documents and negotiations point out that the aim of deliberation and the MRC research is to guide investment decisions to a state of balanced development. Balanced development can be interpreted in two ways. First, there should be a balance between sectors, which implies that investments should not aim for the development of a single sector at the cost of other sectors. Second, the development process in the Lower Mekong Basin should consider transboundary effects, which emphasises the relevance of a balance between the actual and potential outcomes for each country. The assessment defines one indicator for each perspective of balanced development: cross-sector and transboundary.

Cross-sector relationships can be positive or negative. Typically, positive cross-sector relationships are referred to as synergies. This implies that investments in one sector achieve improvements in this target sector, but also trigger improvements in one or more other sectors. Negative cross-sector relationships imply trade-offs. Investments in one sector lead to improvements in the target sector, but trigger losses in other sectors.

Based on this understanding, the cross-sector indicator was calculated as the value improvement or value loss for each MRC sector by comparing across the entire set of development and sub-scenarios. For instance, the comparison of hydropower output (in economic value) in scenario M1 (water infrastructure situation in 2007) and M2 (planned water infrastructure situation for 2020) results in what is gained for the hydropower sector through the additional investment defined by the 2020 scenario. This can be calculated for all MRC sectors based on the outputs of the macroeconomic assessment approach. Dividing the sectoral value differences leads to an important insight:

$$\frac{\text{Fisheries sector [M2]} - \text{Fisheries sector [M1]}}{\text{Hydropower sector [M2]} - \text{Hydropower sector [M1]}}$$

The proportional relationship defines how much is gained or lost in one sector (e.g. fisheries) for every dollar gained in another sector (e.g. hydropower). For example, if the macroeconomic assessment indicated that the hydropower sector output increases in the 2020 scenario by $100 million and the fisheries output decreases in the same scenario comparison by $50 million, then the result shows that for every dollar gained in hydropower about 50 cents are lost in fisheries. Comparing all sectors identifies not only synergies and trade-offs but also how synergies and trade-offs shift as investments gradually increase or shift between sectors. From a wider systems perspective, these results can guide the management of cross-sector trade-offs and the realisation of conceivable synergies.

→ Transboundary impacts

The second perspective of balanced development requires the management of transboundary impact. Typically, transboundary impacts are calculated as sectoral gains or losses, which are included in the macroeconomic assessment and should therefore not be repeated in the cumulative impact assessment. The development of the cumulative indicator that goes beyond the sectoral perspective focused on the broader system perspective. Transboundary impacts were calculated as the ratio of the two previous composite indicators (sustainability and cross-sector relationship) that can be attributed to the change in any of the three other countries. In other words, this indicator calculates

(1) which percentage of the sustainability index change is due to transboundary impacts and
(2) which percentage of cross-sector synergies/trade-offs is due to transboundary impacts.

Two sub-indicator results were estimated from the calculations and complement the macroeconomic assessment perspective by identifying overall (considering gains in one sector and losses in another sector) transboundary impacts that affect sustainability and cross-sector relationships in a particular way.

Methodologically this was achieved in four steps. First the weight of each sector was calculated for each scenario. Second, the scenario investment was mapped to its geographic location. Third, the two values were multiplied with each other to gain sector-country coefficients. Then, the coefficients were multiplied with (1) the sustainability index change and with (2) the cross-sector effect. The result shows how much of the sustainability index change (comparing two scenarios) is due to transboundary effects and how much of the cross-sector synergy or the cross-sector trade-off results from investment in other Member Countries.

2.3.3 Relation to MRC strategic assessment indicators

The MRC specified in a parallel process a set of strategic indicators. Assessment indicators described in the previous sub-sections were specified based on this list. Table 7 provides an overview of all CIA indicators and how they map into the MRC indicator framework.

Scenarios were assessed across three groups of indicators. The first group is part of the qualitative and quantitative synthesis. This group includes results for social impacts utilising well-being and employment in particular to match the MRC's focus on these two important indicators. These were combined with environmental impacts, particularly, changes in water flow conditions, water quality changes, and the status of other environmental assets, which aligns with the MRC indicator framework. The CIA adds to the synthesis effects on the economic value of environmental assets and the contribution of economic sectors to the macroeconomic growth of the Lower Mekong Basin. This is equivalent to the (draft) MRC indicator framework. This part of the synthesis is complemented by applying the resilience concept to these cross-disciplinary assessment results. The set of CIA indicators were selected to respond to the increasing importance of the resilience concept for decision making in MRC Member Countries.

The second group of strategic assessment indicators quantified impacts on sustainability, cross-sector effects, and on transboundary effects. These quantitative results allow a direct comparison of all the main scenarios and sub-scenarios for each of the three indicators. The combination of the quantitative results and the more qualitative synthesis shaped a more robust and consistent assessment approach.

Climate change is another MRC strategic indicator dimension, covered in the comparative analysis by the definition of three climate change scenarios. The comparison of the climate change sub-scenarios allowed a more concise understanding of the impact of climate change on the range of assessment indicators employed in the Council Study .

Table 7 Composite strategic indicators for use in the Cumulative Impact Assessment based on selected indicators from the disciplinary assessments

Assessment approach	Dimensions	Strategic Indicators	
		CIA Indicator Framework	MRC Indicator Framework
Qualitative & Quantitative synthesis	Social	Well-being Employment	Living conditions and well-being Employment in MRC sectors
	Environmental	Water flow conditions in mainstream Water quality and sediment conditions in mainstream Status of environmental assets	Water flow conditions in mainstream Water quality and sediment conditions in mainstream Status of environmental assets
	Economic	Economic value of MRC sectors Contribution to national economy	Economic performance of MRC sectors Contribution to national economy
	Integrated	Resilience; Vulnerability	
Quantitative analysis	Integrated	Resource sustainability Cross-sectoral synergies Transboundary balance	
Scenario comparison	Climate change		Greenhouse gas emissions Climate change trend and extreme Adaptation to climate change
	Cooperation		Equity of benefits derived from the Mekong River system Benefits derived from cooperation Self-finance of the MRC Level of information sharing and participation

Finally, the MRC defined a group of cooperation-focused indicators in their list of strategic indicators. These were not explicitly covered as their nature is not directly linked to the scenarios and the overall design of the Council Study. However, the transboundary impact indicator of the CIA provides an effective perspective on how the benefits derived from the Mekong mainstream shift between the four Lower Mekong countries.

3 Impact assessment results

3.1 Community resilience and vulnerability

3.1.1 Main scenario comparison

Section 2.3.1 explained the generic resilience framework and its two framing questions.

- Resilience of what?

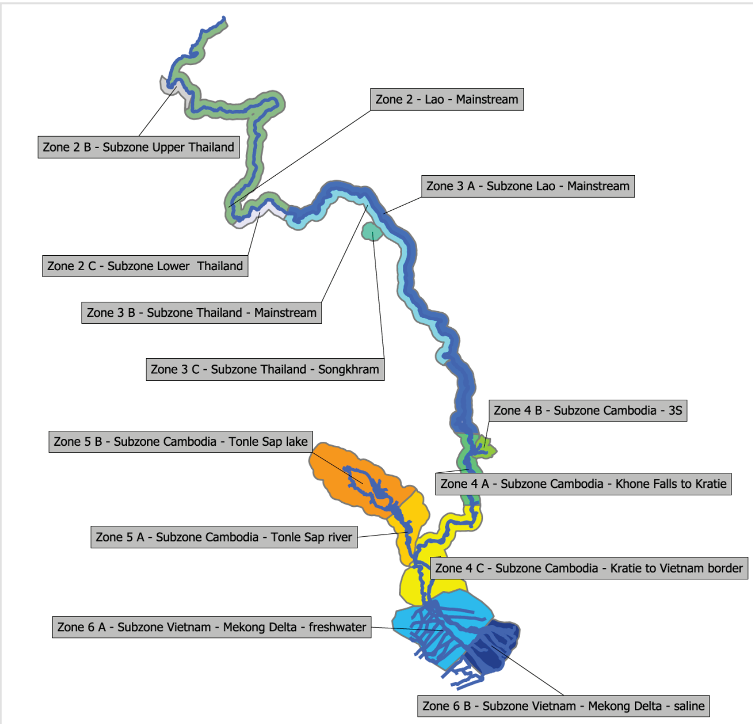
The assessment addresses the resilience of communities and their livelihoods. Based on the disciplinary assessments, communities are grouped into corridor zones. Additionally, impacts were discussed for communities outside the corridor. Where possible and necessary, the geographical distinction were overlaid with livelihood specific assessments.

- Resilience to what?

Communities face a variety of vulnerabilities and households, and governments put a lot of measures in place to either

- reduce exposure; or
- reduce the sensitivity; or
- improve the adaptive capacity of communities.

- **Figure 3 Map sub-zones of SIMVA 2014 (source: SIMVA 2014)**



Vulnerabilities are linked to stressors, which this assessment groups into environmental, social, and economic dimensions. Mekong basin communities can face a diversity of stresses depending on their location and their livelihood diversification strategy. For instance, communities in north-east Thailand are regularly confronted with drought conditions, while communities in the Mekong Delta increasingly face the need to adapt to salinity intrusion. These kind of stresses are not static but evolve over time.

Here is a list of important stressors related to the context of MRC's sectoral focus:

Environmental

- Deforestation
- Loss of wetlands
- Intensification and increasing frequency of floods
- Depleting fish stocks
- Water quality decline
- Eroding riverbanks

Social:

- Declining food security
- Migration pressure (emigration)
- Migration pressure (immigration)
- Public health concerns
- Cultural identity due to activities or landscapes

Economic

- Income security based on existing livelihoods
- Crop prices
- Land title security
- New livelihoods opportunities
- Market access conditions

Lao PDR

The main scenario M2 is likely to provide very mixed outcomes for Lao PDR. The key impacts are summarised as listed in Table 9. Several factors were identified as likely to increase community vulnerability. These vulnerabilities are partly increasing at a national scale, most importantly the decline in food security, and partly at a local scale within the corridor.

Deforestation-related vulnerabilities will increase in areas where further reduction of deciduous forest areas are being planned due to the loss of existing livelihoods and the hydrological implications. In planned reforestation areas these vulnerability effects are likely to be reversed depending on livelihood development potential and geomorphological characteristics.

The planned expansion of agricultural production combined with the surge in government spending based on increasing export earnings are likely to push up wages and, thereby labour costs. This tendency has the potential to diminish existing foreign direct investment in the manufacturing industries and thereby further increase vulnerabilities in many other parts of Lao PDR.

Development gains and increasing investments in infrastructure (e.g. irrigation) imply that more assets are exposed to extreme events, such as floods. The increasing risk can convert into increasing vulnerabilities if no additional protective or adaptive mechanisms are put in place. Floods are an important driver for community vulnerability. Table 8 shows the net present value of investments in flood protection included in the relevant scenarios. The overall investment by Lao PDR (M2: $23 million; M3: $99 million, M3CC: $119 million) would result in reduced exposure and, thereby reduce vulnerability, and a positive net present value of $162 million for scenario M3CC. Extreme floods (1:100 years) would not be averted and would cause damages of around $144 million.

