Drought Management Strategy
For the Lower Mekong Basin 2020 - 2025
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Process
This document was prepared by the MRC Secretariat. The first draft version 1.1 was discussed in the first regional consultation workshop on 12 December 2017 in Siem Reap, Cambodia and, thereafter, was updated to version 1.2 and discussed in the national consultation meetings with the MRC Member Countries during February and March 2018. The version 2.1 document was then prepared by incorporating inputs from national consultants on national issues and needs and was discussed again in the Second/Final Regional Consultation Meeting on 26 February 2019 in Bangkok, Thailand.

The update version 2.2, attributed to the recommendations and advice by the Member Countries during the Final Regional Consultation and Office of the CEO of the MRC Secretariat, was submitted to the MRC Joint Committee in August 2019 for the 49th Joint Committee Meeting in September for consideration and approval. The meeting had some additional advice and feedback for the Secretariat to address before final decision on granting approval to the document.

This final version updated in November 2019 was sent to the Member Countries, with the Joint Committee and Council Meeting on 25-27 November 2019 providing endorsement and approval for implementation of the Drought Management Strategy.
Preface
Executive Summary

In the past few decades, the Lower Mekong Basin (LMB) has been experiencing severe drought hazards with serious economic losses due to damages of agricultural crops, negative impacts on the environment, and effects on people's livelihoods. The impacts have extended from agricultural water use to industry and domestic water consumption. The duration and magnitude of the impacts have significantly increased over the past two decades if comparing the drought hazards from one event to another. This is a strong indication that the lower Mekong region is currently at high risk of droughts, and the trend is growing.

In addition, with different climate scenarios, the LMB is likely to see more severe droughts in the next 30, 60, and 90 years due to less precipitation, high air temperature, and high evapotranspiration. The increase of population, from currently more than 60 million people relying on the Mekong water to about 100 million people in ten years’ time, also increases water demands from all sectors. These are the reasons why the MRC Secretariat was requested by the MRC Joint Committee to formulate a regional strategy for drought management and mitigation.

This Drought Management Strategy (DMS) 2020-2025 was developed based on a series of national and regional findings, including a drought risk assessment of the LMB, national drought impacts and vulnerability assessments, crop modelling and scenarios on land and water availability, and information from national drought early warning systems. The objectives and strategic goals of the DMS 2020-2025 are formulated based on the objectives and strategic goals of the Drought Management Programme 2011-2015, which were defined through a number of national and regional consultations to incorporate the needs of the Member Countries into the proposed outputs and action plans for implementation.

Though drought has been posing a serious threat to the region for decades, it is still new to the Mekong countries in terms of adaptation and mitigation. The national strategies for disaster risk management and mitigation are largely or solely focused on floods, rather than droughts. Therefore, until now, almost no concrete national drought management policies and mitigation strategies are available for reference.

The DMS 2020-2025 is a regional strategy aiming to address interests and needs in drought management and mitigation in the MRC Member Countries. It has been reviewed and discussed with all relevant agencies and stakeholders, including the MRC Expert Group on Data, Modelling and Forecasting, before being finalised and approved by the Joint Committee. To achieve a regional perspective, issues of regional relevance contained in national policies, strategies, and plans were compared with the MRC policies, strategic priorities, and actions, as defined in the Basin Development Strategy (BDS) 2016-2020 as well as the Mekong Adaptation Strategy and Action Plan (MASAP).

The DMS 2020-2025 has five main clusters, each with specific priority areas:

(i) Indicator Monitoring
   (a) Hydro-meteorological and reservoir monitoring
   (b) Monitoring on agreed dry season flows (Article 6A) under the Procedures for Maintenance of Flows on the Mainstream (PMFM), and Procedures for Water Use Monitoring (PWUM)
   (c) Groundwater monitoring
   (d) Soil moisture and crop condition monitoring
   (e) Salinity level monitoring
(ii) **Drought Forecasting and Early Warning**
   (a) Drought monitoring
   (b) Drought forecasting and early warning

(iii) **Capacity Building in Drought Assessment and Planning**
   (a) National and regional trainings
   (b) Regional and international workshops and conferences
   (c) Experience exchanges with other river organizations

(iv) **Mitigation Measures**
   (a) Collaboration with MRC Dialogue Partners
   (b) Collaboration with national agencies and regional institutions on drought disaster management
   (c) Feasibility study on basin water retention through collaboration with Thailand on the Monkey Cheeks or Kaeng Ling project
   (d) Water demand management measures
   (e) Development of guideline on drought adaptation
   (f) Pilot activities on drought adaptation measures

(v) **Information Sharing and Dissemination**
   (a) Drought information dissemination
   (b) Drought data and information documentation

Recommendations are made regarding the alignment of the DMS 2020-2025 strategic priorities and actions with the strategic priorities and actions outlined in the BDS and the MASAP.
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<td>ADPC</td>
<td>Asian Disaster Preparedness Centre</td>
</tr>
<tr>
<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
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<tr>
<td>BDS</td>
<td>Basin Development Strategy of the MRC</td>
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<tr>
<td>CDI</td>
<td>Combined Drought Indicator</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CHIRP</td>
<td>Compressed High Intensity Radiated Pulse (Satellite)</td>
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<tr>
<td>CMI</td>
<td>Crop Moisture Index</td>
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<td>DMP</td>
<td>Drought Management Programme of the MRC</td>
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<td>DMS</td>
<td>Drought Management Strategy of the MRC</td>
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<tr>
<td>DMT</td>
<td>Drought Management Team</td>
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<td>DSF</td>
<td>Decision Support Framework</td>
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<td>Drought Severity Index</td>
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<td>ENSO</td>
<td>El Niño/Southern Oscillation (ENSO)</td>
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<tr>
<td>GFS</td>
<td>Global Forecast System</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System, software</td>
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<td>GISDA</td>
<td>Geo-informatics and Space Technology Development Agency</td>
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<tr>
<td>GIZ</td>
<td>Deutsche Gesellschaft für Internationale Zusammenarbeit</td>
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<tr>
<td>GMI</td>
<td>Generalized Monsoon Index</td>
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<tr>
<td>GPM</td>
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<td>GRACE</td>
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<td>GRI</td>
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<td>HMS</td>
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<td>HYCOS</td>
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<td>IKMP</td>
<td>Information and Knowledge Management</td>
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<td>IOD</td>
<td>Indian Ocean Diploe</td>
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<tr>
<td>IQQM</td>
<td>Integrated water Quantity and Quality simulation Model</td>
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<td>IRI</td>
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<td>IWRM</td>
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MRC  Mekong River Commission
MRCS  Mekong River Commission Secretariat
NASA  National Aeronautics and Space Administration, US
NASA JPL  NASA Jet Propulsion Laboratory, US Agency
NCDM  National Committee for Disaster Management
NCEP  National Centres for Environmental Prediction
NCHMF  National Centre for Hydro-Meteorological Forecasting
NDVI  Normalized Difference Vegetation Index
NMCs  National Mekong Committees
NMME  North America Multi-Model Ensemble
NOAA  National Oceanic and Atmospheric Administration
PDSI  Palmer Drought Severity Index
PET  Potential Evaporation
PMFM  Procedures for Maintenance of Flows on the Mainstream
PWUM  Procedure on Water Use Monitoring
QA/QC  Quality assurance and quality control
RFDMC  Regional Flood and Drought Management Centre
RHEAS  Regional Hydrological Extreme Assessment System
SDI  Stream-flow Drought Index
SDG  United Nations Sustainable Development Goals
SERVIR  Regional Visualization & Monitoring System
SMDI  Soil Moisture Deficit Index
SMI  Soil Moisture Index
SMOS  Soil Moisture and Ocean Salinity (satellite)
SPI  Standardized Precipitation Index
SRI  Standardized Runoff Index
SWAT  Soil and Water Assessment Tool
TM  Thematic Mapper
TRMM  Tropical Rainfall Measuring Mission (satellite)
USAID  United States Agency for International Development
1. INTRODUCTION

1.1. Rationale: Why do we need the MRC Drought Management Strategy?

The Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin—or the 1995 Mekong Agreement, as it is informally known—documents the commitment of the four Member Countries, Cambodia, Laos, Thailand, and Viet Nam, to promote, support and coordinate the mutually beneficial cooperation in all fields of sustainable development and management of the Mekong River Basin, with emphasis on joint and/or basin-wide projects, programmes, and basin planning. For example, in Article 1, the riparian states pledge to

‘...cooperate in fields of sustainable development, utilisation, management, and conservation of the water and related resources of the Mekong River Basin, including, but not limited to ...’

Additionally, Article 2 commits the Member Countries to

‘...cooperate and coordinate in the development of the full potential of sustainable benefits to all riparian States...with emphasis and preference on joint and/or basin-wide development projects and basin programmes through the formulation of a basin development plan...to implement at the basin level.’

The above two articles indicate that the Mekong Agreement provides a broad mandate for the MRC in relation to drought management that can generate a sustainable and basin-wide benefits by reducing the impacts of drought on agriculture, socio-economics, and the environment.

The need for drought management work in the MRC’s programmes was recognised in 2010 and on 4 March 2011, the four MRC Member Countries reaffirmed their need for moving forward with developing an effective regional drought risk management strategy to cope with meteorological, hydrological, agricultural, and socio-economic drought vulnerability. The process for formulating the Drought Management Strategy included a regional study on drought risk assessment for the LMB in 2013, national studies and fact-finding missions between 2013 and 2017 and a regional study on land and water resources analysis in 2017-2018. The draft drought strategy report was discussed at a regional consultation workshop on 12 December 2017 in Siem Reap, Cambodia. National consultation workshops were held in February and March 2018 and a second regional consultation workshop was held on 26 February 2019 in Bangkok, Thailand. After approval of the draft Drought Management Strategy 2020-2025 by the MRC Joint Committee, the following tasks will follow:

- Based on the strategy preparatory works, formulate a draft five-year project work plan, including detailed bankable project components, and elaborating the details of the action plan;
- Review of the draft work plan and action plan by the four countries;
- Conduct a regional workshop to discuss the detailed work plan and action plan;
- Finalise the action plan and the detailed project components;
- Incorporate the drought management five-year work plan into the MRC’s annual work programme under the new structure of the Regional Flood and Drought Management Centre (RFDMC).

1.1.1. 2016 drought

The latest drought in 2016 has broken the MRC 100-year historical record for Mekong water scarcity, high temperature and severe levels of salinity intrusion in the Mekong Delta. The impacts brought serious economic...
losses to Thailand, estimated at US$1.7 billion (62 billion BHT). The Government of Thailand recognised the seriousness of the threat posed, regarding it as the highest priority issue the country is facing, and has put in place immediate drought relief measures. The official Thai national drought status report, dated 5 February 2016, listed 55 districts, 290 counties, 2,666 villages, and 14 provinces, including 13 provinces that lacked sufficient water for agriculture. This means that more than 50% of the total area of the Mekong watershed in north-eastern Thailand was at a critical drought status.

Meanwhile, the Government of Viet Nam reported: “more than 200,000 tons of rice were damaged, resulting in a loss of over 1 trillion VND (US$44.64 million) to the Mekong Delta region. The Ministry of Agriculture and Rural Development (MARD) reported in early 2016 that salt water intrusion appeared two months earlier than previous years due to serious river water shortages. The salinity in the Vam Co, Tien, and Hau rivers and other rivers near the West Sea is now higher than traditional levels. Meanwhile, salt water has intruded 50–60 km upstream into the mainland up to even 93 km in the Vam Co River’s neighbourhood, about 15–20 km deeper than previous years. That was the worst salt water intrusion so far in the rice hub of Viet Nam, according to MARD. In the winter–spring crop 2015–2016, more than 339,200 ha of rice in coastal Mekong Delta provinces were affected by salt water intrusion and drought, accounting for 35.5% of the rice-producing area in these localities and 21.9% of the region’s total rice-producing area. Of the 339,200 ha, 104,000 ha were severely impacted. Total costs of the 2016 drought amounted to US$669 million (VND15 trillion) and costs to recover from the drought were estimated at US$1.5 billion (VND 34 trillion).

In Cambodia, water scarcity started looming in rural areas in early 2016, affecting both agriculture and domestic water consumption. The National Committee for Disaster Management (NCDM) announced on 24 April 2016 that drought caused water shortages in 18 out of 25 provinces, with 2.5 million people lacking water.