Table 8 Net present value for flood protection investments

	Lao PDR	Thailand	Cambodia	Vietnam	TOTAL
	M$	M$	M$	M$	M$
Scenario M1	$3	$6	$541	$3,061	$3,611
Scenario M2	$38	$139	$335	$2,014	$2,527
Scenario M3	$26	$411	$46	$1,384	$1,867
Scenario M3 CC	$162	$1,264	$337	$3,791	$5,554
Scenario F1	$12	$21	$0	$0	$32
Scenario F2	$355	$2,420	$189	$3,858	$6,821

Table 9 Important vulnerability effects for Lao PDR

Effect	Vulnerability
Declining food security	Increase (national)
Increasing food prices	Increase (national)
Increased risk of riverbank erosion	Increase (local)
Increasing migration pressure	Increase (local)
Substantial reduction of fisheries related livelihood	Increase (local)
Losses in cultural identity due to fish losses and changing landscapes	Increase (local)
Substantial deforestation in some areas and reforestation in other areas	Increase/Decrease
Stable electricity prices	Neutral
Increasing wages (labour costs)	Neutral/Decrease
Increasing export earnings	Decrease (national)
Substantial expansion of agricultural production and employment (if feasible)	Decrease (local)
Agricultural income would increase	Decrease (local)
Potential reduction in flood risk	Decrease (local)

Thailand

Thailand is likely to become a main beneficiary of the hydropower expansion planned for scenario M2. The energy-related ripple effects are likely to be positive for a range of economic sectors and the employment therein. It is unknown if this increase of power supply will actually benefit areas within the Lower Mekong Basin or if the additional electricity will mainly benefit areas outside the basin. Livelihood-related vulnerabilities are likely to decline, particularly if the gains in the energy sector are going to translate into lower domestic tariffs and thereby reduce production costs for secondary and tertiary sectors. How much of these gains will benefit the north-east of Thailand depends on investments in secondary and tertiary sector employment in this region. The navigation expansion is likely to add to this positive picture as transport costs for manufacturing industries in north-east Thailand are likely to drop. This would potentially open new overseas markets and diversify the current dominance of domestic costumers.

Vulnerabilities related to agricultural activities are likely to decline if irrigation expansion plans are being implemented. However, existing labour shortages in the agricultural sector of Thailand combined with the expansion plans in other industries are likely to further deepen labour shortages for agriculture. This makes the agricultural expansion plans unrealistic to achieve without substantial immigration. Immigration, however, is likely to introduce risks to community vulnerabilities from a local perspective. The loss of fisheries in scenario M2 is likely to increase vulnerabilities in a number of communities along the Mekong and create pressure for many to replace their current livelihoods, directly or indirectly related to fishing.

Table 10 Important vulnerability effects for north-east Thailand

Effect	Vulnerability
Declining food security	Increase (north-east)
Increasing food prices	Increase (north-east)
Increasing migration pressure	Increase (local)
Increased risk of riverbank erosion	Increase (local)
Substantial reduction of fisheries related livelihoods	Increase (local)
Losses in cultural identity (fish losses)	Increase (local)
Declining electricity prices	Decrease (national)
Increasing earnings in the energy sector	Decrease (national)
Declining transportation costs in navigation sector	Decrease (north-east)
Substantial expansion of agricultural production and employment (if feasible)	Decrease (local)
Agricultural income would increase	Decrease (local)
Potential reduction in flood risk	Decrease (local)

The loss of fish is likely to emerge as the most dominant effect in the environmental domain. Particularly losses in biodiversity are likely to reduce the resilience. The related food security challenge is likely to impact the north-east region as prices for fish and crops are likely to substantially increase. From a distributional perspective, this would affect this population segments with lower income substantially and trigger social tensions.

Scenario M3 is likely to worsen the negative impacts without further strengthening the positive impacts. Fisheries-related impacts would trigger a further decline in food security, affecting the north-east of Thailand. The pressure to replace livelihoods will further increase, particularly in communities along the corridor, which will increase vulnerabilities and reduce existing resilience.

Floods are a reoccurring driver for community vulnerability across Thailand's north-east. Similar to in other parts of the Lower Mekong Basin, increasing levels of private and public investments convert into more assets being exposed and thereby increasing risk and vulnerability. Table 8 quantifies the net present value of investments in flood protection at nearly $1.3 billion for M3CC. The planned investments (M2: $83 million; M3: $149 million; M3CC: $178 million) would reduce flood-related vulnerabilities. Only 1:100 year events would continue to cause substantial damage, estimated at around $639 million per event.

Cambodia

For scenario M2, most impacts on Cambodia's community are likely to be negative. The vulnerability of communities is likely to increase substantially due to reduced food security, particularly increasing food prices. This might be partially mitigated if agricultural productivity improvements outpace population growth. However, the fisheries losses are likely to put pressure on livelihoods of many communities in the Tonle Sap area. Adaptation strategies are likely to make outmigration necessary, which can lead to deep social problems, depending on how successful public investments will be in creating new employment opportunities.

Deforestation between 2007 and 2015 in areas between the Cardamom Mountains and the Tonle Sap and along the border to Thailand is likely to have added to increasing vulnerability. If combined with the fisheries-driven losses around the Tonle Sap and Tonle Sap River, it is likely that national losses in resilience emerge due to cumulative economic and social processes, particularly related to increased migration, and reductions in public revenue and natural capital.

Positive developments depend on the structure and functioning of a few key markets. For instance, many communities would benefit if electricity prices decline. Also Cambodia's market share in the fish market is likely to increase substantially, which would create potential to increase related export earnings and partially substitute the losses in fisheries volume for fish-dependent households as fish prices are very likely to substantially increase.

Table 11 Important vulnerability effects for Cambodia

Effect	Vulnerability
Declining food security	Increase (national)
Increasing food prices	Increase (national)
Increasing migration pressure	Increase (local)
Increased risk of riverbank erosion	Increase (local)
Substantial reduction of fisheries related livelihoods	Increase (local)
Losses in cultural identity (fish losses & changing landscapes)	Increase (local)
Declining electricity prices	Decrease (national)
Increasing earnings in the energy sector	Decrease (national)
Declining transportation costs in navigation sector	Decrease (Northeast)
Substantial expansion of agricultural production and employment (if feasible)	Decrease (local)
Agricultural income would increase	Decrease (local)
Potential reduction in flood risk	Decrease (local)

In scenario M3 many of the negative effects would worsen as fish losses, particularly within Cambodia, would increase. Thereby, some of the export-related gains would be put at risk. The domestic pressure on creating new employment would be even higher, and social challenges related to livelihoods, migration and identity would require serious public investments.

Floods are an important factor for Cambodia and introduce a mix of positive and negative effects. Flood-related losses are likely to increase as increasing development involves more assets being exposed and thereby increases risk and vulnerability. Table 8 suggests that the net present value of investments in flood protection is about $337 million for M3CC. The planned investments (M2: $4 million; M3: $482 million; M3CC: $579 million) would mitigate flood-related vulnerabilities. Only 1:100 year events would continue to cause substantial damage, possibly up to $325 million per event.

Vietnam

Vietnam is likely to experience a diversity of vulnerability-related effects. Fish-related losses are likely to be substantial for M2 and M3, translating into economic losses and livelihood adaptation pressure. Some might be balanced by agricultural expansion, which would also compensate food security losses, particularly if land use change will continue diversification trends (incl. aquaculture and upland crops). Sediment losses are likely to demand serious investments to mitigate erosion and to maintain agricultural nutrients inputs. Importantly, these changes need to be seen in combination with increasing vulnerability of salinity intrusion due to sea-level rise. The combined adaptation pressure is likely to spur outmigration, which would shift social pressures into urban areas.

Table 12 Important vulnerability effects for Vietnam's Mekong Delta

Effect	Vulnerability
Declining food security	Increase (national)
Increasing food prices	Increase (national)
Increased risk of erosion	Increase (local)
Substantial reduction of fisheries related livelihoods	Increase (local)
Losses in cultural identity (fish losses)	Increase (local)
Declining electricity prices	Decrease (national)
Declining transportation costs in navigation sector	Decrease (Northeast)
Substantial expansion of agricultural production and employment (if feasible)	Decrease (local)
Agricultural income would increase	Decrease (local)
Potential reduction in flood risk	Decrease (local)

Positive developments can be expected from declining electricity and navigation prices, which is likely to benefit many communities in Vietnam. Depending on economic policy, price reductions are likely to convert into improved livelihood conditions in several sectors, particularly those that are export oriented. Ultimately, many communities might experience a decline in their vulnerabilities and improve their resilience.

Floods are part of life in Vietnam's Mekong Delta and are typically connected with a rage of positive effects (e.g. sediment, nutrients) and negative impacts. While positive effects are projected to decline sharply with upstream hydropower, negative effects are likely to be mitigated by substantial investments in flood protection (M2: $36 million; M3: $1 billion; M3CC: $1.25 billion). Table 8 combines an increasing level of assets exposed to floods, changing flood intensities and frequency, and planned flood protection infrastructure. Resulting net present value of investments in flood protection for M3CC is about $3.8 billion, which indicates that these investments are worth considering. However, investment plans would not cover 1:100 year events, which would cause substantial damages of about $3.2 billion.

Table 13 Directional vulnerability effects for Lower Mekong Basin countries

	Zone (population)	Social	Economic	Environmental	Response*
Lao PDR ↘	Zone 2A (507,316)	↓	↘	↘	RBWO
	Zone 3A (1,016,355)	↓	→	↘	RBWO
	Rest of Lao	→	↗	→	BBB
Thailand →	Zone 2B (83,108)	↘	→	↘	BB
	Zone 2C (84,025)	↘	→	↘	RBWO
	Zone 3B (743,228)	↘	→	↘	RBWO
	Zone 3C (83,233)	↘	→	↘	BB
	Rest of NE Thailand	→	↗	→	BBB
Cambodia ↘	Zone 4A (89,655)	↘	→	↘	RBWO
	Zone 4B (6,998)	↘	→	↘	RBWO
	Zone 4C (4,113,428)	↘	→	↘	RBWO
	Zone 5A (1,395,154)	↘	↘	↘	RBWO
	Zone 5B (948,201)	↘	↘	↘	RBWO
	Rest of Cambodia	↘	→	→	BB
Vietnam ↘	Zone 6A (8,279,059)	↘	↘	↘	RBWO
	Zone 6B (3,309,355)	↘	↗	↓	RBWO

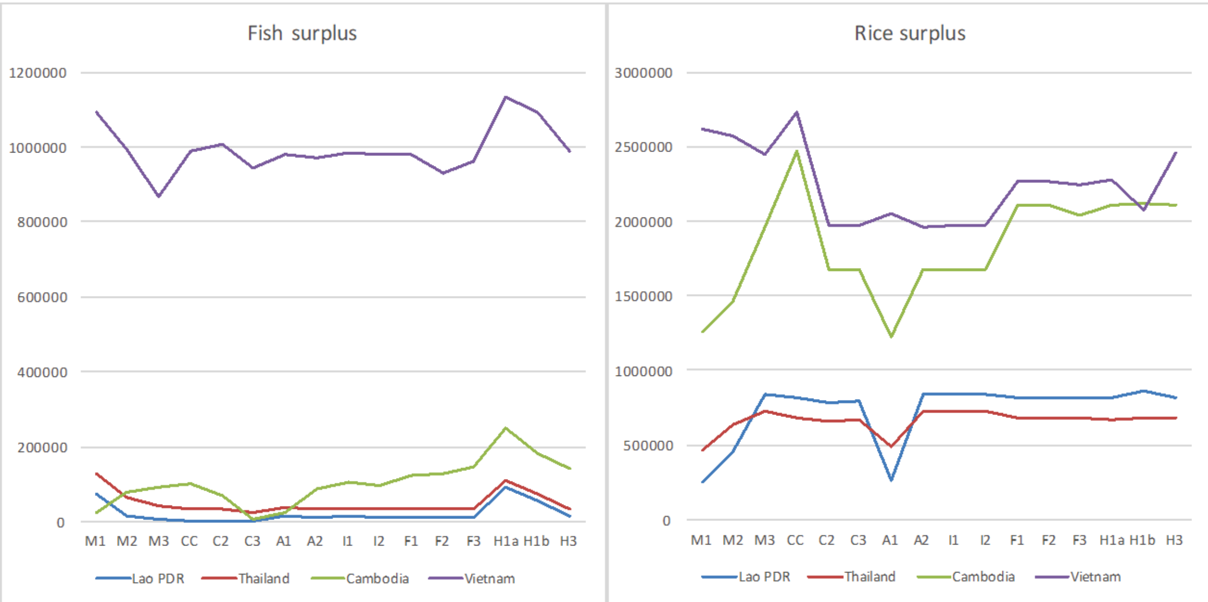
* BBB (Bounce back better); BB (Bounce back); RBWO (Recover But Worse Off); C (Collapse) (see)

3.1.2 Sub-scenario perspective

Sub-scenarios provide an important insight for the management of resilience as they allow for unbundling of the investment composition of the main scenarios. The comparison of the main scenario M3CC and any of the sub-scenarios establishes a sensitivity analysis and reveals which dimensions of the main scenario exert the greatest resilience effect in the four countries.