In Lao PDR, the 2015 drought that started in December 2014 affected more than 1,000 hectares (2,470 acres) of upland crop areas with 420 hectares (1,040 acre) reported as seriously damaged, according to Agriculture and Forestry Department officials in the province. More than 104,000 hectares (256,990 acres) of freshly planted rice seedlings were also affected, with some 48,000 hectares (118,610 acres) in the districts of Ngeun, Xienghon, Phiang and Kaenthao sustaining notable damage. Additionally, crops such as sweet corn, sesame and job’s tear fruit were affected on more than 8,000 hectares (19,770 acres) with some 3,800 hectares (9,390 acres) reported as damaged. The drought continued up to 2016.

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In general, droughts have severe impacts on the socio-economic conditions in a country and affect specifically the livelihoods of poor communities and people living in rural areas. This is about 85% to 90% of the population in the LMB region.

Next to saltwater intrusion in delta areas, salinization of groundwater may occur in coastal areas due to higher pressure from seawater and increased groundwater abstraction in times of drought. Salinization is consequently an important impact of droughts.

These are among the main reasons why the MRC needs a regional drought management strategy. The strategy is “to support the Member Countries in managing and mitigating drought impacts and vulnerability in terms of water management and planning to reduce water shortage in the dry season.”

1.1.2. Transboundary effects

The drought devastation in 2016 is also an example of a regional drought management issue that needs an immediate measure and collaborating support from upstream countries that are in control of water storage and regulation. For instance, seeing such a serious situation with abnormally low flows in the Mekong mainstream, the MRC Member Countries called for an emergency release of water from Chinese dams in January 2016 to ensure sufficient river levels downstream, mainly for agriculture. Subsequently, China responded positively to the request by releasing a considerable amount of water, 12.65 billion cubic meters, from March to May 2016 from the Jinghong dam to supply downstream countries.

Another convincing piece of evidence supporting drought as a transboundary issue is the devastating level of salinity intrusion in the Mekong Delta, which was due to insufficient rainwater from both local and regional locations. This in turn decreased the extent of the flooding of the Cambodian flood-plain in the Tonle Sap area, compared to usual levels. The Tonle Sap Lake functions as a central heart that pumps the flooded water out to the lower part of the Mekong basin and to the Mekong Delta after the end of each rainy season, when the flow of the Mekong Mainstream drops down to normal levels (Campbell, Say, & Beardall, 2009). Significant lack of flood-water in Tonle Sap, due to either insufficient rainwater or inflows from upper parts of the mainstream, means none or little water will be drained from Tonle Sap to the Mekong Delta during the beginning of the next dry season. This reduces the flow in the delta and triggers salinity intrusion from inflowing sea-water. Thus, insufficient flooding of the Tonle Sap flood-plain during the wet season can cause a serious salinity issue in the Mekong Delta during the next dry season, showing a transboundary connection between the lower Mekong countries. To mitigate such transboundary impacts of droughts, a close coordination and collaboration is ultimately needed, with a proper and transparent joint management plan. The MRC Secretariat can play a key role in this sense to establish regional coordination and collaboration to manage and mitigate these regional threats.

At the local level, on the other hand, measures can be taken to mitigate the local drought impacts, like building small water storage reservoirs. The MRC Secretariat can play a role in supporting capacity development to develop and implement such measures.

Based on this concept, the DMS 2020-2025 is developed to “support the Member Countries in managing water resources in the region to mitigate regional and transboundary drought hazards”.

1.1.3. Developments in the LMB

Another consideration is that, based on the MRC’s projection, the population of the Mekong region will keep growing rapidly, from 60 million people currently using the Mekong water to 100 million people in about ten years. This will lead to increased water demands in different sectors, while the water resources of the Mekong River are not increasing to meet such growing demands. In response to the urgent need for additional water for agriculture
during the dry season in 2015, for instance, the Thai Government decided to implement a rain-making mission by using a chemical substance, spreading it into thick clouds to create artificial rains in north-eastern Thailand. This rain-making project in Thailand was initiated by King Bhumibol Adulyadej in 1955 and began its operation in 1969 to generate artificial rainwater for rural areas of Thailand.⁷

Also, the energy demand is rising in the region and the development of hydropower dams is increasing. Where hydropower dams in general dampen the flow in rivers, reducing the flow in the wet season and increasing the flow in the dry season, the combined effects of hydropower dams in the Mekong basin are difficult to assess. The generally reduced floodwater can, for instance, influence the flooding mechanism in the Tonle Sap region.

### 1.1.4. Water demand management

To achieve sustainable use of the water resources of the Mekong River, especially with the rapid growth of the regional population, a regional mechanism for management of water resources, also in relation to socio-economic developments, is inevitably needed. Reducing water demand at the source is an important element of water use management. Water use or water demand management can be divided into two categories that will be explained below:⁸

1. **Systemic water management**
   a. Policy: This is about creating incentives for water users to improve their own water use efficiency of their own accord or requiring water use efficiency improvements by regulatory measures. Such policies will generally work if water users also have information about how much water they are using, price signals, and access to new technologies appropriate to the circumstances of the water users.
   b. Technology: A range of technologies exists to reduce water use including water efficient irrigation, cooling water reuse, water efficient toilets, water use metering, etc.

2. **Sectoral water management**
   a. Environment: In places where water that is supplied for environmental assets such as wetlands can be controlled, there are considerable potential efficiency opportunities from improved water management techniques.
   b. Agriculture: This includes improving the design and management of channels and other distribution systems, and improving on-farm systems delivering water to crops, like drip irrigation.
   c. Energy: The energy sector is a significant water consumer especially for power plant cooling. Hydropower on the other hand is generally non-consumptive but can require large reserves of water reservoirs, which may or may not be available for other uses at certain times. Hydropower dams also can have substantial implications for river ecosystems and can impact fish and other food production. A shift to solar photovoltaics and wind power will help to reduce the water demand and are the most sustainable forms of power generation.
   d. Municipal and household: The replacement of inefficient taps, toilets, showerheads, washing machines, among others, with more efficient models can have significant effects on water consumption in the home, reducing per capita consumption significantly.

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National plans for water demand management should go hand in hand with national plans for water use or diversion from the Mekong mainstream. These should be shared and agreed upon among the MRC Member Countries and incorporated into the regional management plan.

Under this important objective, the regional DMS 2020-2025 is formulated to “support the Member Countries in developing a regional mechanism on water use management and planning for sustainable and long-term benefits among the Mekong countries.”

1.1.4. Climate change effects

Finally, the climate scenarios performed by the Climate Change Adaptation Initiative have indicated that there will be a dramatic increase in temperature, while the number of dry days and more severe low flows in the region may substantially increase in many areas in the LMB by 2030, 2060 and 2090. This means that the LMB region will likely be facing more severe droughts in the coming decades and therefore a proper planning and management mechanism at the MRC level needs to be developed and put into practice before the impacts of the climate change materialise (MRC, 2017b).

Therefore, the final reason for having a regional drought management strategy is to “build a regional mechanism framework to adapt to the long-term climate change impacts in drought severity occurrence to reduce drought impacts and vulnerability.”

1.2. Background: Regional drought management at MRC

The MRC Secretariat officially launched its first drought management activity in June 2012 under the Strategic Plan 2011-2015, called the Drought Management Programme (DMP) 2011-2015. The programme document was formulated based on results of a series of national and regional consultations with the MRC Member Countries and stakeholders, dating back to 2006, and inspired by high-level decisions of the Member Countries’ Heads of Government (1st MRC Summit), the Council, and the Joint Committee. The DMP 2011-2015 progressively developed, including through the development of the DMP document (dated March 23, 2007), the DMP Start-Up Project in 2008, the Initial Drought Management Project 2010-2011, and the decision on agreement to formulate a regional strategy for drought management and mitigation at the 2nd Regional Meeting, which took place in Ho Chi Minh City on March 4, 2011.

The DMP 2011-2015 was well aligned with the MRC Strategic Plan 2011-2015, which called for an effective regional framework for integrated and comprehensive drought mitigation and management.

In addition to the DMP 2011-2015, a three-year project document, called Drought Management’s Core Functions Project 2011-2013, was developed to meet the requirements of the Japan-ASEAN Integration Fund (JAIF). The project was then approved by the MRC Joint Committee in March 2011 and at its 33rd Joint Committee Meeting in Cambodia. The project was finally funded by JAIF and launched in January 2015, and run through 2018 under the Drought Management Team (DMT) of the Technical Support Division of the MRC Secretariat. The DMT was officially dissolved on 31 December 2016 when the MRC Transition Period ended and was delegated to be operated under the Regional Flood and Drought Management Center (RFDMC) from early 2019 onwards.

The immediate objectives of the DMP’s Core Functions Project are to strategically provide the MRC Member Countries with technical support for effective use of the Mekong River’s water and related resources to reduce the vulnerability of people and water-related resource systems to severe drought conditions. The RFDMC worked with the Member Countries’ National Mekong Committees (CNMCs) of national line agencies to provide knowledge-based operational services and technical assistance on drought preparedness, awareness and management strategies in order to mitigate impacts of drought on the livelihoods of vulnerable people in the region.
The DMP’s Core Functions Project focuses on four main outputs:

1. Drought impacts and vulnerability assessment
2. Capacity needs assessment and building
3. Land and water resources analysis
4. Formulation of a regional drought management strategy

1.3. Alignment with other MRC strategies

The DMS 2020-2025 will be fully aligned with the Basin Development Strategy (BDS) 2016-2020 and the Mekong Adaptation Strategy and Action Plan (MASAP) 2018-2022. Like the BDS, the DMS aims at engaging riparian stakeholders and promoting a basin-wide cooperation between the Member Countries. It also looks at the future trends, taking a long-term outlook.

Strategic priorities of the BDS relevant for the DMS are listed in the table below.

| 1) Reduce remaining knowledge gaps to minimise risks | • Study of rural livelihoods and measures to cope with transboundary changes and by which sector development plans and projects can adopt a pro-poor agenda  
• Study of options to increase storage within LMB for flood and drought management purposes  
• Study of transboundary impacts of climate change on water and related resources of LMB in medium to long term and potential adaptation options  
• Study of the use surface and groundwater and the potential for increasing the use and conjunctive use of groundwater |
<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Optimise basin-wide sustainable development and cost and benefit sharing</td>
<td>• Promote, further identify, and implement cost and benefit sharing opportunities and deal structures emphasising national projects of basin-wide significance and joint projects</td>
</tr>
<tr>
<td>3) Strengthen the protection mutually agreed environmental assets</td>
<td>• Analyse the functioning and services of environmental assets and establish and agree on criteria for the selection and protection of these assets, including biodiversity sites, in the LMB</td>
</tr>
</tbody>
</table>
| 4) Strengthen basin-wide procedures and national implementation capacity | • Review institutional structure and capacity of the National Mekong Committees and implement support measures tailored to each country’s needs  
• Strengthen capacity in decentralised core river basin management functions |
| 5) Improve national water resources development and manage | • Consolidate and support the implementation of guidelines for improvement of watershed management practices  
• Prepare and implement guidelines for addressing climate change risks and opportunities in water and related sector projects, including guidelines to adapt to water shortage and drought impacts |
| 6) Enhance information management, communications and tools | • Improve data, information and knowledge management and its access and communication for stakeholders  
• Establish regional emergency communication network for flood and drought management |
• Develop and maintain harmonised methods, models, tools and databases for monitoring and assessment purposes

7) Increase cooperation with partners and stakeholders

• Strengthen cooperation with China on technical exchanges, information sharing and operation of Lancang hydropower dams to capture potential benefits and minimise adverse impacts

Table 1: Strategic priorities of the BDS relevant for the DMS

Specifically regarding priority number 5) ‘Improve national water resources development and management’, the item “Share experiences and jointly learn on the application of guidelines for the development and operations of water and related projects, including dams for irrigation, hydropower and flood management, on the tributaries” in the evaluation and revision of the BDS in 2020 can be extended to cover drought management as well.

Strategic priorities of the MASAP relevant for the DMS are listed in the table below.

<table>
<thead>
<tr>
<th>Strategic priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Mainstream climate change into regional and national policies, programmes and plans</td>
</tr>
<tr>
<td>• Climate proof MRC sectoral strategies 2016-2020 and the next BDS</td>
</tr>
<tr>
<td>• Promote mainstreaming of MASAP’s adaptation strategic priorities at national level</td>
</tr>
<tr>
<td>2) Enhance regional and international cooperation and partnership</td>
</tr>
<tr>
<td>• Promote improved coordination between NMCs, national climate change focal agencies and related line agencies</td>
</tr>
<tr>
<td>3) Enable implementation of transboundary and gender sensitive adaptation measures</td>
</tr>
<tr>
<td>• Promote implementation of transboundary adaptation projects in climate change hotspot areas as the suggested adaptation measures and their PINs</td>
</tr>
<tr>
<td>5) Continue monitoring, data collection and sharing</td>
</tr>
<tr>
<td>• Promote enhanced and continued data collection and sharing on the agreed list of CCA indicators following the Procedure for Data Exchange and Information Sharing (PDEIS)</td>
</tr>
</tbody>
</table>

Table 2: Strategic priorities of the MASAP relevant for the DMS

The priority number 6 ‘Strengthen capacity on development of climate change adaptation strategies and plans’ of the MASAP can in general be applied to developing drought management strategies at national and regional levels that account for future climate developments as well.

The priorities mentioned above show the close relationship between the DMS and the BDS and MASAP and also show how these strategies can reinforce each other.
2. GOALS AND OBJECTIVES OF THE DROUGHT MANAGEMENT STRATEGY

2.1. Scope and focus

Scope

The scope of the Drought Management Strategy (DMS) 2020-2025 is to provide an “overall framework to support the Member Countries in developing sustainable capabilities and capacity for managing drought vulnerability in the LMB in an effective, sustainable, and equitable manner” in line with the principles of integrated water resources management (IWRM) and integrated risk management, and in view of climate change. The DMS 2020-2025 will be aligned with and contribute to the Basin Development Strategy (BDS) and the MRC Climate Change Adaptation Strategy and Action Plan (MASAP). Implementing the DMS 2020-2025 will contribute to the United Nations International Strategy for Disaster Reduction (UNISDR) Sendai Framework and the United Nations Sustainable Development Goals (SDG).

Focus

The DMS 2020-2025 of the MRC focuses on sustainable use, management, and planning of the Mekong River water resources, with stakeholder participation in managing current and future drought risk and vulnerability of the Mekong countries.

2.2. Vision, mission, goals, and objectives

The vision, mission, goal, objectives and outcomes of the Drought Management Strategy 2020-2025 are as follows:

Vision

Member Countries manage water use and drought risk in the Mekong Basin in an effective, sustainable, and equitable manner.

Mission

To support the Member Countries in strengthening capacity and using advanced technology for detecting and managing drought risk and hazards in the Mekong River Basin with sustainable use of the Mekong water resources.

Strategic Goal

Reduced vulnerability of people and water related resource systems to severe drought conditions in the Lower Mekong Basin, and improved capacity to collaboratively develop and implement cost-effective and sustainable drought management projects.

Objective

To strengthen adaptive capacity of the Member Countries in combatting drought hazards and mitigating drought impacts through a sustainable use of water resources, assist the Member Countries in drought forecasting and early warning for drought preparedness, water resources planning, and impacts mitigation, and develop a regional guideline on drought adaptation to address both national and transboundary impacts.
2.3. Principles

The DMS 2020-2025 recognises the General Principles of the 1995 Mekong Agreement and observes the IWRM principles of managing water in an integrated fashion, balancing social, economic and environmental objectives. The DMS 2020-2025 also observes all the MRC procedures, including:

- Procedures for Water Quality (PWQ)
- Procedures for Water Use Monitoring (PWUM)
- Procedures for Maintenance of Flows on the Mainstream (PMFM)
- Procedures for Data and Information Exchange and Sharing (PDIES)
- Procedures for Notification, Prior Consultation and Agreement (PNPCA)

2.4. Links with regional and global goals

The DMS 2020-2025 will be aligned with the overall MRC strategy as laid down in the BDS and with the adaptation strategy as laid down in the MASAP. The BDS states the following strategic actions on droughts:

- Study of options to increase storage within LMB for flood and drought management purposes (2018)
- Prepare and implement guidelines for addressing climate change risks and opportunities in water and related sector projects, including guidelines to adapt to water shortage and drought impacts (2018)
- Establish regional emergency communication network for flood and drought (2017)

The results from these actions are input to the DMS 2020-2025 when available.

The MASAP calls for mainstreaming climate change into regional and national policies, programmes and plans, enhancement of regional and international cooperation on adaptation, enabling the implementation of transboundary adaptation options, promoting monitoring, data collection and sharing, and strengthening the capacity on climate change adaptation and strategy development. The DMS will answer to these strategic priorities.

The Sendai Framework for Disaster Risk Reduction 2015-2030 was conceived to reduce and to prevent disaster risk and losses related to lives and livelihoods, economic losses and damages to infrastructure and was adopted by the United Nations Member States in 2015. It aims at substantially reducing disaster risk and losses through a better understanding of disaster risk and investing in disaster reduction and preparedness. While the effects of water related disasters such as flood and drought are prioritised in the LMB, the DMS consequently also contributes to implementing the Sendai Framework. Monitoring under the Sendai Framework focuses on disaster mortality, the number of people affected by disasters, disaster economic losses, disaster damages to critical infrastructure and disruption of basic services, presence of national and local disaster risk reduction strategies, presence of international cooperation to complement national actions, and availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people.

3. NATIONAL AND REGIONAL FINDINGS

3.1. Drought risk assessment for the Lower Mekong Basin

One of the most important tasks of the Drought Management Programme (DMP) 2011-2015 was to assess drought risk for the whole LMB in order to understand the nature of drought disaster, its magnitude, and geographical impacts. The study required the use of GIS-based modelling techniques with all available data in the MRC historical record, together with the existing satellite imagery from all open sources.

Based on data availability during the study period, May 2013, one of the simple models was selected in the study. It was used to create various important drought risk indicators with weighted scores that later can be combined to produce a map of overall drought risk extent with some indication of the severity of the possible drought risk in different areas.

It is important to understand that the model we chose to adopt for this study is relatively simple and only attempts to evaluate current agricultural systems’ vulnerability to droughts. To be more specific, the focus of the drought model used in this study is primarily to assess the risk to crops. It does not attempt to evaluate the many other multiple risks posed by a major drought, such as forest fires, disruption to fisheries, economic losses in other sectors, etc. The model also does not attempt to evaluate any potential future impacts of droughts that may occur due to climate change.

The actual impacts of droughts in the real world are undoubtedly much more complex, extensive, and cross-sectoral than our simple model suggests. However, very complicated and specific models would have to be developed separately to assess each of these potentially significant impacts, including forest fires models, fishery models, models that can forecast the possibility of increased salt water intrusion into rice paddies in the Mekong Delta, etc. This will be an enormous modelling task. A model that incorporates more aspects should be used in the next cycle of the DMS.

3.1.1. Supporting dataset and indicators required for the model

The model used the following six indicators with six weighting factors to assess the drought risk in the LMB.

- **Precipitation**: TRMM satellite data was used to obtain monthly rainfall.
- **Agricultural irrigation**: GlobCover land cover maps with 250-meter resolution was used because the MRC Land Cover 2010-2011 was not yet available when the study took place in early 2013.
- **Groundwater potential**: Old data on groundwater from the MRC was used, including the Hydrogeological Map of the LMB by Adisai Churatana and Tran Hong Phu (1992) which was compiled from various national and sub-national maps (some as old as 1972) and re-digitized by the MRC in 2005. Specifically, this map gives aquifer groundwater potentials (in m³/hour), which can be weighted and directly used as one of the indicators in our drought model.
- **Surface water**: All available MRC data layers were used with buffer zones to identify areas with access to surface water.
- **Soil drainage**: The existing soil data of the MRC was used for the calculation.
- **Land use**: The GlobCover 2009 dataset, with resolution of 250 meters, was used for the land use weighting factor.
3.1.2. Results of drought risk assessment for the LMB

Weighting factors of all six indicators were calculated through the following: \( \text{(Rainfall + 2*Irrigation + 1.5*GroundwaterRates + 2*SurfaceWater + 2.5*Soil Drainage + LandUse)/10} \).

Please note: The weighting factors shown are only for illustrative purposes and will continue to be modified as necessary to fit changing expert opinions as more historic and current drought data is collected, processed, and reviewed.

Based on the calculation method above, the result is shown through the map below:

![Drought Risk Map of the LMB](image)

**Figure 1: Drought risk assessment map of the LMB**
3.1.3. Conclusion and recommendations

North-eastern Thailand is the most vulnerable area to drought hazards in the region. Irrigation is the main issue where surface water is insufficient to build linkages between the main water sources and agricultural lands in the area.

The second most drought vulnerable area in the LMB is Cambodia. Less seasonal precipitation coverage in the Northwest has made the area dry, with no access to irrigation schemes. The northern and southern parts around the Tonle Sap Lake are also prone to drought with similar conditions.

Like Cambodia, some parts of Lao PDR, including the southern and northern areas (Champassak and Vientiane provinces) are also relatively vulnerable to drought due to insufficient amounts of rainfall and absence of irrigation systems. The areas are too far from water bodies and the Mekong River and therefore irrigation schemes are most likely undoable.

In Viet Nam, the Central Highland is seriously vulnerable to drought like some other areas of the basin. However, unlike the other parts of basin, the Mekong Delta of Viet Nam is not only vulnerable to drought but also seriously vulnerable to salinity intrusion, which cannot be presented by the model. Salinity intrusion occurs when flows in the Mekong mainstream are too low to counter the force of sea currents flowing backwards from the sea mouth. Additionally, the groundwater is also threatened by salinity intrusion during drought years.

From the study, we can draw the following recommendations:

- Regional drought vulnerability should be re-assessed every five to ten years to accommodate the changing land use, development of irrigation schemes at national levels, population growth, and climate change effects.
- For more accurate results, national data should be used with more variables and parameters including soil moisture and temperature to be able to calculate the drought indices.
- The model used for the assessment should be reviewed and updated to the most appropriate one in the next assessments.
- More information on economic losses is needed for improved decision making (also see next section).
- Drought forecasts should also be developed for long-term developments.

3.2. Drought impacts and vulnerability assessment by the MRC Drought Management Programme

Besides the statistical data that the DMP had received from relevant national line agencies on historical drought impacts, under financial support by GIZ in 2013 and JAIF from 2015 to 2017, the DMP conducted its own drought impacts and vulnerability assessment on agriculture, socio-economic conditions, and environment. The assessment timeframe focused on three different periods; the historical (H) situation, the current (c) situation, and the potential impact or future trend (P).

We adopted the methodology of drought preparedness planning, which includes drought impact and vulnerability assessment (Wilhite et al., 2000). The assessment followed the sequential steps below:

- Impacts identification;
- Impact selection and ranking;
- Vulnerability assessment; and
- Identification of actions to be taken.
The main stakeholders for the assessment included representatives from

- Relevant departments at the national level;
- Provincial departments on disaster risk reduction of the drought-prone provinces;
- Relevant departments at the provincial level;
- Provincial government of the drought-prone provinces; and
- District administration of the drought-prone districts

Results of the impacts and vulnerability assessment

3.2.1. Cambodia

Drought-prone area selection:

Cambodia has identified six provinces as the most drought-prone areas to include in the assessment, namely Battambang, Banteay Meanchey, Kampong Cham, Kampong Chhnang, Prey Veng, and Svay Rieng (Figure 2). The selection was based on a national agricultural census, food security, historical drought situations, and water resources and irrigation systems of the country. Stakeholders in these provinces were asked to list the most important impacts of droughts (Em, 2015).
The overall impacts, trend, and impact ranking are summarized in Table 3 below:

<table>
<thead>
<tr>
<th>Province/districts</th>
<th>Impact type</th>
<th>Trend</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battambang</td>
<td>- Annual and perennial crop loss, mainly rice, cassava, and corn</td>
<td>Increasing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>- Insufficient water for local consumption, up to 80%</td>
<td>Decreasing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>- Losses of agricultural land</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>- Water use conflict</td>
<td>Increasing</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>- Losses of income with 32% migration workers</td>
<td>Increasing</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>- Losses of timber products</td>
<td>Increasing</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>- Damages to biodiversity</td>
<td>Increasing</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>- Reduction of fish and animal habitats</td>
<td>Increasing</td>
<td>8</td>
</tr>
<tr>
<td>Banteay Meanchey</td>
<td>- Perennial crop losses between June and August of rice, bean, corn, and cassava</td>
<td>Increasing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>- Environmental damages (losses of forest and wetland)</td>
<td>Increasing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>- Losses of income with 60% migration workers</td>
<td>Increasing</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>- Decrease of food production and increase of food prices</td>
<td>Increasing</td>
<td>4</td>
</tr>
<tr>
<td>Province/districts</td>
<td>Impact type</td>
<td>Trend</td>
<td>Rank</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>Kampong Cham</td>
<td>Perennial crop losses of rice, corn, and cassava</td>
<td>Increasing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Crop damages by insects</td>
<td>Increasing</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Reduction of fish and animal habitats</td>
<td>Increasing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Reduction of groundwater</td>
<td>Increasing</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Respiratory disease</td>
<td>Normal</td>
<td>5</td>
</tr>
<tr>
<td>Kampong Chhnang</td>
<td>Perennial crop losses of rice, cassava, and corn</td>
<td>Increasing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Decrease of agricultural products and livestock</td>
<td>Increasing</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Decrease of biodiversity</td>
<td>Increasing</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Losses of income, migration</td>
<td>Increasing</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Reduction of fish and animal habitats</td>
<td>Increasing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Water use conflicts</td>
<td>Increasing</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Insufficient water for irrigation</td>
<td>Increasing</td>
<td>3</td>
</tr>
<tr>
<td>Pre Veng</td>
<td>Losses of annual and perennial crops</td>
<td>Increasing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Reduction of fish and animal habitats</td>
<td>Increasing</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Losses of income, migration</td>
<td>Increasing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Respiratory disease</td>
<td>Increasing</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Decrease of agricultural products</td>
<td>Increasing</td>
<td>4</td>
</tr>
<tr>
<td>Svay Rieng</td>
<td>Losses of annual and perennial crop, mainly rice</td>
<td>Increasing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Increase of insects</td>
<td>Increasing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Increase of migration for jobs</td>
<td>Increasing</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Decrease of rice production</td>
<td>Increasing</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3: List of drought impacts and ranking in Cambodia

The impact ranking is evaluated based on the severity of the impacts and the economic losses that the impacts caused. The ranking varies from one district to another. In the table above, the ranking is calculated by averaging all ranking numbers by district, and the lowest average is ranked highest.

The study identified the main causes of the impacts, proposed actions to be taken to mitigate the impacts, and evaluated the existing mitigation and adaptation strategies and tools that were applied in those drought-prone...
districts. From the study it is concluded that droughts have severe impacts, both current and potential, in all districts of the targeted provinces on the agricultural sector, animal and human life in Cambodia. While droughts have severe impacts, representatives from the targeted provinces indicated that there is a shortage of water for them, their crops and animals in the dry season every year. To respond to these impacts, more irrigation systems and reservoirs in their district need to be restored and constructed.

3.2.2. Lao PDR

Drought-prone area selection:

Lao PDR evaluated and identified five provinces as being the most drought-prone areas based on historical records of drought occurrence, loss of agricultural income, population density, and geographical locations, and selected them for drought impacts and vulnerability assessment in July 2017 (Phetpaseuth, 2017). Those provinces include Borikhamxay, Khammuan, Savannakhet, Saravane, and Champassak.
The drought vulnerability levels for the selected drought-prone provinces are presented in the graph below:

The result shows that Savannakhet is the most vulnerable area among the five provinces, followed by Saravane and Khammuan. The main problem is that this area has almost no access to surface water that farmers can rely on.
Natural ponds become more important during the dry season. Yet, how much a natural pond can capture and store for the next dry period depends on the rainfall during the rainy season.

Based on the report, the main impacts are listed, evaluated, and ranked by order of severity in the table below:

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Borikhamxay</td>
<td>Economic/production sectors impacted by drought</td>
<td>87.5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Environment sectors impacted by drought</td>
<td>50</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Social sector impacted by drought</td>
<td>100</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Khammuan</td>
<td>Economic/production sectors impacted by drought</td>
<td>100</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Environment sectors impacted by drought</td>
<td>75</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Social sector impacted by drought</td>
<td>79</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Savannakhet</td>
<td>Economic/production sectors impacted by drought</td>
<td>100</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Environment sectors impacted by drought</td>
<td>75</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Social sector impacted by drought</td>
<td>100</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Saravane</td>
<td>Economic/production sectors impacted by drought</td>
<td>100</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Environment sectors impacted by drought</td>
<td>100</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Social sector impacted by drought</td>
<td>67</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Champassak</td>
<td>Economic/production sectors impacted by drought</td>
<td>87.5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Environment sectors impacted by drought</td>
<td>87.5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Social sector impacted by drought</td>
<td>68.5</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4: List of drought impacts and ranking on agricultural/economic, environmental, and social sectors by Provinces of Lao PDR

The value of cost ranges from 1 to 100, representing cost levels from low to high. The cost value for Savannakhet, for instance, is 275 for the total of the impacts across three sectors, which is the highest value among all the provinces. This means that Savannakhet experiences greater drought impacts than others and will be the most vulnerable area of Lao PDR.

Table 5 shows the basal causes for the vulnerabilities for each province. Based on these causes, for each province a range of measures has been identified and assessed for their feasibility, effectivity and benefits.
<table>
<thead>
<tr>
<th>Drought impact</th>
<th>Basal causes of vulnerability</th>
<th>Province</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Borikhmaxa</td>
</tr>
<tr>
<td>Economic impact</td>
<td>Lack of water</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Lack of fertilizer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low soil quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insect infestation</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Limited or no irrigation scheme</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>No drought warning</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Unappropriated crop</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Lack of hydro-agriculture technology</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of land agriculture management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insufficient technical and financial support from Government</td>
<td>X</td>
</tr>
<tr>
<td>Loss from crop production</td>
<td>Lack of water for pasture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High mortality of pasture</td>
<td></td>
</tr>
<tr>
<td>Loss from fishery production</td>
<td>Increased low water quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced from spring</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Reduced water in the wetland area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage of natural fish habitat</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Insufficient enhance on aquaculture</td>
<td></td>
</tr>
<tr>
<td>Decline in food production/disrupted food supply</td>
<td>No agriculture, livestock and fishery production</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>No community market</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Lack of commute agriculture production</td>
<td>X</td>
</tr>
<tr>
<td>Environment impact</td>
<td>Potential of climate change</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>No storage in the wet season</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Decreased forest cover</td>
<td>X</td>
</tr>
<tr>
<td>Loss of biodiversity</td>
<td>The threat to forest from people</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low level of natural spring and river</td>
<td></td>
</tr>
<tr>
<td>Increased number and severity of fires</td>
<td>High temperature/hot weather</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low awareness on forest fire</td>
<td>X</td>
</tr>
<tr>
<td>Social impact</td>
<td>Lack of water in spring</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Lack of shallow well and groundwater</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limited water supply distribution</td>
<td>X</td>
</tr>
<tr>
<td>Insufficient or lack of water for domestic use and drinking water</td>
<td>No water filter system</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Hotter climate</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Limited health care service</td>
<td>X</td>
</tr>
<tr>
<td>Health-related low-flow problems</td>
<td>Unemployment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of income from agriculture production</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 5: Basal causes of vulnerability to drought in the drought-prone Provinces of LAO PDR
3.2.3. Thailand

Drought-prone area selection:

The assessment of drought impacts and vulnerability for Thailand was conducted mainly based on historical studies, past reports on damages from drought and water supply management, together with a consultative approach with relevant line agencies and local stakeholders. The study was carried out from October 2015 to March 2016, under financial support from JAIF for the DMP’s Core Functions Project of the MRC Secretariat (TNMC, 2016).

Within the LMB part, Thailand considers all areas in the Northeast to be drought-prone. The area is drained by Chi-Mun River, which covers 20 provinces including Nong Khai, Bueng Kan, Nakhon Phanom, Udon Thani, Sakon Nakhon, Khon Kaen, Kalasin, Mukdahan, Chaiyaphum, Maha Sarakham, Roi Et, Yasothon, Amnat Charoen, Nakhon Ratchasima, Buriram, Surin, Si Sa Ket, and Ubon Ratchathani. North-eastern Thailand is facing persistent drought, which occurs almost every year, with high economic losses mainly on agricultural production. Areas with high drought vulnerability for their domestic water are in the provinces of Buriram, Surin and Si Sa Ket, Maha Sarakham, Roi Et, Yasothon, Nong Bua Lamphu, Chaiyaphum. Areas with high drought vulnerability for agriculture include Buriram, Surin, Si Sa Ket, Maha Sarakham, Roi Et, Yasothon, Chaiyaphum and Nongbua Lamphu.

Some significant findings from the national drought impacts and vulnerability assessment are listed, with description, below:

![Drought risk map of north-eastern Thailand by Land Development Department (2013)](image)

**Figure 5:** Drought risk map of north-eastern Thailand by Land Development Department (2013)
The map above shows frequent occurrence of droughts, mainly water scarcity during the wet and dry seasons during a ten-year period recorded by the Land Development Department. The red areas represent more frequent drought occurrence than the orange and the green ones.

Figure 6: Map of drought vulnerability for agricultural water in north-eastern Thailand

The study also produced a drought vulnerability map for agricultural water: the darker the red, the more vulnerable the area is to agricultural water drought.

The main causes of severe drought impacts are low amounts of rainfall, which produce low runoff and discharge, and high population density and extensive agricultural areas. The low adaptive capacity to drought, due to the low income of farmers, is also a major concern, which makes some potential mitigation options impossible.

For provinces in the north-eastern part, vulnerabilities are moderately high as drought impacts are relatively lower than other parts due to lower population density and smaller size of agricultural lands. The north-eastern area nevertheless experiences moderate to high levels of vulnerability for both agricultural and domestic water uses. Climate change in this region does not have significant effect, only if the rainfall amount decreases in the future.

Possible measures can be categorised into three groups; demand side management, supply side management and improve water management. In the long term, measures comprise changing agricultural practices, e.g., to high value crops which require less water, adopting other occupations which do not require agricultural water, water resources development, providing enough rainfall collectors such as containers, pool, or reservoirs, recycling of water, keeping soil moisture and decreasing planting area evaporation, river basin development, etc. Groundwater quality needs to be reviewed and enhanced to provide water scarcity prevention measures.
3.2.4. Viet Nam

Drought-prone areas of Viet Nam

In southern Viet Nam, the drought-prone area is divided into two different parts based on socio-economic and geographical locations, namely the Central Highland and the Mekong Delta. The assessment of drought impacts and vulnerability was conducted in 2013 with financial support from GIZ under the DMP 2011-2015 (Pham, 2015a, 2015b).

- **Central Highland**

The types of impacts on agricultural economic sectors is illustrated by the graph below:

![Graph showing types of impacts on agricultural economic sectors, Central Highland, Viet Nam](image-url)

**Figure 7: Types of impacts on agricultural economic sectors, Central Highland, Viet Nam**

The types of impacts on agricultural economic sectors over different time periods (past, current, and future trend) are illustrated below:

![Graph showing types of impacts on agricultural economic sectors over different time periods, Central Highland, Viet Nam](image-url)

**Figure 8: Types of impacts on agricultural economic sectors over different time periods, Central Highland, Viet Nam**
The types of impacts on the environmental sector over different time periods (past, current, and future trend) are summarized in the graph below:

![Figure 9: Types of impacts on the environmental sector over different time periods, Central Highland, Viet Nam](image)

The types of impacts on the social sector in the Central Highland are summarized in the graph below:

![Figure 10: Types of impacts on the social sector, Central Highland, Viet Nam](image)

A summary of impacts, and their associated rank, on agricultural economic, environmental and social sectors are presented in the following table:
Table 6: List of drought impacts on the agricultural economic, environmental, and social sectors, Central Highland, Viet Nam

It is concluded that the vulnerability of the Highland provinces is middle to low. Measures to mitigate the effects of droughts include diversification of crops and the cropping schedule, improved environmental protection, better coordinated use of water resources and improved monitoring and research to be able to better respond to future challenges. These require improved regulations and capacity building.