A key dimension for vulnerability is food security. The social assessment report derives a proxy for food security from surplus from fish and rice production as other key data is not available to estimate food security. An important constraint for this proxy is the distributional effect. Surplus means that this is the part of the production that can be traded and be made available to people that do not engage in fishing or rice production. However, an overall surplus does not mean that full food security has been established for all population segments. First, (large) parts of the surplus can be exported. Second, household income needs to be considered to establish if people can actually buy the surplus produced. Third, surplus needs to be distributed, which shifts food largely into urban areas because of higher incomes (and potentially improved prices for production) and into areas that surround the production location because of low transportation costs. Food prices typically increase if food surplus production declines. The most vulnerable people for any decline in surplus production are poor people (urban or rural) without or with low subsistence production as their income is insufficient to increase their spending on food. Urban poor are often the most vulnerable because they typically lack any opportunity for subsistence production. Rural households are also affected, especially if they live some distance from the production areas and their income doesn't increase proportionately with food price increases. In summary, surplus production is a good proxy, but it means that any decline increases vulnerability, starting with the poorest population segment. The larger the drop is, the more affected are the poor and the more population segments are likely to experience higher vulnerability.

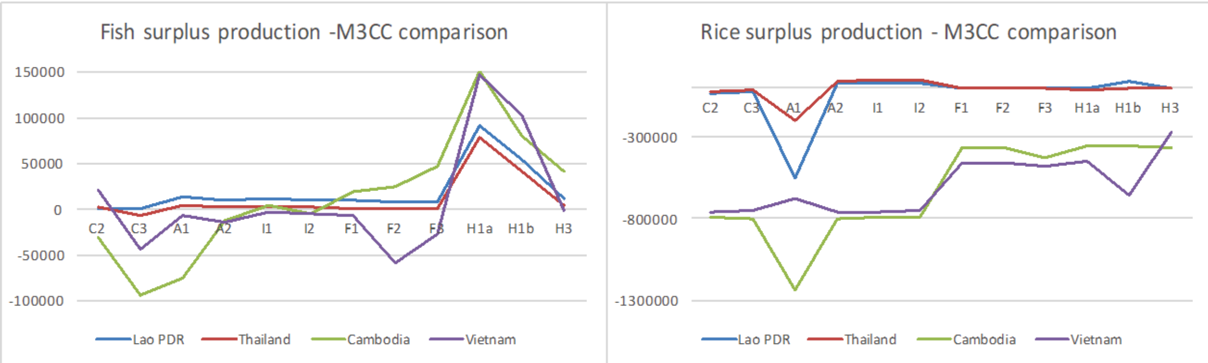
Figure 4 Fish and rice surplus from national production for all main and sub-scenarios



indicates that for Vietnam, fish and rice production exceed consumption substantially. However, as explained above, and considering the high share of export-focused production in both sectors, poor households are likely to become more vulnerable because M3, C3, and F2 cause major dips for fish surplus and C2, C3, A1, A2, I2, I3, and H1b reduce rice surplus. Vietnam is likely to see substantial reductions in vulnerability if no or fewer dams would be built (H1a or H1b), see .

The vulnerability of several population segments is likely to increase in Lao PDR for most main and sub-scenarios. Sub-scenarios A1, I1, H1a, and H1b provide an interesting insight as they assess the impact of sector-specific investment bundles on surplus production. If focussing on fish, all four sub-scenarios trigger an improvement of food surplus, in the cases of H1a and H1b a substantial increase can be observed. The comparison of these four sub-scenarios means that the largest increase of vulnerability occurs due to mainstream dams, followed by tributary dams. Considering the points raised above, vulnerability is likely to increase substantially. Given that the overall surplus is for most scenarios very small, it is likely that food prices will increase substantially (as also mentioned in the macroeconomic assessment report) and trigger an increase of vulnerability for larger population segments. shows the difference in surplus production comparing all subs-scenarios with main scenario M3CC. This perspective confirms that the vulnerability increase is mainly linked to mainstream dams, which applies to all four countries.

Figure 5 Fish and rice surplus for sub-scenarios if compared with main scenario M3CC



Agricultural plans in Lao PDR target a substantial increase in rice production, which would decrease food-based vulnerability. It needs to be emphasised that rice does not directly provide a substitute to the protein loss due to the fisheries decline. The macroeconomic assessment report raised an important point related to the plans for expanding agriculture. These plans demand a substantial increase in workforce, even if farm consolidation processes and mechanisation continue. Typical development processes, however, imply a substantial reduction in the agricultural workforce due to improved education, higher income in secondary and tertiary sectors, and lifestyle-related value changes. This means that the higher production level that suggests is potentially overestimating realistic growth potential. Nevertheless, food-related vulnerability based on rice production is likely to decline.

The assessment of Thailand follows a similar pattern as Lao PDR, and most arguments remain the same. However, fish production surplus is higher and is thereby likely to affect fewer households. This coincides with higher mean income level, if compared with Lao PDR, which means that vulnerability is likely to increase, but less than in Lao PDR. Nevertheless, as aforementioned urban poor and landless people are likely to face substantial fish price increase that will increase their vulnerability.

Table 14 Fish production surplus changes for sub-scenarios and zones

	Zone 2 Lao	Zone 3A Lao	Zone 2B Thailand	Zone 2C Thailand	Zone 3B Thailand	Zone 3C Thailand	Zone 4A Cambodia	Zone 4B Cambodia	Zone 4C Cambodia	Zone 5A Cambodia	Zone 5B Cambodia	Zone 6A Vietnam	Zone 6B Vietnam
C2	26%	6%	9%	5%	1%	1%	-7%	**-117%**	1%	**61%**	10%	5%	17%
C3	**-13%**	-2%	-4%	**-25%**	-4%	-4%	4%	**-117%**	**-12%**	**-104%**	**-58%**	-2%	-7%
A1	**58%**	15%	0%	9%	3%	3%	**64%**	**-140%**	5%	1%	6%	1%	2%
A2	**51%**	12%	0%	-2%	0%	0%	**86%**	**-18%**	1%	-123%	2%	0%	-1%
I1	**64%**	11%	0%	7%	0%	0%	**87%**	3%	28%	-53%	7%	0%	1%
I2	**55%**	12%	-1%	-1%	1%	0%	**82%**	-8%	2%	-46%	4%	0%	-1%
F1	**56%**	12%	0%	0%	1%	1%	1%	-5%	2%	15%	4%	0%	-1%
F2	**54%**	11%	0%	0%	0%	0%	1%	**-114%**	1%	2%	23%	-6%	**-18%**
F3	**55%**	11%	0%	0%	0%	0%	-4%	**-114%**	2%	**95%**	30%	-3%	-10%
H1a	**363%**	14%	**64%**	**220%**	2%	2%	-1%	22%	-7%	**181%**	**70%**	16%	**50%**
H1b	**331%**	10%	46%	**197%**	-1%	-2%	26%	**-82%**	-11%	**108%**	19%	6%	19%
H3	**73%**	13%	0%	12%	1%	1%	-11%	**-140%**	8%	72%	11%	-2%	-5%

Cambodia shows increased fish production surplus for M2 and M3 if compared with M1, which would help reduce the vulnerability of many households. However, considering the likely price increases, vulnerability improvements in poorer population segments are likely to be small. Sub-scenario C3, which assumes a drier climate change than defined for M3CC, is likely to cause a substantial drop in surplus production of fish, which highlights the climate-related vulnerability of many Cambodian communities. In other words, if current expectations of climate change are too positive, and climate change turns out to be drier, M3-related impacts are likely to be amplified. The investments in the flood protection–related sub-scenarios are likely to provide a substantial improvement, as indicated by . Cambodia would experience the largest improvements of food-related vulnerabilities if no or fewer dams would be built (H1a or H1b).

Table 14 quantifies the impacts of the various sub-scenarios on fish production surplus as an important vulnerability dimension for all zones. Strikingly, apart from the drier climate change variation, all sub-scenarios trigger substantial vulnerability improvements to zone 2 (Lao PDR), which suggests that none of the investment bundles considered in M3CC enhances the protein-based food security of communities in this zone. Zone 3 (Lao PDR) is affected similarly, but at a lower level. Zones 2b and ac in Thailand and zones 5a and 5b in Cambodia would experience substantial vulnerability reductions linked to the availability of fish under sub-scenarios H1a and H1b.

Vulnerability and community resilience do not only depend on food security, however, this is one of the major changes the other assessment reports highlight. The combination of food and income security provides a substantial measure for vulnerability improvements. In areas where both indicators decrease, vulnerability is likely to increase and community resilience likely to decline.

Table 15 Income-related vulnerability changes for scenario M3CC compared with M1 per sector and zone (Source: Socioeconomic assessment report)

	Vulnerability M1 yr 24 M3 yr 24			
Corridor zone	Primary	Fishing	Manufacturing	Service
Zone 2 Lao PDR	56%	-64%	-71%	-16%
Zone 3 A-Lao PDR	119%	-19%	-86%	-35%
Zone 2 B-Thailand	16%	-36%	-33%	-11%
Zone 2 C-Thailand	95%	-58%	-78%	-54%
Zone 3 B Thailand	63%	-19%	-63%	5%
Zone 3 C Thailand	-5%	-19%	-21%	7%
Zone 4 A Cambodia	-45%	-35%	2%	14%
Zone 4 B Cambodia	28%	-35%	-30%	-40%
Zone 4 C Cambodia	68%	-14%	-77%	-24%
Zone 5 A Cambodia	234%	-35%	-62%	-5%
Zone 5 B Cambodia	12%	-38%	-40%	1%
Zone 6 A VietNam Delta	1%	-17%	-38%	5%
Zone 6 B VietNam Delta	15%	-38%	-47%	2%

Table 15 estimates how M3CC development investments affect income-related vulnerability of households. The approach assigned households into one of four income groups for primary, secondary and tertiary. Vulnerable households were defined as those with incomes less than the 25th percentile and those less than the median income estimated for each sector. The values of Table 15 approximate how many people will be in one of the two lower income groups if compared with scenario M1. The development strategies reduce income-related vulnerability for those employed in the manufacturing and service industries for most of the zones and countries. Fishermen are likely to experience substantial improvements, which is a consequence of two coinciding dynamics. First, with declining fish stocks, fewer people remain in fishing, which converts into a decline in the lower income segments in particular. Second, fish prices are likely to increase, which benefits those that remain in this sector and adds to the declining number of fishermen in the lower income segments. Agriculture-related (here labelled as primary) income is likely to experience substantial increases in the number of households in the lower income segments. The only exception are zones 3c (Thailand) and 4a (Cambodia).