- **Mekong Delta**

A summary of drought impacts, and their associated rank, on agricultural, economic, environmental, and social sectors in the Mekong Delta of Viet Nam is summarized in the table below:

<table>
<thead>
<tr>
<th>No</th>
<th>Groups of drought impact types in Central Highlands</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loss from crop production</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Decline in food production/disrupted food supply</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>General environment</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Loss from timber production</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Reduced quality of life, changes in lifestyle</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Increased conflicts</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Inequity in the distribution of drought relief</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 7: List of drought impacts, and their associated rank, on agricultural economic, environmental, and social sectors, Mekong Delta, Viet Nam

<table>
<thead>
<tr>
<th>No</th>
<th>Groups of drought impact types in Mekong Delta</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Loss from crop production</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Loss from dairy and livestock production</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Loss from timber production</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Loss from fishery production</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Decline in food production/disrupted food supply</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Revenue to water supply firms</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Damage to animal species</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>General environment</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>General society</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Increased conflicts</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Inequity in the distribution of drought relief</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Reduced quality of life, changes in lifestyle</td>
<td>2</td>
</tr>
</tbody>
</table>
An historical drought took place in 2015-2016 in the Mekong Delta, when the water level at the Prek Kdam (Great Lake) was 2.62 m lower than its long-term average over the period 1980-2013 and 1.5 m lower than in the same period in 2014-2015. The monthly temperatures in the dry season of 2016 was 0.5 to 1.5 °C higher than the long-term average, increasing the evaporation and water demand for crops. Salinity intruded inland up to 50 to 70 km in all estuaries. In the Vam Co River the salinity intrusion reached 90 km, where its long-term average is 15 to 25 km. By the end of June 2016, rainfall started in the Central Highland and the Mekong Delta, ending the drought. During the drought, an estimated 2 million people (400,000 households) lacked water for hygiene. The total financial loss of the drought was estimated at US$ 48.5 million.

Table 8 provides an overview of the financial losses for the ten provinces in the Mekong Delta that were affected.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Tiền Giang</th>
<th>Bến Tre</th>
<th>Trà Vinh</th>
<th>Sóc Trăng</th>
<th>Hậu Giang</th>
<th>Kiến Giang</th>
<th>Long An</th>
<th>Vĩnh Long</th>
<th>Bạc Liêu</th>
<th>Cà Mau</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy</td>
<td>3.886</td>
<td>16.000</td>
<td>29.281</td>
<td>24.000</td>
<td>653</td>
<td>56.506</td>
<td>8.761</td>
<td>18.029</td>
<td>14.500</td>
<td>49.343</td>
</tr>
<tr>
<td>Vegetable</td>
<td>55</td>
<td>500</td>
<td>699</td>
<td>7.000</td>
<td>27</td>
<td>64</td>
<td>519</td>
<td>5.000</td>
<td>10.000</td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td>113</td>
<td>5.800</td>
<td>4.014</td>
<td></td>
<td>496</td>
<td>4.506</td>
<td>10.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquaculture</td>
<td>475</td>
<td></td>
<td></td>
<td></td>
<td>13.772</td>
<td>8.000</td>
<td>52.467</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Estimated loss due to the 2015-2016 drought and salinity intrusion in the MDK

It is concluded that the Cà Mau, Kiên Giang, Bạc Liêu, An Giang and Long An provinces have a high vulnerability to drought, while Bến Tre, Cần Thơ, Hậu Giang, Tiền Giang, Sóc Trăng and Trà Vinh provinces have a medium vulnerability. Vulnerability to drought is low in Đồng Tháp province. Measures to mitigate the effects of droughts include diversification of crops and cropping schedule, investments in the construction and maintenance of hydraulic works, improved environmental protection and improved monitoring and research to be able to better respond to future challenges. All these require improved regulations and capacity building.

3.2.5. Conclusion and recommendations

- None of the MRC Member Countries has a system or mechanism for recording annual drought impacts on socio-economics, the environment and agriculture. Improved collection of this information will enhance decision making on drought adaptation.
- More small and medium-sized water storage systems in local areas need to be rehabilitated, especially in Cambodia, Lao PDR and even Thailand, to provide sufficient water during the dry season and during dry spells in the rainy season.
- Groundwater, which is the second most important water source, has not been widely explored, nor even studied for future benefits, especially in Cambodia and Lao PDR.
- Although important, a transboundary mechanism for drought impact mitigation has not been applied yet at the bordering areas.
- Early warning of droughts has not reached rural areas. Farmers are relying on their traditional methods for determining when and where to start planting their crops during the beginning of the monsoon.
Depending on the situation in the respective provinces as studied, specific measures have been identified that can be implemented.

3.3. National drought early warning systems

A national survey on existing drought early warning systems, which included drought monitoring, forecasting, and early warning services, at the country level was carried out from 2015 to 2016. The objectives of the survey were to identify the data and knowledge gaps that need to be addressed as well as to provide recommendations and a work plan for the follow-up technical analysis that is required to develop and implement a regional drought monitoring and forecasting system for the LMB. In addition, country reports were developed in 2018 to describe the drought early warning systems at national level.

3.3.1. Cambodia

The National Committee for Disaster Management (NCDM) of Cambodia is the main line agency responsible for all kinds of natural disaster prevention and mitigation tasks. The committee focuses mainly on floods and typhoons but is not sufficiently equipped for drought early warning facilities. Nevertheless, data and information are collected at provincial level and sent to NCDM. In the dry season, the information is analysed and a decision is made if farmers need to be informed.

3.3.2. Lao PDR

Lao PDR does not have any drought early warning system in operation yet. A flood early warning system is in place and operational. The line agency in charge is currently building capacity in drought early warning systems to be able to implement such a system in the near future.

3.3.3. Thailand

In Thailand, several institutions, divided over 6 ministries, are involved in drought issues. The Department of Disaster Prevention and Mitigation, Ministry of Interior (DDPM), is the coordination centre for disasters, and sets up measures, promotes and supports disaster prevention, mitigation and rehabilitation. Disaster prevention and mitigation activities are carried out through the establishment of safety policies, a prevention and warning system, rehabilitation of disaster devastated areas, and the follow-up and evaluation, in order to secure the safety of lives
and property. The Civil Defence Act 1979 defines the coordinating, commanding, supervising, assisting and requesting channels as shown in the disaster management and coordination diagram in Figure 12 (DDPM, 2015).

![Figure 12: Disaster risk management mechanism of Thailand](image)

The Department of Water Resources (DWR), Ministry of Environment and National Resources (MONRE), is responsible for the development of the knowledge base and technologies, and the collection of data related to water resources management. Research is done on drought disasters and the preparedness of communities in disaster prone areas in order to reduce disaster damages. DWR has installed an early warning system (EWS)\(^9\) for both flood and drought.

### 3.3.4. Viet Nam

Drought management in Viet Nam is laid down in the Law on Natural Disaster Prevention and Control that was adopted in 2013. The Law states the responsibilities of line agencies for conducting disaster prevention and control in terms of the national strategy and planning, forecasting and early warning, responding and recovering. The Law

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on Water Resources (2012) states that water resources planning at the regional and provincial levels has to define the percentage and priority of water allocation for users in the case of drought and water shortage and to allocate water resources for domestic water supply. In addition, the Law prescribes that the operational procedures of dams have to consider drought and water shortage prevention for the downstream areas. The Ministry of Natural Resources and Environment (MONRE) is responsible for the implementation and supervision for the Law on Water Resources, and for reporting the drought and water shortage situation and for resolving conflicts over water resources between provinces. MONRE is responsible for reviewing, adjusting and modifying the policies related to forecasting, early warning and information dissemination, and for performing hydrometeorological research, forecasting, early warning, and dissemination of forecasts at the national level. MONRE is also responsible for updating the climate change and sea level rise scenarios that are the base for the review of and design of response measures/alternatives. The National Hydro-Meteorological Service (HMS), under MONRE, provides weather forecasting and other climate services through the National Centre for Hydro-Meteorological Forecasting (NCHMF).

<table>
<thead>
<tr>
<th>Mandates</th>
<th>Task</th>
<th>Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Designing national natural disaster prevention and control strategy</td>
<td>Ministry of Agriculture and Rural Development (MARD)</td>
</tr>
<tr>
<td>Preparing and responding</td>
<td>Natural disaster control Planning</td>
<td>MARD</td>
</tr>
<tr>
<td></td>
<td>Forecasting and early warning</td>
<td>Ministry of Natural Resources and Environment (MONRE)</td>
</tr>
<tr>
<td></td>
<td>Disseminating forecasting and early warning news</td>
<td>Viet Nam Television and Voice of Viet Nam</td>
</tr>
<tr>
<td>Responding</td>
<td>Disseminating forecasting and early warning news</td>
<td>Viet Nam Television and Voice of Viet Nam</td>
</tr>
<tr>
<td>Recovering</td>
<td>Recording damages and estimating financial loss</td>
<td>Provincial People’s Committees (PPCs) and MARD</td>
</tr>
<tr>
<td>International cooperation</td>
<td>Exchanging forecasting and early warning news with the international organizations</td>
<td>MARD</td>
</tr>
</tbody>
</table>

Table 9: Responsibilities and tasks of line agencies in natural disaster prevention and control in Viet Nam

3.3.5. Regional cooperation in early warning

Improved drought monitoring, forecasting and early warning at the national level can be improved by the exchange of information among neighbouring countries, especially upstream countries. A regional drought early warning system for the LMB can provide for such information exchange and sharing.

3.3.6. Conclusions and recommendations

In Cambodia, the NCDM is the responsible line agency and has a flood and typhoon early warning system in place. A drought early warning system does not exist yet.

Lao PDR has a flood early warning system in place and is currently working to develop a drought early warning system.
Thailand has well developed its capacity in terms of drought monitoring, forecasting, and early warning, with multi-analysis of drought indicators. Thailand is capable of obtaining satellite imageries on their own, enabling more frequent access to data with better resolution on climatic indicators, including air temperature, rainfall, humidity, vegetation condition, etc., for detailed drought analysis. Various agencies are working on drought condition analysis with different responsibilities and tasks. However, a communication channel is missing among those responsible departments before the final assessment and announcement are made for drought forecasting and early warning.

For Viet Nam, drought monitoring and forecasting mainly focuses on meteorological and hydrological indicators. Drought monitoring and forecasting are separated from salinity monitoring and forecasting. It would nevertheless be beneficial if the two were combined. Moreover, the historical drought of 2015-2016 showed that the drought and the salinity early warning systems are not yet fully developed while the hydrologic system is not in full operation yet. There is nevertheless good cooperation between the line agencies.

Based on the findings, the MRC Secretariat should support the Member Countries, especially in Cambodia and Lao PDR, in drought early warning services and provide capacity building to relevant line agencies as follows:

- Develop a comprehensive regional drought early warning system for the LMB by reviewing all drought indicators used by line agencies at national level.
- Conduct capacity building on drought monitoring, forecasting, and early warning, focusing on all available and essential tools.
- Produce monthly or, when relevant, weekly bulletins on the drought condition of the LMB and share with the Member Countries and national line agencies.
- Develop drought information and data sharing among the Member Countries and the MRC Secretariat to exchange emergency information and data on drought and water use conditions.

### 3.4. Water demands and availability for crops as well as future scenarios

The study on water availability in the LMB and water demand for crops was carried out from July 2017 to July 2018 under output 3 of the DMP’s Core Functions Project. The study aimed at analysing water use gaps for crop areas of the LMB. The objectives of the study are to:

- a) Estimate cropping areas for each Member Country and the changes under future scenarios;
- b) Estimate water availability for crop areas of the LMB under future scenarios;
- c) Calculate crop water requirement volume in each catchment based on the irrigation nodes within the LMB in terms of annual, wet, and dry season needs under future scenarios; and
- d) Calculate the volume of water deficit between the demand and supply for cropping areas of the LMB under different scenarios.

The MRC’s Decision Support Framework (DSF), which includes the Integrated Water Quality and Quantity Simulation Model (IQQM) and the Soil and Water Assessment Tool (SWAT), were used to run crop models for all MRC catchments and consulted irrigation projects. Land cover data from 2003 along with the MRC standard land cover classification were the main inputs for the models. The scenarios consisted of 3 different time periods, M1, M2 and M3CC.

- Baseline scenario (M1) was adopted from 1984 to 2007 for both SWAT and IQQM which represents the natural condition without any dam development nor water regulation in the Lower Mekong Basin.
- **M2**: a period from 2007 to 2020 with half-way development of the hydropower dams without any climate change effects.
- **M3CC**: a period from 2020 to 2040 with full development of the hydropower dams and future climate change effects. M3CC considers a climate variation of wetter conditions during wet season and drier conditions during dry season. Sub scenarios C2 and C3 consider overall wetter conditions and drier conditions respectively based on the M3CC main conditions.