Disaggregating the individual sector investments that M3 combines can be achieved by looking at the sub-scenarios. Hydropower sub-scenarios H1a and H1b show that the largest income vulnerability reductions are being achieved by hydropower. However, sub-scenario A1 highlights that these effects would be much higher if agricultural expansion was not implemented as planned for M3, but at lower levels. The combination of four sub-scenarios shown in Table 23 indicates that income-related vulnerability benefits from some more hydropower (e.g. H1b), but that there is only smaller benefit gains from realising all hydropower projects as the difference between H1a and H1b, which suggests smaller vulnerability reductions. Such “decreasing marginal returns” are often encountered in these development situations. Irrigation investments seem to reduce income-related vulnerability negatively across all zones and, surprisingly, also agricultural households in most zones. Agricultural expansion components in M3 are likely to trigger a substantial transition of workforce from primary sectors to secondary and tertiary sector employment.

Table 16 Income-related vulnerability changes for development sub-scenarios compared with M3CC per sector and zone (Source: Socioeconomic assessment report)

	Vulnerability M3 A1				
Corridor zone	Primary	Fishing	Manufacturing	Service	Av'ge
Zone 2 Lao PDR	-36%	-4%	29%	27%	4%
Zone 3 A-Lao PDR	-53%	-28%	60%	60%	10%
Zone 2 B-Thailand	-19%	-22%	17%	15%	-2%
Zone 2 C-Thailand	-50%	-34%	131%	129%	44%
Zone 3 B Thailand	-31%	-24%	37%	37%	5%
Zone 3 C Thailand	5%	-27%	-1%	-2%	-6%
Zone 4 A Cambodia	0%	-27%	4%	4%	-5%
Zone 4 B Cambodia	-6%	-28%	6%	6%	-5%
Zone 4 C Cambodia	-34%	20%	32%	30%	12%
Zone 5 A Cambodia	-34%	-16%	8%	7%	-9%
Zone 5 B Cambodia	-6%	-19%	4%	4%	-4%
Zone 6 A VietNam Delta	-11%	0%	10%	9%	2%
Zone 6 B VietNam Delta	-1%	-1%	2%	1%	0%

	Vulnerability M3 Irrl				
Corridor zone	Primary	Fishing	Manufacturing	Service	Av'ge
Zone 2 Lao PDR	0%	-6%	1%	0%	-1%
Zone 3 A-Lao PDR	0%	-30%	2%	2%	-6%
Zone 2 B-Thailand	0%	-22%	1%	0%	-5%
Zone 2 C-Thailand	0%	-34%	4%	4%	-7%
Zone 3 B Thailand	0%	-26%	2%	2%	-5%
Zone 3 C Thailand	0%	-29%	2%	1%	-7%
Zone 4 A Cambodia	-8%	-26%	14%	13%	-2%
Zone 4 B Cambodia	0%	-27%	2%	2%	-6%
Zone 4 C Cambodia	-11%	25%	8%	7%	7%
Zone 5 A Cambodia	-8%	-20%	3%	2%	-6%
Zone 5 B Cambodia	-6%	-6%	3%	2%	-2%
Zone 6 A VietNam Delta	-13%	0%	12%	11%	2%
Zone 6 B VietNam Delta	-1%	-1%	2%	1%	0%

	Vulnerability M3 H1a				
Corridor zone	Primary	Fishing	Manufacturing	Service	Total
Zone 2 Lao PDR	1%	186%	-6%	-6%	44%
Zone 3 A-Lao PDR	-3%	-32%	6%	6%	-6%
Zone 2 B-Thailand	-7%	-22%	7%	7%	-4%
Zone 2 C-Thailand	-3%	-36%	12%	12%	-4%
Zone 3 B Thailand	-7%	-28%	10%	10%	-4%
Zone 3 C Thailand	-9%	-32%	7%	7%	-7%
Zone 4 A Cambodia	-49%	-27%	67%	67%	15%
Zone 4 B Cambodia	-53%	-28%	33%	33%	-4%
Zone 4 C Cambodia	3%	19%	-6%	-5%	3%
Zone 5 A Cambodia	17%	-12%	-3%	-3%	0%
Zone 5 B Cambodia	5%	3%	-2%	-2%	1%
Zone 6 A VietNam Delta	-8%	-1%	7%	7%	1%
Zone 6 B VietNam Delta	10%	-3%	-8%	-8%	-2%

	Vulnerability M3 H1b				
Corridor zone	Primary	Fishing	Manufacturing	Service	Av'ge
Zone 2 Lao PDR	1%	131%	-4%	-5%	31%
Zone 3 A-Lao PDR	2%	7%	-2%	-2%	1%
Zone 2 B-Thailand	-7%	19%	6%	5%	5%
Zone 2 C-Thailand	-2%	23%	2%	1%	6%
Zone 3 B Thailand	-5%	6%	5%	5%	3%
Zone 3 C Thailand	-9%	7%	5%	4%	2%
Zone 4 A Cambodia	-16%	2%	21%	20%	7%
Zone 4 B Cambodia	-53%	2%	30%	30%	2%
Zone 4 C Cambodia	2%	16%	-3%	-4%	2%
Zone 5 A Cambodia	18%	8%	-4%	-4%	5%
Zone 5 B Cambodia	7%	6%	-3%	-3%	2%
Zone 6 A VietNam Delta	-13%	4%	12%	11%	4%
Zone 6 B VietNam Delta	9%	11%	-9%	-9%	0%

Table 17 Income-related vulnerability changes for climate change sub-scenarios compared with M3CC per sector and zone (Source: Socioeconomic assessment report)

	Vulnerability M3 C2				
Corridor zone	Primary	Fishing	Manufacturing	Service	Av'ge
Zone 2 Lao PDR	0%	-8%	1%	0%	-2%
Zone 3 A-Lao PDR	-5%	-31%	8%	8%	-5%
Zone 2 B-Thailand	-8%	-18%	7%	6%	-3%
Zone 2 C-Thailand	-5%	-35%	17%	16%	-2%
Zone 3 B Thailand	-8%	-27%	11%	11%	-3%
Zone 3 C Thailand	-7%	-31%	6%	5%	-7%
Zone 4 A Cambodia	-42%	-27%	59%	58%	12%
Zone 4 B Cambodia	-49%	-28%	31%	31%	-4%
Zone 4 C Cambodia	-11%	18%	9%	8%	6%
Zone 5 A Cambodia	-8%	-20%	3%	2%	-6%
Zone 5 B Cambodia	-6%	-13%	3%	3%	-3%
Zone 6 A VietNam Delta	-13%	1%	12%	11%	3%
Zone 6 B VietNam Delta	-1%	2%	1%	1%	1%

	Vulnerability M3 C3				
Corridor zone	Primary	Fishing	Manufacturing	Service	Total
Zone 2 Lao PDR	-11%	-6%	-56%	-54%	-32%
Zone 3 A-Lao PDR	-6%	29%	-73%	-72%	-30%
Zone 2 B-Thailand	-15%	-15%	-17%	-16%	-16%
Zone 2 C-Thailand	-4%	-41%	-41%	-41%	-32%
Zone 3 B Thailand	-4%	22%	-2%	-2%	3%
Zone 3 C Thailand	-21%	28%	-14%	-13%	-5%
Zone 4 A Cambodia	-34%	-26%	-18%	-18%	-24%
Zone 4 B Cambodia	1%	-26%	-45%	-45%	-29%
Zone 4 C Cambodia	7%	-5%	-68%	-66%	-33%
Zone 5 A Cambodia	129%	-31%	-60%	-59%	-5%
Zone 5 B Cambodia	10%	-52%	-38%	-37%	-29%
Zone 6 A VietNam Delta	5%	-10%	-40%	-39%	-21%
Zone 6 B VietNam Delta	16%	-22%	-48%	-47%	-25%

The combination of income and food security indicates mixed results. Lao PDR is likely to be able to offset food production–related vulnerability increases by income gains. However, those that will not be able to increase income – especially while transitioning from primary to secondary and tertiary sector employment – will face substantially higher vulnerabilities.

Thailand's food-related vulnerability changes are largely driven by hydropower. The hydropower-focused sub-scenarios highlight that H1b would not able to offset the increasing vulnerabilities by higher income, while H1a would (better than M3). This is likely to be based on the fact that tributary dams will cause losses in fisheries, without providing substantial hydropower gains. This defines a difficult situation, as it would be best for Thailand's households in the north-east not to have any tributary or mainstream dams in the LMB. However, if dams are built, then the second best situation is that the related hydropower gains benefit Thailand to compensate for parts of the fish losses. The worst situation would be the construction of tributary and mainstream dams without any gains for Thailand.

While food- and income-related issues are here being defined as the core of household and community vulnerabilities, these are being impacted by a set of external drivers, that include macroeconomic conditions, environmental conditions, and disasters.

Relatively consistent macroeconomic conditions are likely to unfold for all four countries. The macroeconomic assessment suggests that M1 is the best development strategy considered by the Council Study and explains that this implies a strong development focus on manufacturing and service industries, while providing the necessary energy by alterative power generation options (other than hydropower) and supporting this development with a strong focus on education. Second to this scenario comes scenario M2, followed by A1. This suggests that a promising development strategy is likely to entail some selected hydropower, a few highly profitable agricultural extension projects with a focus on productivity gains to slowly release the workforce for the continued expansion of secondary and tertiary sectors. Scenario M3 is likely to provide macroeconomic conditions that further accelerate vulnerability problems, particularly in Lao PDR and Cambodia.

Environmental conditions decline rapidly with the investment bundles of M2 and M3, as the BioRA report outlines. The majority of impacts on river channel conditions and the extent of inundated forests seems to emerge from M2, compared with the overall effects of M3 investments. Effects on biodiversity that define an important ecological dimension for human vulnerabilities show more linear effects if comparing M2 and M3 investments. The sub-scenario perspective reveals that the vast majority of these vulnerability-related losses are triggered by dams, in particular mainstream dams. Similar to the macroeconomic perspective, M1 emerges as the optimal strategy to maintain these boundary conditions of human vulnerabilities. The second best solution is likely to be H1a, followed by H1b.

Another critical environmental driver is the frequency and intensity of floods as well as the exposure to floods. The flood analysis prepared under the Council Study highlights that climate change is likely to lead to higher flood peaks under the main scenario M3CC due to the increasing variability. This coincides with a larger exposure as development gains and the increasing investment in infrastructure convert into more assets likely to be affected by flood events. However, the proposed flood mitigation investments are likely to reduce risks substantially. Rare floods (1 in a hundred year events) would still cause significant economic losses. Additionally, experience has shown that hydropower cascades are prone to trigger man-made floods, which might severely affect numerous communities. However, in comparison, droughts are likely to have larger impacts on livelihoods throughout the Lower Mekong Basin.