**Analysis results:**

![Figure 13: M1 IQQM crop area in hectares for dry Season](image1)

![Figure 14: M1 IQQM crop area in hectares for wet season](image2)

![Crop Area for dry season comparison between M1, M2 and M3CC](image3)
In this study, crop area is the area where agricultural crop is planted under irrigation conditions. The rainfed agriculture is not counted as crop area in this model although rainfall is considered in the irrigated crop land.

- During the dry season, the crop area in Lao PDR increases from M1 to M2 and M3CC. Its size is almost doubled from one scenario to another. For Cambodia, there is an increase of about 30% from M1 to M2 while the number is doubled in M3CC scenario. For Thailand, the crop area during the dry season increases around 25% in M2 and 45% in the M3CC scenarios. Viet Nam has the biggest crop area in both dry and wet seasons with almost fully irrigated agricultural land. Therefore, there is only a slight increase in M2 of about 10% and no increase in the M3CC scenario.

- During the wet season, the crop area of Lao PDR increases to almost 200,000 ha for baseline conditions, 370,000 ha for M2, and more than 600,000 ha for M3CC. It shows that the demand for agriculture plantation will increase in the long term. On the contrary, the cropping area of Cambodia decreases from over 300,000 during the dry season to around 200,000 ha for M1 and M2 during the wet season and from 1,000,000 ha down to just 500,000 ha for the M3CC scenario, a 50% decrease. The results show that Thailand increases the size of its cropping area considerably from more than 300,000 ha during the dry season to almost 1,200,000 ha for M1 condition during the wet season and to 1,900,000 ha for the M3CC scenario. Meanwhile, Viet Nam decreases its cropping area from 2,000,000 ha during the dry season to only 1,300,000 ha during the wet season for M1; and from 2,100,000 ha during the dry season to only 1,700,000 ha during the wet season for the M3CC scenario.

As previously mentioned, the IQQM model only considers irrigated crop lands and excludes the rainfed type. As a consequence, the reduction in crop area between seasons may be caused by dynamic changes in land use; as the wet season provides more rainfall water which allows to switch from irrigated to rainfed crop land. It is therefore excluded from the IQQM calculation.
3.4.1. Water availability for catchments and crops

Based on the M1 scenario dataset, which goes from 1984 to 2007, SWAT has produced water yield information for the basin for each catchment. This water yield represents water availability for the catchment after subtracting evapotranspiration, infiltration to the ground and other hydrological conditions. The water yield is the amount of water available to be subtracted from the catchment to crop areas if water transportation or diversion systems are available.

In reality, water diversion can be done only when there is an irrigation system. Therefore, even when there is ample water availability, there is still water deficit due to the absence of irrigation systems, reservoirs or canals.

The case of water diversion projects in Northeast Thailand is a good example where large amounts of water are available in the Mekong mainstream, but water transportation to the agricultural fields is not available. Thus, there is a need to promote small and big irrigation projects that divert water from river mainstreams to crop fields to mitigate the water scarcity problems.

Comparing between M1, M2 and M3CC, the water availability for each catchment does not change substantially as the precipitation in the Mekong basin does not change much between the baseline and future scenarios influenced by dam developments or climate change. Results show that there is a water surplus compared to the demands in the current and future scenarios. However, there is a need to transport the water to the fields (except for the Vietnam Delta where such a hydrologic study was not developed).

Figure 17: M1 SWAT water availability in milliliters per day for dry season

Figure 18: M1 SWAT water availability in milliliters per day for wet season

Water availability for crops in the IQQM model is the amount of water transported to the fields through irrigation canals. This was calculated using the IQQM model and based on the irrigation nodes. It does not matter how much
water is available in both the Mekong mainstream and tributaries, crop areas can only receive the amount that is transported via irrigation canals with the limit of the pumping capacity of the area. Therefore, the total diversion is considered as the water availability for crops in the basin; see Figure 19 and Figure 20 below.

3.4.1. Water Requirement for Crops

Water requirement for crops was calculated using the IQQM model based on the irrigation nodes. The calculation was done daily so it is possible to separate between the dry and wet seasons to see the different water needs between both seasons. Water requirement is represented as points where crop areas exist with water diversion. In this way, it is easy to estimate water deficits for crop areas in the Mekong basin.

Water requirement for crops was calculated based on many factors including crop factor, irrigation efficiency and return efficiency. Crop factor refers to the water consumption of each crop type. Irrigation and return efficiency refer to the effectiveness of the irrigation system, involving irrigation loss and irrigation return in the field.

The results from the baseline data show that Cambodia and Thailand require the biggest amount of water in the region and that crops need more water in the dry season than wet season. This implies that rainfall supplies large amounts of water to crops during the wet season while dry season crops fully depend on water from irrigation canals. Data from Lao PDR and Viet Nam show a lower water demand while the demand is largely at the same level in both dry and wet seasons.
Figure 21: M1 IQQM crop water requirement in milliliters per day per hectare for dry season

Figure 22: M1 IQQM crop water requirement in milliliters per day per hectare for wet season

Comparing between LMB countries for all scenarios, Cambodia shows the highest water requirement for its crops per hectare, followed by Thailand. Lao PDR and Viet Nam have the lowest water requirement: around 0.1 ml/day/ha.

Figure 23: Comparison of average of crop water requirement per country in milliliters per day per hectare between scenarios during dry season
Cambodia and Thailand have an extremely low irrigation efficiency with a high return in comparison to Lao PDR and Viet Nam. There is consequently a lot of water lost during the irrigation process. The Mekong Delta of Viet Nam, on the other hand, has the highest irrigation efficiency up to 0.8, which means 80% efficient with 0.0 returns, it means that no water is returned to the river from irrigation systems. For Lao PDR, the irrigation efficiency is low, but the return efficiency is also very low. These are the main reasons why the water requirement for irrigation in Cambodia and Thailand is high and Lao PDR and Viet Nam is low.

3.4.3. Crop Water Deficit

Crop water deficit is the difference between water requirement and water availability that can be diverted to irrigate crops. Referring to the graphs below, Cambodia has the highest percentage of water deficit per day per hectare due to its low irrigation efficiency.

It is followed by Thailand, that also requires big amounts of water for irrigation for both dry and wet seasons. Lao PDR and Viet Nam have the least water deficit for crop due to the effectiveness of their irrigation systems proportional to their production and the crop factor, which requires less water than Cambodia and Thailand.

Crop water deficit increases in all four countries between the M1 and M3CC scenarios during the dry season. During the wet season, there is not much change between M1 and M3CC except for Cambodia, where crop water deficit decreases, while there is some increase in Thailand.

Results indicate that the current irrigated agriculture faces extreme water deficit conditions, especially in Cambodia and Thailand, and that this deficit may increase during the dry season. With a growing population, the demand for water needed for agricultural production is expected to increase, aggravating the problem.
Figure 25: Comparison of average crop water deficit per country in milliliters per day per hectare between scenarios during dry season.

Figure 26: Comparison of average crop water deficit per country in milliliters per day per hectare between scenarios during wet season.
3.5. Problem identification based on the findings

In summary, below is a table summarizing the impacts and impact ranking for Cambodia, Lao PDR, Thailand, and Viet Nam.

<table>
<thead>
<tr>
<th>City / Province</th>
<th>Impact Areas</th>
<th>Impact Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cambodia</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Battambang     | • Annual and perennial crop losses (rice)  
• Insufficient of water for irrigation and local consumption  
• Increase of migration and poverty  
• Reduction of fish and animal habitats | 1 2 3 4 |
| Banteay Meanchey| • Annual and perennial crop losses of rice and cassava  
• Environmental damages  
• Losses of income with 60% migration workers  
• Decrease of food production and increase of food prices | 1 2 3 4 |
| Kampong Cham    | • Annual and perennial crop losses (rice, cassava, corn)  
• Reduction of fish and animal habitats  
• Ground water depletion  
• Crop damages by insects | 1 2 3 4 |
| Kampong Chhnang | • Annual and perennial crop losses (rice)  
• Reduction of fish and animal habitats  
• Insufficient of water for irrigation  
• Increase of migration and poverty | 1 2 3 4 |
| Prey Veng       | • Annual and perennial crop losses (rice)  
• Reduction of fish and animal habitats  
• Increase in food prices  
• Increase of migration and poverty | 1 2 3 4 |
| Svaí Rieng      | • Annual and perennial crop losses (rice)  
• Reduction of fish and animal habitats  
• Loss of biodiversity  
• Human diseases due to lack of water consumption | 1 2 3 4 |
| **Lao PDR**     |              |               |
| Borikhamxay     | • Loss from crop production  
• Loss from fishery production  
• Loss from dairy and livestock production | 1 2 3 |
| Khammuan        | • Loss from crop production  
• Decline in food production/disrupted food supply  
• Loss from fishery production  
• Loss from dairy and livestock production | 1 2 3 4 |
| Savannakhet     | • Loss from fishery production  
• Loss from crop production  
• Loss from dairy and livestock production  
• Damage to animal species  
• Decline in food production/disrupted food supply | 1 2 3 4 5 |
| Salavane        | • Loss from fishery production  
• Loss from crop production  
• Loss from dairy and livestock production  
• Damage to animal species  
• Decline in food production/disrupted food supply | 1 2 3 4 5 |
<table>
<thead>
<tr>
<th>Country</th>
<th>Province/Area</th>
<th>Impacts</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champasack</td>
<td></td>
<td>• Loss from crop production</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss from fishery production</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss from dairy and livestock production</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Damage to animal species</td>
<td>4</td>
</tr>
<tr>
<td>Thailand</td>
<td>Northeastern part</td>
<td>• Decrease water resources making water cost higher for agriculture,</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>industry and daily consumption</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss from crop production (rice, cassava, corn, and sugar cane)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduction of fish and animal habitats due to reduced water quality</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increase of unemployment rate</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss of animal habitats and diseases</td>
<td></td>
</tr>
<tr>
<td>Viet Nam</td>
<td>Mekong Delta</td>
<td>• Loss from crop production</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increase of unemployment with more migration to cities</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss from fishery production</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water quality effects</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Central Highland</td>
<td>• Loss from crop production</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water quality effects</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss from timber production and increase in forest fires</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increase of ground water depletion and land subsidence</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 10: List of impacts and ranking for Cambodia, Lao PDR, Thailand, and Viet Nam
After a series of national and regional studies, gaps of drought management at both national and regional levels together with the future trends on water demands and deficit can be summarised in the table below:

|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|---------------------------------|----------------------------|---------------------|---------------------|------------------------|
| **Cambodia**  | - No drought impacts reporting mechanism  
- Lack of capacity on drought management as a concept  
- Lack of information on hydrological change regimes from upstream countries  
- No proper seasonal water planning  
- No early-warning system and lack of capacity  
- The drought impact reporting system is not yet well organized, reporting from communes to national level, NCDM. | • Reduced water flow from mainstream causes hydrological drought in the region  
• Insufficient flood water in Tonle Sap causes salinity intrusion in the Mekong Delta of Viet Nam  
• Over practice of rain making in Thailand causes less precipitation in Thailand-border of the other Country  
• Overuse of ground water at the border causes slow ground water recharge in bordering downstream  
• No seasonal forecast or weather outlook yet for early warning information to Member Countries  
• Hydrological data sharing framework is not yet in place for hydrological change regime | 524,441 ha in wet season  
1,001,053 ha in dry season | 280,035 millilitres per day in wet season  
1,156,918 millilitres per day in dry season | -260,705 millilitres per day in wet season  
-1185,605 millilitres per day in dry season |
| **Laos**      | - No drought impacts reporting mechanism  
- Lack of capacity on drought management as a concept  
- Lack of information on hydrological change regimes from upstream countries  
- No proper seasonal water planning  
- No early warning system and lack of capacity  
- The drought impact reporting system is not yet well organized, reporting from villages and districts. | • 632,290 ha in wet season  
315,946 ha in dry season | 40,191 millilitres per day in wet season  
77,212 millilitres per day in dry season | -17,389 millilitres per day in wet season  
-44,993 millilitres per day in dry season |
| **Thailand**  | - No regular drought impacts reporting mechanism in place  
- Lack of information on hydrological change regimes from upstream countries  
- Early warning system in place, but better alignment between the different departments and institutes still needed  
- A Decision Support System is being developed to support early warning, among others. | • 1,892,566 ha in wet season  
723,354 ha in dry season | 722,642 millilitres per day in wet season  
550,225 millilitres per day in dry season | -562,720 millilitres per day in wet season  
-499,386 millilitres per day in dry season |
| **Viet Nam**  | - No regular drought impacts reporting mechanism in place yet, reporting through national TV and radio  
- Integration between drought management and salinity intrusion needs to be improved  
- Lack of information on hydrological change regimes from upstream countries  
- Monitoring indicators at the national level are limited to only hydrological and meteorological indicators, in some parts more extensive drought monitoring is done  
- No early warning to end-users | • 1,751,778 ha in wet season  
2,214,749 ha in dry season | 62,623 millilitres per day in wet season  
508,899 millilitres per day in dry season | -35,855 millilitres per day in wet season  
-399,686 millilitres per day in dry season |