In the absence of appropriate integrated simulation modelling, which would allow for the analysis of dynamic interactions between these various system components (economic, social, ecological, and physical changes), M1 and H1b seem to be the most effective development strategies to reduce the vulnerability of the majority of households across the LMB, while maintaining favourable macroeconomic and environmental boundary conditions.

3.2 Sustainability

The assessment of sustainability is a highly complex task, which requires more time and more sophisticated methodology than available in this study. Most importantly, the SDG perspective was introduced after the initial design phase of the Council Study and, while supported by the Member Countries, the scope of the disciplinary and thematic teams could not be adjusted to cover all indicators listed in Table 6. This dimension of the cumulative impact assessment should be understood as a first step towards reporting against SDGs in the long term. For future studies it is recommended to consider the selected of SDGs during the design phase, rather than as a design addendum, to inform the overall design of the assessment study. The participatory indicator section process that informed Table 6 represents an important starting point for future studies.

This part of the cumulative assessment involved a participatory approach in four steps. First, all SDG indicators were collated and reduced based on the scope of the Council Study. Second, the remaining indicators were presented to the Member Countries for selection and prioritisation. Third, the remaining indicators were presented to the disciplinary teams. This step resulted in further SDG indicators to be omitted because the required data was not being generated (e.g. child mortality) or because the detail of the definition did not match the Mekong context (e.g. sustainability of fish catch). During this step, teams were invited to suggest alternatives. The result of this step is presented in Table 18. The fourth step involved the calculation and interpretation of the index.

Table 18 Sustainability indicators selected and prioritised by Member Countries

Economic Indicators	Lower bound	Upper bound	Priority
Average farming household income	$3,000	$30,000	High
Annual growth rate of real GDP per capita	-5%	+7%	Medium
Social Indicators			
% of population below national poverty line	50%	0%	High
% of population undernourished	75%	0%	Medium
% of people living below 50 per cent of median income	50%	5%	Medium
Under-five mortality rate	50	0	Medium
Environmental indicators			
Integrity score for fish stocks	0	2.37	N/A
Integrity score for geomorphology	0	2.37	N/A
Integrity score for vegetation	0	2.37	N/A
Integrity score for macroinvertebrates	0	2.37	N/A
Integrity score for herpetofauna	0	2.37	N/A
Integrity score for birds	0	2.37	N/A
Integrity score for mammals	0	2.37	N/A

The SDG-based assessment method provides a simple approach to approximate how development investments as defined under the various main and sub-scenarios impact sustainability. Table 19 and

Table 20 provide an overview of development effects on sustainability in the four LMB countries and the LMB as a whole. Table 19 shows

- the sustainability level (on a scale from 0 to 14) for scenario M1
- the differences between main scenario and M1
- the differences between sub-scenarios and main scenario M3CC

Based on this first version of a SDG-based sustainability index, the results indicate a rather low level of sustainability for Vietnam's Mekong Delta. Another key insight is that Lao PDR would incur the greatest loss for main scenario M2. Main scenario M3, on the other hand, would result in the same absolute loss of sustainability points for Cambodia and Vietnam. Thailand would most likely experience the lowest reduction in sustainability across all scenarios.

The sub-scenario perspective reveals that lower investment levels in hydropower would lead to more sustainable development pathways in all countries. Table 19 shows that the sustainability index would increase by between 1.12 points in Thailand to up to 1.73 points in Cambodia. The comparison of H1a and H1b shows that this index suggests a similar impact from tributary as from mainstream dams. H3 indicates that substantial improvements in dam management and the implementation of mitigation measures can provide substantial gains in Cambodia. Also sub-scenario ALU1 highlights that excessive agricultural expansion can lead to overall sustainability losses, as shown for Cambodia. This echoes many key messages from the macroeconomic and the socio-economic assessment.

Table 19 Scenario impacts on SDG-based sustainability indicators

		Scenarios													
	M1	M2 -M1	M3 -M1	M3CC -M1	ALU1 -M3CC	ALU2 -M3CC	CC2 -M3CC	CC3 -M3CC	IRR1 -M3CC	IRR2 -M3CC	FP1 -M3CC	FP2 -M3CC	FP3 -M3CC	H1a -M3CC	H1b -M3CC	H3 -M3CC
Cambodia	**7.62**	-1.38	-2.24	-2.27	0.31	-0.05	-0.01	-0.23	0.10	-0.07	0.18	0.07	0.33	1.73	0.79	0.20
Lao PDR	**8.27**	-2.08	-2.24	-2.28	-0.07	-0.02	-0.05	-0.09	-0.06	0.03	0.01	0.01	-0.08	1.41	0.37	-0.09
Thailand	**8.70**	-1.18	-1.47	-1.51	0.02	-0.03	-0.02	-0.27	-0.05	-0.01	0.04	0.00	-0.04	1.12	0.58	-0.08
Vietnam	**5.41**	-1.22	-1.70	-1.24	0.04	-0.38	0.04	-0.17	-0.24	-0.32	-0.14	-0.29	-0.29	1.18	0.52	-0.11
LMB	29.99	-5.85	-7.63	-7.30	0.30	-0.49	-0.04	-0.76	-0.24	-0.37	0.08	-0.21	-0.08	5.44	2.27	-0.08

Table 20 provides the results at an indicator level, revealing the contribution of each component to the overall change in sustainability. The main scenarios affect nearly all indicators negatively. Slight positive effects are encountered for income, poverty, and malnutrition. However, the level of positive effects does not sufficiently compensate the majority of negative impacts.

The results are likely to change if the Member Countries decide to expand the index, whereby additional sub-indicators will change the result. However, the assessment of specific scenarios requires defining and selecting additional (SDG-based) indicators very early in the process to allow the analytical assessment stage to collate representative data and adjust methods accordingly.

Once an accepted index has been established, Member Countries can derive planning guidance from the disaggregated view presented in Table 20. Focusing on the highest sustainability losses introduces two approaches to prioritise investments. For instance, Thailand, Lao PDR, and Cambodia experience the highest sustainability losses due to the decline in fish stocks and the change in geomorphology (sediment flux). This means that maintaining sustainability could be best achieved by focussing on these factors. The second approach requires enumerating absolute values (not provided in Table 20) and would derive guidance from focussing on the lowest levels of the sustainability indicators. Vietnam, for instance, gets zero scores for integrity of mammals, birds, and vegetation.

This might indicate that the overall sustainability score could be improved by investing in improvements of these sub-indicators. A future version has the potential to provide a third sustainability dimension, quantifying the costs of improvements per sub-indicator unit. The suggested efficiency analysis would help maximise sustainability gains.

Table 20 Scenario impacts on SDG-based sustainability indicators

	CIA indicator	Dimension	Scenario differences (Mainscenarios compared with M1 and sub-scenarios compared with M3CC)														
			M2 -M1	M3 -M1	M3CC -M1	ALU1 -M3CC	ALU2 -M3CC	CC2 -M3CC	CC3 -M3CC	IRR1 -M3CC	IRR2 -M3CC	FP1 -M3CC	FP2 -M3CC	FP3 -M3CC	H1a -M3CC	H1b -M3CC	H3 -M3CC
Cambodia	Average farming household income	Economic	0.01	0.04	0.07	-0.07	-0.04	-0.04	-0.04	-0.04	-0.04	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02
	Annual growth rate of real GDP per capita	Economic	-0.05	-0.07	-0.08	0.08	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
	Integrity score for macroinvertebrates	Environme	-0.08	-0.04	-0.08	0.00	0.04	0.04	-0.08	0.04	0.04	0.08	0.04	0.08	0.04	0.00	0.04
	Integrity score for fish stocks	Environme	-0.34	-0.93	-0.93	0.04	0.00	0.04	-0.03	0.04	0.00	0.04	0.00	0.08	0.72	0.55	0.08
	Integrity score for geomorphology	Environme	0.29	0.25	0.24	0.00	0.00	0.01	-0.05	0.01	0.00	0.02	0.01	0.03	0.12	0.05	0.02
	Integrity score for vegetation	Environme	-0.13	-0.17	-0.17	0.08	-0.04	0.00	-0.04	0.00	0.00	0.04	0.00	0.04	0.13	0.04	0.04
	Integrity score for herpetofauna	Environme	-0.42	-0.51	-0.55	0.13	-0.08	0.00	-0.08	0.08	0.00	0.04	0.00	0.08	0.42	0.13	0.04
	Integrity score for birds	Environme	-0.11	-0.11	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Integrity score for mammals	Environme	-0.34	-0.58	-0.58	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.07	0.07	0.32	0.07	0.03
	Forest area as a proportion of total land area	Environme	-0.27	-0.27	-0.27	0.27	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of population below national poverty line	Social	0.04	0.03	0.02	-0.05	0.02	-0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	Proportion of population undernourished	Social	-0.01	-0.01	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00
	Proportion of children under 5 with malnutrition	Social	0.04	0.15	0.23	-0.23	-0.13	-0.13	-0.13	-0.13	-0.13	-0.06	-0.06	-0.07	-0.06	-0.06	-0.06
	Proportion of people living below 50 per cent of median income	Social	-0.01	-0.03	-0.05	0.05	0.03	0.03	0.20	0.03	0.03	0.01	0.01	0.02	0.01	0.01	0.01
Lao PDR	Average farming household income	Economic	0.03	0.10	0.10	-0.11	0.01	0.00	-0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.00
	Annual growth rate of real GDP per capita	Economic	-0.04	-0.09	-0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00
	Integrity score for macroinvertebrates	Environme	-0.04	0.00	0.04	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	0.00
	Integrity score for fish stocks	Environme	-0.76	-0.83	-0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.20	0.00
	Integrity score for geomorphology	Environme	-0.51	-0.59	-0.59	0.08	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.55	0.17	0.00
	Integrity score for vegetation	Environme	-0.04	-0.04	-0.04	0.00	-0.04	-0.04	0.00	-0.04	-0.04	0.00	0.00	-0.04	0.00	-0.04	-0.04
	Integrity score for herpetofauna	Environme	-0.30	-0.21	-0.21	0.08	-0.08	0.00	-0.17	-0.04	0.00	0.00	0.00	-0.04	0.13	-0.17	-0.04
	Integrity score for birds	Environme	-0.04	-0.04	-0.04	0.04	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.04	0.00
	Integrity score for mammals	Environme	-0.34	-0.54	-0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.07	0.00
	Forest area as a proportion of total land area	Environme	0.02	0.03	0.03	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of population below national p	Social	0.07	0.05	-0.01	-0.09	0.09	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	-0.01
	Proportion of population undernourished	Social	-0.07	-0.10	-0.10	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.05	0.00
	Proportion of children under 5 with malnut	Social	-0.03	0.11	0.09	-0.20	0.03	-0.02	-0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.04	0.00
	Proportion of people living below 50 per ce	Social	-0.02	-0.09	-0.08	0.10	0.00	0.01	0.22	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
Thailand	Average farming household income	Economic	0.08	0.12	0.09	-0.10	0.02	-0.01	-0.01	0.02	0.02	0.00	0.00	0.00	0.01	0.02	0.00
	Annual growth rate of real GDP per capita	Economic	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00
	Integrity score for macroinvertebrates	Environme	-0.04	-0.08	-0.04	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
	Integrity score for fish stocks	Environme	-0.63	-0.87	-0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.37	0.00
	Integrity score for geomorphology	Environme	-0.34	-0.42	-0.42	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.17	0.00
	Integrity score for vegetation	Environme	-0.04	-0.04	-0.04	0.00	-0.04	-0.04	0.00	-0.04	-0.04	0.00	0.00	-0.04	-0.04	-0.04	-0.04
	Integrity score for herpetofauna	Environme	-0.21	-0.17	-0.17	0.13	0.00	0.04	-0.17	0.00	0.04	0.04	0.00	0.00	0.08	-0.08	0.00
	Integrity score for birds	Environme	0.04	0.04	0.08	0.00	-0.04	-0.04	-0.04	-0.04	-0.04	0.00	0.00	0.00	-0.13	0.00	-0.04
	Integrity score for mammals	Environme	-0.21	-0.25	-0.34	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.13	0.00
	Forest area as a proportion of total land area	Environme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of population	Social	0.01	0.00	-0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of population undernourished	Social	0.06	0.08	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-0.04	0.00
	Proportion of children under 5 with malnutrition	Social	0.05	0.07	0.06	-0.05	0.01	-0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of people living below 50 per cent of median income	Social	0.05	0.06	0.05	-0.03	0.01	0.00	0.07	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Vietnam	Average farming household income	Economic	-0.01	-0.01	0.01	-0.05	-0.06	-0.06	-0.06	-0.06	-0.06	-0.03	-0.03	-0.04	-0.03	-0.05	-0.02
	Annual growth rate of real GDP per capita	Economic	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Integrity score for macroinvertebrates	Environme	-0.04	-0.17	0.08	0.03	-0.02	-0.02	-0.03	0.03	0.01	0.02	-0.03	-0.03	0.08	0.09	0.00
	Integrity score for fish stocks	Environme	-0.67	-0.94	-0.90	0.02	-0.04	0.18	-0.04	0.00	-0.04	0.02	-0.04	-0.04	0.98	0.59	0.02
	Integrity score for geomorphology	Environme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Integrity score for vegetation	Environme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Integrity score for herpetofauna	Environme	-0.37	-0.37	-0.31	0.07	-0.06	0.14	-0.06	0.01	-0.02	-0.02	-0.06	-0.06	0.17	0.05	-0.04
	Integrity score for birds	Environme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
	Integrity score for mammals	Environme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Forest area as a proportion of total land area	Environme	-0.10	-0.14	-0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of population below national p	Social	-0.01	-0.01	-0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Proportion of population undernourished	Social	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	Proportion of children under 5 with malnut	Social	-0.01	-0.04	0.04	-0.19	-0.21	-0.21	-0.21	-0.21	-0.21	-0.12	-0.12	-0.13	-0.12	-0.17	-0.07
	Proportion of people living below 50 per ce	Social	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.21	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00