Table 11: Summary of problems identification on drought management with future trends on water requirement and deficit for agriculture
Summary on drought adaptation actions by each Member Country can be mapped in the following table with responsibilities of involved Line Agencies:

<table>
<thead>
<tr>
<th>Mitigation Actions</th>
<th>Cambodia</th>
<th>Lao PDR</th>
<th>Thailand</th>
<th>Viet Nam</th>
<th>MRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early notification by MOWRAM / Seasonal Outlook</td>
<td>• Build hydro-met monitoring stations in drought prone areas</td>
<td>• Use of ground water</td>
<td>• Request upstream countries to release water</td>
<td>• Provide technical support in adding drought monitoring indicators and extending new monitoring stations</td>
<td></td>
</tr>
<tr>
<td>NCDM provide water pumps to irrigate agriculture</td>
<td>• Carry out rehabilitation project on agricultural irrigation</td>
<td>• Water diversion from the mainstream</td>
<td>• Provide drought monitoring on meteo and hydrological indicators</td>
<td>• Provide drought forecasting and early information including seasonal outlook</td>
<td></td>
</tr>
<tr>
<td>Supply water tank to drought prone areas</td>
<td>• Build hydro-met monitoring stations in drought prone areas</td>
<td>• Monkey Cheek dams</td>
<td>• Assist Member Countries in building capacity on drought management work</td>
<td>• Help Member Countries develop a regional drought adaptation guideline</td>
<td></td>
</tr>
<tr>
<td>Introduce crops diversification (resilience crops)</td>
<td>• Carry out rehabilitation project on agricultural irrigation</td>
<td>• Crops diversifications</td>
<td>• Carry out necessary study on drought related issues as needed</td>
<td>• Carry out monthly study on drought related issues</td>
<td></td>
</tr>
<tr>
<td>Build hydro-met monitoring stations in drought prone areas</td>
<td>• Request upstream countries to release water</td>
<td>• Drought monitoring &amp; seasonal outlook</td>
<td>• Build regional mechanism on cross-country collaboration and data sharing</td>
<td>• Issue monthly bulletin on drought forecasting</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Implementing Line agencies</th>
<th>MOWRAM:</th>
<th>MONRE:</th>
<th>DDPM:</th>
<th>MARD:</th>
<th>RDFMC of TD:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Early warning on seasonal outlook</td>
<td>- Build hydro-met monitoring stations in drought prone areas</td>
<td>- Build hydro-met monitoring stations in drought prone areas</td>
<td>- Set up policy and coordinate on drought mitigation</td>
<td>- Design national disaster prevention and control strategy</td>
<td></td>
</tr>
<tr>
<td>- Release water from dams to the farms</td>
<td>- Carry out rehabilitation project on agricultural irrigation</td>
<td>- Carry out rehabilitation project on agricultural irrigation</td>
<td>DWR of MOENRE:</td>
<td>HMS of MONRE:</td>
<td></td>
</tr>
<tr>
<td>- Provide generators to farmers for water pumping</td>
<td>- Develop drought management strategy</td>
<td>MAF:</td>
<td>- Develop knowledge-based technology including early warning system</td>
<td>- Provide drought monitoring, forecasting, and early warning</td>
<td></td>
</tr>
<tr>
<td>- Build hydro-met stations in drought prone areas</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Collect data on water resources management</td>
<td>Viet Nam Television and Voice of Viet Nam:</td>
<td></td>
</tr>
<tr>
<td>NCDM:</td>
<td>- Build hydro-met monitoring stations in drought prone areas</td>
<td>MAF:</td>
<td>RJD:</td>
<td>- Disseminate the forecasting and early warning information</td>
<td></td>
</tr>
<tr>
<td>- Provide water tanks to farmers</td>
<td>- Carry out rehabilitation project on agricultural irrigation</td>
<td>MAF:</td>
<td>- Carry out ground water projects</td>
<td>PPCS and MARD:</td>
<td></td>
</tr>
<tr>
<td>- Report disaster impacts to the Council Ministers</td>
<td>NDMC:</td>
<td>MAF:</td>
<td>- Carry out rain making activities</td>
<td>- Record damages and estimate economic losses</td>
<td></td>
</tr>
<tr>
<td>- Develop drought management strategy</td>
<td>- Develop disaster management strategy</td>
<td>MAF:</td>
<td>- Carry out water diversion</td>
<td>MARD:</td>
<td></td>
</tr>
<tr>
<td>MAFF:</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Collect drought impacts and condition from community level</td>
<td>- Design national disaster prevention and control strategy</td>
<td></td>
</tr>
<tr>
<td>- Provide generators to farmers for water pumping</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Conduct water resources planning</td>
<td>HMS of MONRE:</td>
<td></td>
</tr>
<tr>
<td>- Introduce water-resilience crops to farmers</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>DAE:</td>
<td>- Provide drought monitoring, forecasting, and early warning</td>
<td></td>
</tr>
<tr>
<td>CRC:</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Monitor crop growing progress</td>
<td>Viet Nam Television and Voice of Viet Nam:</td>
<td></td>
</tr>
<tr>
<td>- Provide post disaster aids to drought victims</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>DLD:</td>
<td>- Disseminate the forecasting and early warning information</td>
<td></td>
</tr>
<tr>
<td>RID:</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>GISTDA:</td>
<td>PPCS and MARD:</td>
<td></td>
</tr>
<tr>
<td>- Carry out ground water projects</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Carry out drought monitoring and seasonal outlook</td>
<td>- Record damages and estimate economic losses</td>
<td></td>
</tr>
<tr>
<td>- Carry out rain making activities</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>DWR of MOENRE:</td>
<td>MARD:</td>
<td></td>
</tr>
<tr>
<td>- Carry out water diversion</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Collect drought impacts and condition from community level</td>
<td>- Design national disaster prevention and control strategy</td>
<td></td>
</tr>
<tr>
<td>- Collect drought impacts and condition from community level</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Conduct water resources planning</td>
<td>HMS of MONRE:</td>
<td></td>
</tr>
<tr>
<td>- Conduct water resources planning</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>DAE:</td>
<td>- Provide drought monitoring, forecasting, and early warning</td>
<td></td>
</tr>
<tr>
<td>DAE:</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>- Monitor crop growing progress</td>
<td>Viet Nam Television and Voice of Viet Nam:</td>
<td></td>
</tr>
<tr>
<td>- Map drought frequency occurrence</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>DLD:</td>
<td>- Disseminate the forecasting and early warning information</td>
<td></td>
</tr>
<tr>
<td>GISTDA:</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>GISTDA:</td>
<td>PPCS and MARD:</td>
<td></td>
</tr>
<tr>
<td>- Carry out drought monitoring and seasonal outlook</td>
<td>MONRE:</td>
<td>MAF:</td>
<td>GISTDA:</td>
<td>- Record damages and estimate economic losses</td>
<td></td>
</tr>
</tbody>
</table>

Table 12: Summary on drought mitigation actions and responsible line agencies
4. MRC DROUGHT MANAGEMENT STRATEGY

4.1. Key strategic priorities and related actions

Through all the studies and surveys carried out in Member Countries on drought management issues in recent years, it can be inferred that there is a need for the countries to improve their responses to drought hazards, and capacity in the field needs to be enhanced and developed.

The LMB lacks a regional mechanism on drought conditions and related data sharing in the dry seasons, especially on water use planning, including water diversion from the Mekong mainstream, which needs to be efficient and transparent. It also shows the need for upstream collaboration on data sharing and support on water resources sharing during severe drought conditions.

Based on the information above, the following key areas are found to be more or less poorly functioning and should be given priority for receiving technical support from the MRC between 2020 and 2025:

(i) Indicator Monitoring
   (a) Hydro-meteorological and reservoir monitoring
   (b) Monitoring on agreed dry season flows (Article 6A) under the Procedures for Maintenance of Flows on the Mainstream (PMFM), and Procedures for Water Use Monitoring (PWUM)
   (c) Groundwater monitoring
   (d) Soil moisture and crop condition monitoring
   (e) Salinity level monitoring

(ii) Drought Forecasting and Early Warning
   (a) Drought monitoring

Figure 27: Common drought transboundary issues for key strategic priority areas
(b) Drought forecasting and early warning

(iii) Capacity Building in Drought Assessment and Planning
   (a) National and regional trainings
   (b) Regional and international workshops and conferences
   (c) Experience exchanges with other river organizations

(iv) Mitigation Measures
   (a) Collaboration with MRC Dialogue Partners
   (b) Collaboration with national agencies and regional institutions on drought risk management
   (c) Feasibility study on basin water retention through collaboration with Thailand on the Monkey Cheeks or Kaem Ling project
   (d) Water demand management measures
   (e) Development of guideline on drought adaptation
   (f) Pilot activities on drought adaptation measures

(v) Information Sharing and Dissemination
   (a) Drought information dissemination
   (b) Drought data and information documentation

These five priority areas are important for the Member Countries to prepare for seasonal drought disasters.

4.1.1. Indicator monitoring

For drought disaster preparedness and planning, some essential indicators need to be closely and frequently monitored, especially during the period of water scarcity. There are three main drought indicators when considering drought impacts and risks, namely meteorological, hydrological, and agricultural indicators. These three indicators need to come together when performing the analysis. If one of the three elements is lacking or missing, this might result in incomplete or misleading information.

For meteorological and hydrological indicators, the MRC currently has 45 HYCOS stations being operated together with 13 new stations being constructed in the drought-prone areas of the Member Countries. In addition, the DMS 2020-2025 recommends two other essential elements to be monitored as hydrological indicators, namely reservoir levels and groundwater. Reservoirs play an important role in water resources planning during severe and prolonged drought periods when rainfall is inadequate and water levels are considerably low. Then the final option will come to groundwater, which farmers can rely on for both drinking water and agricultural irrigation to rescue desperate crops that need water to survive.

With regard to agricultural indicators, soil moisture and salinity intrusion are currently the most important indicators in the region. Soil moisture presents the level of moisture in the soil, ranging from the surface to different layers in the ground, showing preferable and un-preferable conditions for agricultural crops. From the national surveys, it appeared that the Member Countries lack capacity to monitor soil moisture as an agricultural indicator and rely on available satellite data without ground-truthing. Salinity intrusion is the primary issue in the Mekong Delta of Vietnam, where the level of salinity in the Mekong mainstream is too high for irrigation and harms the agricultural crops in the surrounding areas during the dry season.

4.1.1.1. Hydro-meteorological and reservoir water monitoring

In the planning process, rainfall and water levels are the most fundamental factors to be looked at. During a dry year, the rainfall amount is most likely below average, which is normally inadequate for rain-fed agriculture. This phenomenon will essentially contribute directly to low flow of the Mekong mainstream, leading to water stress for
agricultural irrigation. To cope with such a situation, policy makers need to consider storing water in small and medium-sized reservoirs as well as getting additional support of water from reservoirs in the major tributaries so that water will be available for farmers when facing severe droughts. Drought planning consequently needs information about the overall availability of water from rainfall, reservoirs, soil moisture, groundwater and river discharge. Based on this information, forecasts can be made with the use of models to identify the severity of the droughts.

There are very limited drought monitoring stations on hydrological and meteorological parameters, 13 stations of which 3 in Cambodia, 5 in Lao PDR, and 5 in Viet Nam. There is a need to deploy more stations in the drought-prone areas of Cambodia, Lao PDR, Thailand and Viet Nam in order to make drought assessment on risk and vulnerability more realistic and reliable.