3.3 Cross-sector impacts

Cross sector impacts can either emerge as a synergy or as a trade-off, as explained in an earlier section. From a development perspective, investments gain efficiency if positive side effects in other sectors can be achieved and negative trade-offs can be avoided. Effective development strategies include additional mitigation investments to reduce trade-offs in other sectors, while still realizing the anticipated expansion in the target sector. This section aims to support the understanding of trade-offs and synergies by quantifying the relationship between three focus sectors, i.e. agriculture, hydropower, and fisheries.

The key question for this approach is: "How much does sector X gain or lose in economic benefit for each dollar of additional benefit or loss in sector Y?" The approach is sufficiently simplistic to be added to the overall Council Study design and yet improve understanding for designing more efficient planning strategies. The primary caveat is that only fisheries-related effects have been assessed across all development scenarios. Agricultural production has only be modelled for two sub-scenarios (ALU2, IRR2) and hydropower only for all but the flood scenarios. This is largely because zero or marginal impacts were expected from the respective interventions on these two sectors. Cases in which a sub-scenario has the same value as M3CC, the trade-off results as being zero.

Transboundary effects can be substantial in a context such as the Lower Mekong Basin. Therefore, cross-sector correlation statistics can be calculated in two ways. First, the relation can be made between the impacts on sector X within the country and the gains/losses of sector Y across other Lower Mekong Basin countries. Second, the quantitative relationship between two respective sectors can be constrained to within the boundaries of each country. This section provides results for both perspectives and alerts to some important transboundary effects. The quantified transboundary effect for each cross-sector relationship was derived by calculating the difference between the transboundary effects and the cross-sector effects. The approach aims to inform discussions concerned with the emerging imperative of benefit- and cost-sharing.

LMB-wide agriculture changes ←→ Country-specific impacts on fisheries

The following quantifies the relationship between LMB-wide agriculture changes and country-specific impacts on fisheries. Table 21 quantifies the relationship between agriculture and fisheries and answers how much economic benefit the domestic fisheries sector either gains or loses for every dollar gained in agriculture across the LMB. The values are based on actual modelling results from both sectors, while the values for sub-scenarios not listed in Table 21 have only fisheries-related results, while agricultural effects are assumed to be zero or are missing.

Table 21 Cross-sector relationship between LMB-wide agriculture and country-specific fisheries. "How much in economic benefits does the fisheries sector change if agricultural expansion increases agriculture benefits by $1?"

	ALU 1	ALU 2	IRR 1	IRR 2
Cambodia	$0.00	$0.01	-$0.05	$0.11
Lao PDR	$0.00	$0.00	$0.00	$0.01
Thailand	$0.00	$0.00	$0.00	$0.01
Vietnam	$0.00	-$0.02	$0.01	-$0.15

The results suggest synergies for ALU2 and IRR2 for Cambodia, Lao PDR, and Thailand. Vietnam's fisheries sector, however, is likely to experience further losses under sub-scenario IRR2 (maximum irrigation expansion). For every dollar gained in agriculture about 15 cents are lost in the fisheries sector. A 15% loss would justify the design of specific mitigation measures, which may involve water quality–focused interventions. For sub-scenario ALU2 (maximum expanded agriculture), the 2% trade-off reinforces the negative correlation between agriculture and fisheries for Vietnam. The Cambodian situation is the reverse, as the fisheries sector is likely to gain 11 cents (or 11%) for every dollar gained in agricultural expansion, which is a substantial synergy. Unfortunately, some important effects lack a comprehensive assessment. In particular, climate change–related effects are relevant as the modelling of changes in fish biomass indicate substantial responses across the climate change scenarios. Analysis of the agricultural production across sub-scenarios CC2 and CC3 has not been conducted for the Council Study. CC3, which involves a drier climate until 2040, is likely to introduce additional pressure and stresses on agricultural production. If that assumption is correct, then fisheries-related effects along the Mekong are likely to be exacerbated by agricultural income losses. If not, fisheries losses would be offset by positive income changes in agriculture. The importance of the future response of agriculture to the climate change scenarios warrants further assessment.

Country-specific agriculture changes ←→ Country-specific impacts on fisheries

Shifting the focus to the relationship between agriculture and fisheries within each respective country provides the potential to separate out transboundary effects. Table 22 indicates larger negative cross-sector relationships for sub-scenario IRR1 in Cambodia and Vietnam. The Cambodian fisheries sector is likely to experience a loss of $0.13 for every dollar gained in Cambodian agriculture. In Vietnam, the loss in fisheries is about $0.09 (or 9%).

Table 22 Cross-sector relationship between country-specific agriculture and country-specific fisheries. "How much in economic benefits does the fisheries sector change if agricultural expansion increases agriculture benefits by $1?"

	ALU 1	ALU 2	IRR 1	IRR 2
Cambodia	$0.00	$0.02	-$0.13	$0.00
Lao PDR	$0.00	$0.00	$0.00	$0.06
Thailand	$0.00	-EXP	$0.00	$0.01
Vietnam	$0.00	-EXP	-$0.09	-EXP

Sub-scenario IRR2, on the other hand, is likely to trigger unidirectional effects between agriculture and fisheries in Lao PDR and Thailand. For instance, in Lao PDR every dollar gained in domestic agriculture due to irrigation investments under IRR2 trigger increases in Lao PDR's fisheries sector of $0.06.

LMB-wide hydropower changes ←→ Country-specific impacts on fisheries

Table 23 compares economic changes in fisheries with economic changes in hydropower. Sub-scenario ALU1 generates only marginal, mostly negative changes. The analyses of sub-scenarios ALU2, CC2, IRR1 and IRR2 identify similar patterns, revealing an important cross-sector relationship. Agricultural and climate change–related changes trigger a strong positive correlation in Vietnam, which means that both sectors respond in the same way (unidirectional). For instance, for every dollar of hydropower gains/declines (due to agriculture/climate change), the fisheries sector also gains/declines by 22% (or $0.22). For Cambodia, Lao PDR, and Thailand this relationship is always negative, which means if hydropower gains, then fisheries is likely to decrease, and *vice versa*.

Table 23 Cross-sector relationship between fisheries and hydropower. "How much in economic benefits does the fisheries sector change if hydropower expands by $1 in benefits?"

	ALU 1	ALU 2	CC 2	CC3	IRR 1	IRR 2	HP 1a	HP 1b	HP 3
Cambodia	-$0.01	-$0.08	-$1.54	$0.62	-$1.24	-$0.12	-$0.04	-$0.02	$0.62
Lao PDR	-$0.01	-$0.01	-$0.04	$0.05	-$0.02	-$0.01	-$0.03	-$0.02	$0.02
Thailand	$0.01	-$0.02	-$0.08	$0.09	-$0.02	-$0.01	-$0.04	-$0.03	$0.03
Vietnam	-$0.03	$0.22	$0.30	$0.14	$0.34	$0.15	-$0.02	-$0.01	-$0.01

Most strikingly, Cambodia shows very strong negative relationships for CC2 (wetter climate) and for IRR1. For instance, a wetter climate across the Lower Mekong Basin would cause a considerable gain in the fisheries sector while the hydropower sector would slightly decrease. Such non-linear relationships can provide critical information for management interventions. In this case, it suggests that under wetter climate conditions reductions in hydropower are likely to trigger disproportionately higher benefits in the fisheries sector. While CC3 points out the opposite relationship: If climate change turns out to be drier, both sectors will be effected in the same way (positive correlation coefficient in Table 23). In this particular case, Cambodia's fisheries sector would lose $0.62 for every dollar lost in hydropower. These examples emphasise that the values presented in this section are not the result of a simple causal relationship between two sectors, but can also explain how effects triangulate between two affected sectors.

Sub-scenarios H1a, H1b, and H3 bring this analysis back to a direct cause-effect relationship between hydropower and fisheries. The results for H1a and H1b quantify how much fisheries are likely to gain from a decrease in hydropower. Clearly the fisheries sectors in all four countries would benefit from less hydropower. However, the suggested effect is surprisingly small and ranges between 1%-4%, which is largely because the change in economic benefits in hydropower outpaces fisheries effects by a factor of 7.

Sub-scenario ALU2, however, results in a substantial positive correlation in Vietnam, which results from both sectors being negatively impacted by the agricultural intensification scenario. This strong correlation suggests that for every dollar hydropower declines due to ALU2, the fisheries sector declines by $0.22 (or 22%).

Country-specific hydropower changes ←→ Country-specific impacts on fisheries

Narrowing down the analytical approach to country-level changes in fisheries and hydropower reveals some interesting differences compared to the LMB perspective. Focusing first on the hydropower-specific sub-scenarios indicates a negative relationship between hydropower and fisheries for all countries. Results for H1a suggest that for every dollar Cambodia benefits from hydropower (in Cambodia), the Cambodian fisheries sector declines by about $0.58 (or 58%). In Lao PDR this coefficient is $0.11 for every dollar earned from hydropower. The estimates for Thailand and Vietnam include benefits gained in their hydropower sectors from investments in Lao PDR and Cambodia, respectively.

Sub-scenario H1b quantifies the effects of realizing only tributary dams and no mainstream dams. For Cambodia and Lao PDR the relationship coefficients increase if compared to HP1a, which confirms that mainstream dams have a stronger impact on fisheries than tributary dams.

Table 24 Cross-sector relationship between country-specific fisheries and country-specific hydropower benefits. "How much in economic benefits does the fisheries sector change if hydropower benefits expand by $1?"

	ALU 1	ALU 2	CC 2	CC3	IRR 1	IRR 2	HP 1a	HP 1b	HP 3
Cambodia	-$5.83	$38.90	$8.29	$19.41	$22.84	-$31.09	-$0.58	-$0.61	-$33.74
Lao PDR	-$0.01	-$0.01	-$0.03	$0.12	-$0.03	-$0.01	-$0.11	-$0.12	-$0.13
Thailand	$0.01	-$0.04	$0.22	$0.16	-$0.04	-$0.02	-$0.08	-$0.05	$0.02
Vietnam	-$6.20	-$97.83	-$11.08	$2.82	-$1.31	$10.72	-$0.09	-$0.08	$0.09

Turning to sub-scenario H3 reveals interesting impacts of mitigation investments on the fisheries sector if both are limited to the domestic perspective. The high negative coefficient for Cambodia suggests that the strongest gains from mitigation investments in hydropower could be achieved in Cambodia's fisheries sector. For every dollar lost in Cambodia's hydropower, the Cambodian fisheries sector would gain about $33.74. However, this involves very low absolute levels as the Cambodian hydropower losses add up to $67 million in net present value over the 24-year period. The macroeconomic assessment report provides the details on these sector benefit calculations.

The cross-sector coefficients for Thailand and Vietnam are positive, which results from their hydropower investments in Lao PDR and Cambodia, respectively. These coefficients suggest that mitigation investments in the hydropower sector improve the economic return in both sectors, hydropower and fisheries, in both countries.

The other scenarios need to be seen as triangulated effects as changes in hydropower and fisheries are a consequence of investments in agriculture and climate change. Sub-scenarios ALU1 and IRR2 trigger trade-offs between hydropower and fisheries: if one of these two sectors gains, the other is likely to incur losses. Sub-scenarios ALU2 and IRR1 result in the opposite, as values are positive and indicate a synergetic relationship. This means that if one of the two sector gains, the other will also increase, and if one of the sectors declines, the other one will also incur losses.

Interestingly, the resulting coefficients for Vietnam are the opposite of Cambodia's results, apart from ALU1, which is largely because of Vietnam's hydropower investments in Cambodia and the assumption that losses related to power generation are likely to affect the host countries (in this case Cambodia) more than the investors (in this case Vietnamese companies).

Climate change affects Vietnam's fisheries and hydropower differently. Under wetter conditions a negative relationship emerges between these two sectors, as impacts will occur in opposite directions, while drier climate change is likely to affect both sector in the same way (unidirectional). Drier climate is likely to affect hydropower and fisheries in the same way in all LMB countries, which means that both are likely to incur costs.

LMB-wide hydropower changes ←→ Country-specific impacts on agriculture

The relationship between hydropower and agriculture is the third link investigated by this assessment. As mentioned earlier, impacts of the sub-scenario changes on agricultural sectors are only available for ALU1, ALU2, IRR1, and IRR2. In this first step the link is created between LMB-wide changes in economic benefits from hydropower investments and country-specific returns from agriculture.

ALU1 assumes agriculture is reduced to the level of 2007 (while all other investments under M3CC are realized as planned for 2040). Positive correlation coefficients emerge. This means both sectors move into the same direction. With agriculture declining under ALU1, hydropower returns also decline. The agricultural production increase under ALU2, however, coincides with a decline in hydropower benefits in Cambodia and Lao PDR, while effects in Thailand and Vietnam remain neutral. Similar to sub-scenario ALU1, the reduction of irrigation investments (IRR1) affects agriculture and hydropower in the same unidirectional way, apart from Vietnam, where the opposite occurs. For sub-scenario IRR2 negative relationships emerge for agriculture in Thailand and LMB-wide hydropower returns. Lao PDR also shows a small countervailing relationship between its agriculture and LMB-wide hydropower.

Table 25 Cross-sector relationship between LMB-wide hydropower and country-specific agriculture. "How much in economic benefits does the agricultural sector change if hydropower expands by $1 in benefits?"

	ALU 1	ALU 2	IRR 1	IRR 2
Cambodia	$32.84	-$4.81	$9.27	$0.00
Lao PDR	$2.79	-$7.29	$7.31	-$0.09
Thailand	$4.66	$0.00	$11.97	-$0.96
Vietnam	$11.85	$0.00	-$3.88	$0.00

Country-specific hydropower changes ←→ Country-specific impacts on agriculture

The comparison of LMB-wide benefits of hydropower and country-specific agriculture effects seems to be more academic than practical if the scope is limited to the four agriculture-related sub-scenarios. It would be important to quantify the impacts of hydropower variations (e.g. H1a, H1b, and H3) on agriculture to complete the analysis of this cross-sector assessment.

The results of the comparative analysis of country-specific hydropower impacts and country-specific agricultural impacts is reported in Table 26.

Table 26 Cross-sector relationship between LMB-wide hydropower and country-specific agriculture. "How much in economic benefits does the agricultural sector change if hydropower expands by $1 in benefits?"

	ALU 1	ALU 2	IRR 1	IRR 2
Cambodia	+EXP	+EXP	-EXP	$0.00
Lao PDR	$5.28	-$13.64	$8.15	-$0.19
Thailand	$9.97	$0.00	$28.82	-$1.98
Vietnam	+EXP	$0.01	$15.08	$0.00

Table 26 indicates largely positive cross-sector relationships, which means that if one of the sectors gains, then the other sector is also likely to gain. If one of these two sectors declines, then the other sector is also likely to decline. The important exceptions include Lao PDR under sub-scenario ALU2 and Thailand for sub-scenario IRR2. In these two cases, (strong) trade-offs occur, which implies for

Lao PDR that the hydropower returns decline, while agricultural benefits under ALU2 increase. Similarly for Thailand, agricultural returns increase under IRR2, while hydropower benefits declines.

3.4 Transboundary impacts

The assessment of development plans in the lower Mekong basin requires considering the transboundary context in which many of the consequences unfold. This Section aims to distinguish which portion is due to transboundary consequences and, therefore not due to domestic policy and planning. The following analysis attempts to separate out transboundary effects for the sustainability index and the cross sector dynamics.

Quantifying the portion of change in the sustainability index that is due to transboundary decisions is challenged by the need to attribute effects despite cross-disciplinary dynamics, which is explained below. However, this analysis aims to demonstrate the principle idea and to highlight some key insights and recommendations.

The quantification of transboundary elements of cross-sector dynamics is fundamental for the understanding of benefit sharing mechanisms, which is explained further below.

3.4.1 Transboundary Impacts on the Sustainability Index

Section 3.2 presented largely negative impacts of the proposed development plans on the sustainability of the lower Mekong basin. From a country perspective many sustainability criteria are being affected by decisions across the border. Politically, it is pertinent to distinguish transboundary from domestic effects because each requires different interventions and mitigation approaches.

The methodology described earlier requires two principle steps. First, the percentage is calculated for benefits of each sector within each country (with all sectors adding up to 100% for each country). Second, the percentage of benefit for each country is calculated for each sector across the lower Mekong basin (with all countries adding up to 100% for each sector). The multiplication of both weights approximates the relative dominance of transboundary impacts. This simple approach is used in absence of country specific scenarios. The exact calculation of transboundary effects would require scenarios that include only the development for one country at a time. The assessment of such country-specific scenarios quantifies transboundary impacts. In absence of numerical results for transboundary effects Table 27 provides some limited guidance for understanding transboundary impacts on the sustainability index.

Table 27 Estimates for transboundary impact on sustainability index change

	M2	M3	A1	A2	I1	I2	H1a	H1b	H3
Cambodia	66%	40%	37%	60%	62%	100%	92%	96%	96%
Lao PDR	27%	80%	81%	43%	70%	91%	77%	83%	96%
Thailand	41%	51%	91%	99%	51%	9%	48%	37%	100%
Vietnam	20%	77%	77%	100%	84%	100%	83%	85%	12%
	Multi-disciplinary attribution challange		Misleading as disproportional cause-effect relationships				Potentially meaningful		

Table 27 lists approximations for transboundary impacts on the sustainability in each Member Country. Methodological constraints and the absence of country specific scenarios qualifies the relevance of the results in three groups. The least meaningful group are the results for agricultural scenarios (A1, A2, I1, and I2). These are only listed to highlight the methodological limitations and the need for country-specific scenarios. The results for agricultural scenarios quantify the proportional difference in impacts between countries and not transboundary effects. In other words, agricultural interventions in some countries have a larger impact on their own sustainability indicators than in other countries. The calculation made develops an impact coefficient; the lower the number the worse the cause effect ratio. Consequently, the results for this group cannot be used for estimating transboundary impacts. Instead, transboundary impacts for these four scenarios are close to or equal 0%.

Results for hydropower-focused sub-scenarios (H1a, H1b, and H3), however, provide better guidance although results can only be interpreted as a comparison between the four countries. The challenge is again that the same magnitude of an intervention has different levels of impacts within the country. Without country-specific scenarios the transboundary effect cannot be completely isolated. However, it is likely that the ordinal result would remain robust: Cambodia is likely to suffer the highest level of transboundary impacts on its sustainability from hydropower in the lower Mekong basin, in particular from mainstream dams. Vietnam is likely to follow second. Thailand is likely to have the lowest transboundary effects on its sustainability. It is critical to emphasise that this approach uses benefit streams as a way to delineate transboundary from domestic effects and not the location of development projects. If Thailand's benefits from hydropower in Lao PDR were to be ignored and the approach was limited to the geographical location of development projects, Thailand would rank higher and Lao PDR would rank with the lowest transboundary impacts on its sustainability.

Main scenarios M2 and M3 include meaningful and misleading elements, which cannot be eliminated without country-specific scenarios. These results have only been listed to demonstrate the methodological challenge and the need for country-specific scenarios to effectively determine which portion of the sustainability loss described in Section 3.2 is due to transboundary dynamics.

While this attempt to delineate transboundary impacts on sustainability is highly limited, the following approach is considerably more robust. The following is focused on quantifying transboundary impacts on cross-sector trade-offs and synergies, which provides the foundation for understanding and designing burden sharing or benefit sharing mechanisms.

3.4.2 Transboundary Impact on Cross-Sector Dynamics

The following analyses transboundary impacts in a cross-sector perspective, which is fundamental for creating the foundation for burden sharing or benefit sharing solutions. This part of the assessment covers a fisheries perspective and a sediment perspective as the two most critical dimensions of negative externalities among transboundary impacts. Hydropower as a critical positive externality of transboundary effects is introduced when discussing possible burden sharing mechanisms further below. Other transboundary effects, including migration and crop price effects, cannot be considered at this stage due to methodological limitations.

Fisheries focus

Development plans for the Lower Mekong Basin involves a multitude of investment projects across multiple sectors. The previous section quantified some of the key cross-sector relationships and identified the potential to create sector synergies and trade-offs that will need to be managed. However, many effects within sectors and cross-sectors cannot be readily managed from a country perspective because they are caused by cross-border investments. Transboundary effects have become a major topic of MRC discussions and triggered many questions related to benefit sharing.

An economic perspective of benefit sharing would first require the identification and quantification of the benefits and costs of development investments and the relative source and destination. In a second step, practical mechanisms and instruments would need to be designed that provide the right incentives to re-allocate benefits/costs to affected interests. This section aims to produce relevant results for the first step and start framing some principle options for the second step.

The most important insight this study can provide is that any effective benefit-sharing mechanism needs to approach the issue from a cross-sector perspective. The approach departs from the widely endorsed country-only perspective, as the most disadvantaged would be among fishing households, while energy companies and their shareholders retain the majority of benefits. Affected households are located in all four LMB countries as are hydropower energy companies. The most effective mechanism would fully compensate disadvantaged households (independent of their geographic location) and internalise costs in the proposed investments (independent of the country origin of the investor).

Table 28 Transboundary ‘contribution’ to national hydropower-fisheries trade-off

	M2- M1	M3- M1
Cambodia	90%	92%
Lao PDR	69%	77%
Thailand	56%	47%
Vietnam	85%	84%

Table 28 explains why the LMB would be the most efficient level for such a benefit-sharing mechanism. It quantifies the proportion of losses in national fisheries caused by transboundary investments. The transboundary impact varies from country to country and between scenarios (and also the absolute values vary as shown beforehand), demonstrating that each country could theoretically approach their own benefit-sharing mechanism to compensate fisheries-dependent households by a share of (or levy on) hydropower profits. However, the differences indicate that any LMB-wide solution would be beneficial.

The quantification of transboundary effects is a complex exercise because many relationships are non-linear. For instance, investments in one sector might have small effects on a second sector if the investments are relatively small. Larger investments have the potential to cross a critical threshold whereby the rate and magnitude of side effects increase rapidly. Increased effects might then suddenly decline if investments in the first sector have become very large and cross a second threshold. The sigmoidal curves that typically describe population growth are an example of rapidly increasing and rapidly declining thresholds. Identifying critical thresholds would be an important step of effective decision support. However, it would require more sophisticated dynamic modelling capable of integrating the relevant impacts and their interactions. Previous assessments of development plans in the Lower Mekong Basin have used the Mekong Region Simulation (MerSim) model. Unfortunately, time and resource constraints did not allow for implementing the model for the Council Study. Based on the available spreadsheet tools, which do not take dynamic interactions into account, the estimated trade-off coefficients are specific to the investment bundles of the Council Study development scenarios. These transboundary (and also the cross-sector) coefficients would change if the investment attributes of development scenarios were modified. Minor changes in the scenario definitions are likely to change the coefficient estimates. Consequently, results from this study cannot be reliably transferred to scenarios other than the ones defined by the Council Study .

The first approach for addressing benefit sharing compared sector impacts in key sub-scenarios. The difference between scenario M3 (2040) and sub-scenario H1a (no hydropower) quantifies the negative externalities likely to affect fisheries by the combined bundle of mainstream and tributary hydropower projects. The difference between M3 and sub-scenario H1b (only tributary dams) quantifies the impact of tributary dams only. The difference between these two comparisons approximates the impact of mainstream dams.

Table 29 Comparison of hydropower benefits and fisheries cost for H1a and H1b

	In B$	Hydropower benefits	Fisheries costs	National Cost-Benefit Ratio	Possible Benefit Transfer Levy
Mainstream & tributary dams (2040 scenario)	**Cambodia**	11.1	6.5	58%	
	Lao PDR	36.3	4.0	11%	Mainstream HPP: 18.9%
	Thailand	82.9	6.5	8%	
	Vietnam	26.7	2.5	9%	
Only tributary dams (2040 scenario)	**Cambodia**	3.7	2.3	61%	
	Lao PDR	17.3	2.1	12%	On tributary HPP: 8.6%
	Thailand	63.7	3.1	5%	
	Vietnam	15.2	1.2	8%	

Table 29 compares the country-specific hydropower benefits with the fisheries costs, which result as a side effect of hydropower investments. Critical for this comparison is that hydropower benefits are not retained in the countries where dams are or would be located. Substantial benefits are already "shared" as Thailand's energy companies seek returns on their investment in Lao PDR, and Vietnam's energy companies would benefit from Cambodia's hydropower expansion. From a national perspective, a substantial proportion of total benefits is already being shared, implemented through investment mechanisms. However, the national fisheries sectors are likely to experience substantial losses as illustrated in Table 29 and generally remain excluded from existing investment-based benefit sharing unless corrective distributional systems are in place. The comparison of multiple sectors at the national level can help identify the combined advantages, however, stakeholders from a negatively affected sector typically only incur losses without compensation. Consequently, benefit sharing needs to be concerned with sectors as much as with countries.

This leads to potential mechanisms to compensate affected stakeholders for their losses. Theoretically, the first option could be that fisheries would be compensated at a country level, which could involve a levy similar to the cost-benefit ratios estimated in Table 29. This would involve countries and/or energy companies making a payment similar to an additional tax on hydropower returns. This "tax" would range between 5% for Thailand's companies for mainstream dams and 61%

for Cambodia's companies for the construction of mainstream dams, as shown by Table 29. Clearly, such a country-specific mechanism ignores large elements of transboundary effects. A more inclusive mechanism takes a LMB-wide perspective, which would result in a LMB-wide levy of 8.64% of annual profits for tributary hydropower developments. The difference between the M3-H1a comparison and the M3-H1b comparison reveals the impact of mainstream hydropower alone and leads to an estimated levy of 18.9% of annual profits. Technically, this levy would apply to the entity receiving hydropower revenues, which includes private companies as well as government agencies.

The macroeconomic assessment emphasized an important mechanism that is relevant for the benefit sharing discussion. It points out that prices for fish and other aquatic animals are very likely to change. These price changes are likely to be species-specific, or at least guild-specific, as the BioRA report indicates very different results for the guilds considered in this study. Increasing prices translate into a higher income per kg catch, which means that some of the compensation is likely to be realised through the market mechanism of fisheries products. The consumer of such products would in these cases bear the externality burden. The more costs are compensated through the market mechanism the more the levies suggested above could be reduced. These mechanisms are clearly interrelated, which means that if the levy was imposed as suggested above, fish prices would not have to increase. A sustainable development perspective demands evaluating dynamic processes that require more sophisticated socio-economic modelling to identify:

- which hydropower projects are likely to be most beneficial;
- which sectoral trade-offs and which transboundary effects would result from the "optimal" set of projects;
- what compensation levels would be required; and
- which benefit-sharing mechanism would be most effective.

Any additional levy would trigger an investigation into the viability of several hydropower projects, which is a typical result of internalising external effects. However, the information underpinning this analysis indicates that the majority of hydropower projects would still be profitable and therefore likely to be implemented. Importantly, once a few projects are withdrawn from the M3CC bundle, the external effect on fisheries and the levy would also change, which cannot be captured by the current Council Study methodology. Such a dynamic analysis demands more sophisticated methods, such as socioeconomic simulation models.

An additional challenge is the distribution of funds to equitably and effectively implement benefit sharing. Compensation payments between countries do not automatically compensate affected stakeholders. Countries would have to think about mechanisms that effectively reach affected stakeholders without initializing adverse or perverse incentives. Theoretically, a central (country-by-country or LMB-wide) fund could be established and fishermen could be compensated based on their catch estimated for a (future) situation without hydropower expansion. This and other information would need to be collected in a central register as a precursor of compensation payments. While these steps might appear trivial, without robust auditing of the baseline condition (the sustainable fish catch, how many fishers, their current catch, and the security of fishing rights) they can quickly establish perverse incentives as several assessments of payment for ecosystem services have shown. The analysis of such compensation mechanisms would be absolutely critical for realizing an effective benefit-sharing mechanism.

Erosion

The macroeconomic assessment report provides an overview of costs for river embankments that would need to be constructed to avoid hydropower-driven erosion. The total costs are estimated to be nearly $5.7 billion for the 2040 development scenario and $866 million for the 2020 scenario.

Table 30 Distribution of costs for river embankments caused by hydropower

	Lao PDR	Thailand	Cambodia	Vietnam
Scenario M2	26%	64%	2%	8%
Scenario M3	17%	17%	28%	37%

Table 30 quantifies how the costs for additional river embankments would be distributed among Lower Mekong Basin countries. Thailand would expect the highest cost share of 64% for the 2020 scenario, around $551 million, while Lao PDR would face costs of around $228 million.

For scenario M3, the distribution of costs for additional river embankments would shift substantially. Vietnam is likely to face the highest share of 37% (around $2.1 billion) and Cambodia of 28% ($1.8 billion).

These costs could be addressed by a burden-sharing mechanism. According to the hydrological assessment results

- 35% of the responsible sediment loss is caused by dams in the Lancang,
- 30% by tributary dams of the lower Mekong basin,
- 32% by mainstream dams in the Mekong, and
- 3% by processes in the Mekong Delta.

A proportional mapping of costs would lead to a levy of 1.20% for mainstream dams and 1.12% for tributary dams. This assumes that the Lancang effects ($1.98 billion) are compensated by alternative mechanisms. If this levy for compensating erosion-related costs was combined with the fisheries-focused levy, a combined levy of 9.76% on annual profits from tributary dams and 20.1% on annual profits from mainstream dams would result. The evaluation of benefit sharing and compensation instruments is a broad guide for revised cost calculations, and it might be impractical to combine both burden-sharing mechanisms as the compensation of fisheries costs would need to reach the disadvantaged households, while erosion-related costs are largely faced by the governments.

4 Conclusions and Recommendations

The CIA integrates the results and insights from the other Council Study disciplinary and thematic assessments, but does not replace them. The integration echoes many issues raised by other assessments:

- Development plans include a few highly beneficial hydropower and agriculture projects.
- However, the combined development plans for 2020 and 2040 are likely to trigger a decline in resilience, vulnerability, and sustainability of communities in the Lower Mekong Basin.
- Poor households are likely to be most disadvantaged. The urban poor are likely to face considerable challenges as food prices are likely to increase.
- Overall sustainability effects of the development strategies as defined by the main scenarios would cause substantial sustainability losses, which could be avoided or even reversed by adjusting investment levels in hydropower and agriculture.
- Projected climate variation in several years of the 24-year projected time horizon, combined with the loss of fish-based protein, is likely to create conditions of acute levels of food insecurity in communities in Lao PDR and Cambodia.
- The emerging trade-offs between hydropower and fisheries are substantial and suggest a project-by-project assessment to identify the most harmful and the most beneficial projects.
- Transboundary effects would be significant, combining (a) positive effects for Thailand and Vietnam as return on investments from hydropower in Lao PDR and Cambodia, and (b) negative effects due to losses in fisheries and river sediments.
- Benefit-sharing mechanisms would need to be designed considering important socioeconomic interactions. A hydropower-fisheries focused levy would amount to 18.9% on annual profits from mainstream dams and 8.6% for tributary dams.
- Hydropower is predicted to cause erosion, requiring $6.8 billion for riverbank re-enforcements. A cost-sharing levy amounts of 1.20% on mainstream annual dam profits and 1.12% for tributary dams.

An emerging recommendation is that the large bundles of investment projects considered in this study need to be assessed on a project-by-project basis to identify sustainable development pathways. Sub-scenarios suggest that hydropower and agriculture investments are likely to have the largest impacts and appear to combine both highly beneficial and highly unsustainable projects. A disaggregated assessment would require more robust assessment methods that adequately integrate socioeconomic and biophysical interactions.

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