When dealing with a prolonged drought situation, like the dry year of 2015-2016, emergency actions need to be prepared. For instance, in February 2016, the Thai Government put out a regulation on water pumping and diversion for each household for some particular reservoirs in the Northeast to prevent shortfall of water during the following weeks. The government then put the water level in all main reservoirs at the emergency level and monitored almost every hour.

The purpose of installing the monitoring sensor at some main reservoirs is to equip near-real time function to the existing monitoring work of the Member Countries which will make the monitoring work more efficient and be able to provide near-real time information on reservoir water level in the drought disaster areas especially during the emergency situation to the decision makers and to the MRC Secretariat so that the MRC RFDMC can provide technical assistance and support to line agencies when needed in drought assessment, water resources analysis, and drought mitigation planning.

*The Member Countries are to select the reservoirs by themselves to be monitored as they might think those reservoirs are important during drought emergency periods. Water level is the only parameter to be monitored with near-real time function which can be reviewed online.*

With that experience, the MRC has realised that water sources of all types need to be frequently and closely monitored for drought management and planning. Monitoring sensors can be added at the existing and new stations and connected with online devices for near-real-time observation and data sharing among the Member Countries.

**Objectives**

- Extend hydro-meteorological monitoring stations for drought monitoring in the drought prone areas of the Member Countries in addition to the currently existing stations to support drought condition analysis and ground truth validation in the future for drought management work.
- Install water level monitoring stations for the main reservoirs with near-real time function to monitor water level in the reservoirs for drought emergency responses, preparedness, and planning based on agreement with each country.
4.1.1.2. Capitalise on monitoring under the Procedures for Maintenance of Flows on the Mainstream (PMFM) and Procedures for Water Use Monitoring (PWUM)

**Procedures for Maintenance of Flows on the Mainstream (PMFM)**

By acknowledging that drought is a transboundary water management issue, a minimum flow, which has been analysed and standardised under the MRC’s PMFM at all main points on the mainstream needs to be respected to ensure that downstream communities have enough water for at least agriculture and domestic uses in compliance with the 1995 Mekong Agreement.

PMFM has been developed under the BDP Programme stipulated in Article 2 of the 1995 Mekong Agreement. The working document together with the main thresholds for monitoring have been approved by the Joint Committee. Thus, the DMS will follow the approved monitoring thresholds.

Data and information on critical condition of hydrological indicator is one of the main drought monitoring indices specifically during dry season for the mainstream. Hydrological indicator is a transboundary factor where condition upstream has significant effect on downstream parts. The activity will focus only on monitoring on dry season flows of Article 6A of PMFM.

**Objectives**

The main objectives of partly applying PMFM for drought management purpose are to:

- Develop a regional mechanism for monitoring flows on the mainstream including standard requirements for selection the main locations to be monitored for DMS purpose, time period for monitoring and notification and procedures based on agreed PMFM
- Closely monitor the low flow conditions during the dry season and share the data and information with the Member Countries for hydrological assessment on drought impacts.

**Procedures for Water Use Monitoring (PWUM)**

Since water utilisation of the Mekong River has direct impacts on water allocation for agriculture, it is an ideal concept to have the percentage of water use for some main sectors such as irrigation, industry, and domestic monitored closely for both dry and wet seasons to see if it has much influence on water scarcity especially when the percentage increases.

A regional mechanism for water use monitoring under the drought management strategy starting from the next implementation period shall be in place for the Member Countries to follow. It needs to be consistent with the procedures and rules set by PWUM that the Member Countries have already agreed for the MRC. The RFDMC will follow the agreed concept and guidelines on implementation of PWUM under the Technical Support Division.

The purpose of the activity is to collect and monitor water utilisation by sectors at national level which is essential for drought assessment, preparedness, and planning.

**Objectives**

The main objectives of implementing PWUM are to:

- Develop a regional mechanism and guidelines on water utilization
- Monitor and collect data on water use with different sectors to support drought monitoring and assessment
4.1.1.3. Groundwater monitoring

In developed countries, groundwater has been widely explored to support all water utilisation sectors. Groundwater is globally considered as one of the most important and sustainable resources of water, especially for the areas with less access to surface water or less rainfall distribution. However, overexploitation of groundwater can lead to subsidence situation with serious impacts on people's livelihoods and the environment. Also, overexploitation of groundwater may lead to intrusion of water of unwanted quality, like saltwater intrusion in coastal areas. For a sustainable use, groundwater consequently needs to be well managed and appropriately regulated.

Among the MRC Member Countries, Thailand has been exploring groundwater the most, mainly for agricultural activities in the Northeast region. Based on a national study, Thailand has conducted a thorough groundwater survey with a detailed layout of underground layers for the whole Northeast area.

The purpose of this activity is to comprehensively understand the ground water resources in the drought prone areas of the MRC Member Countries for future drought mitigation planning and to assist the Member Countries in equipping near-real time ground water monitoring stations for drought preparedness and planning in the near future.

Objectives:

- Support the Member Countries in carrying out a comprehensive study on ground water resources in the drought prone areas for future drought impacts mitigation.
- Support the Member Countries in installing ground water monitoring with near-real time function to monitor ground water levels in the drought prone areas.

4.1.1.4. Soil moisture and crop condition monitoring

Soil moisture is the main agricultural indicator for drought. Yet, ground monitoring stations of soil moisture are still very limited in the LMB. As normal practice, the MRC Member Countries use satellite data to analyse agricultural drought, such as the Normalized Difference Vegetation Index from either MODIS or TM Landsat along with SMOS satellite data. Soil data for drought analysis is divided into two classes, namely top-soil and subsoil. Subsoil is more important to monitor for soil moisture as it is rich in minerals and plays an important part in plant growth.

Like other indicators, ground data on soil moisture is significant for indicator monitoring and satellite products calibration. In the long run, the ground data will generate a historical record, which can be used for verifying and calibrating the satellite-based products, aiming at improving the quality of the models and tools. Thus, it is very important for the MRC for this Drought Management Strategy 2019-2023 to start building ground truth stations.

In addition to soil moisture, crop condition is the most important and direct indicator of agriculture for drought. It shows exactly how the crops progress from time to time. This function will enable our scientists to be able to forecast how long the crops can survive under water stress conditions and, therefore, when the warning should be put in place.

For crop condition monitoring, a real-time camera can be attached to the soil monitoring station. The stations and cameras can be deployed right in the agricultural field with some protection tool to secure the equipment.

Objectives

The main objectives of the soil moisture monitoring activity are to:
- Support the Member Countries install soil moisture monitoring stations in the drought prone areas for hourly and daily soil moisture content data collection.
- Develop MRC soil moisture parameter data storage and sharing with the Member Countries for drought indicator assessment in the future.

### 4.1.1.5. Salinity level monitoring

Salinity intrusion is a major concern in agricultural areas around the coastal zones where the sea level is higher than the water level of the connecting river. This situation has occurred in the Mekong Delta of Viet Nam during almost every dry year. In the most recent drought disaster in 2016, salinity intrusion in the Mekong Delta was found as far as 90 km from the main river, damaging agricultural crops within the buffer zone. The cause of the incident is insufficient flood-water in the Tonle Sap flood-plain in the previous rainy season, stimulating low flow in the Mekong Delta of Viet Nam in the dry season, allowing sea-water to infiltrate the main river.

This devastating condition can be alleviated to some extent if the flow regime upstream is increased to sufficient levels, generating high flow in the Mekong Delta and pushing back the sea-water infiltration in the river. This is a regional mechanism, and the MRC might need a collaborating support from its Dialogue Partner – China – on water supply from the storage dams. Therefore, the most updated and frequent data and information on sea-water infiltration in the main river and some connecting tributaries of the Mekong Delta are significantly important for decision makers during disaster periods.

In the LMB, besides the Mekong Delta of Viet Nam, some areas in the coastal zone of Cambodia including Koh Kong, Kep, Kampot, and Sihanoukville provinces are also affected by salinity intrusion of which the level of saline needs to be measured and frequently monitored.

Thus, the purpose of this activity is to detect the level of salinity intruded into rivers and agricultural soil nearby the coastal areas of the Member Countries to measure the impacts of salinity on agricultural productivity.

**Objectives**

The main objectives of this activity are to:

- Support the Member Countries in installing salinity intrusion monitoring stations in selected coastal areas during dry periods to detect the level of salinity in the intruded rivers and agricultural land
- Develop MRC data storage and sharing on salinity level for future reference.

### 4.1.2. Drought forecasting and early warning

Early warning of drought is the first and most crucial step for drought preparedness and planning. Early warning provides the forecast information of what is going to happen and how severe the drought will be in a certain period; hence, it warns about the areas where drought is going to occur, causing different vulnerabilities. By referring to the warning information, policy makers are able to come up with immediate actions for drought impacts mitigation and—at the local level—farmers can arrange their mitigation plan to rescue their crops, preventing them from getting damaged through saving or storing some water, for instance.

Through a national study, among the four Member Countries, only Thailand and Viet Nam are operating drought early warning systems. Yet, the warning services do not provide full nor comprehensive information as the
departments involved are working independently without close cooperation or information sharing among the relevant agencies, thus providing only one-sided drought analysis.

A complete drought early warning system would include:

- Drought monitoring on at least three main drought indicators including hydrological (SRI, SDI or GRI), meteorological (SPI or PDSI), and agricultural indicators (CMI, SMI or NDVI).
- Drought forecasting for a period of weeks and months ahead with at least three main indicators including hydrological, meteorological, and agricultural indicators.
- Early warning of drought situations and trend analysis based on both monitoring and forecasting, announced as likely risks and impacts at the early stage of the drought events to the stakeholders.

4.1.2.1. Drought monitoring

Based on technical collaboration with SERVIR Mekong under a USAID project that was signed in October 2015, the MRC has been granted full access to the most updated satellite imageries for producing weekly and monthly drought monitoring indices under the Regional Hydrological Extreme Assessment System (RHEAS) tool. Those satellite data include precipitation (CHIRPS, TRMM, GPM), soil moisture (SMOS), temperature (NCEP), meteorology (NMME), evapotranspiration (MOD16), and water storage (GRACE). The data will allow us to produce weekly and monthly drought monitoring indices including the Standardized Precipitation Index (SPI), Drought Severity Index (DSI), Standardized Runoff Index (SRI), Soil Moisture Index (SMI), and Soil Moisture Deficit Index (SMDI).

The MRC Secretariat, through the RFDMC, will support the Member Countries in providing weekly and monthly drought monitoring products via a public information-sharing tool under the MRC Information Portal.

Objectives

The objectives of the drought monitoring are to:

- Develop an MRC framework on drought monitoring tools and system to assess drought monitoring indicators including meteorological, hydrological, and agricultural indicators.
- Perform weekly and monthly drought monitoring services to share with the Member countries and relevant line agencies through the MRC website and monthly bulletin.
- Establish a data storage and sharing framework on drought monitoring for future reference and tools verification and validation.

4.1.2.2. Drought forecasting and early warning

Drought forecasting and early warning systems play a vital role in providing early information on drought conditions to both farmers and decision makers since the beginning of the rainy season to end of the season. Based on the early provided information, farmers have a better choice to plan ahead their actions to mitigate drought impacts or recue seasonal crops during the dry periods, while the decision/policy makers will be able to issue the early warning to farmers and start preparing adaptation measures and setting up new regulations to assist local farmers to get through the disaster time.

The MRC has recently set up a drought forecasting system using the Regional Hydrological Extreme Assessment Tools (RHEAS) through collaboration with SERVIR Mekong under technical support from NASA JPL. The forecasting system is using IRI/NMME meteorological forcing that resamples climatology based on the probabilities for meteorological indicator. It provides 90-day forecast results on precipitation, base flow, runoff, soil moisture, evaporation, water balance, temperature, etc.
The proposed activities of the DMS 2020-2025 will allow the RFDMC to maintain weekly and monthly forecasting routine and enhance the forecasting tools for a better and internationally standardized service.

Objectives

The objectives of the drought forecasting and early warning are to:

- Develop an MRC framework on drought forecasting and early warning tools and system to assess drought forecasting indicators including meteorological, hydrological, and agricultural indicators.
- Perform monthly drought forecast and seasonal outlook services to share with the Member countries and relevant line agencies through the MRC website and monthly bulletin.
- Establish a data storage and sharing framework on drought forecasting for future reference.

4.1.3. Capacity building for drought assessment and planning

Referring to the national findings on capacity needs assessment, most national line agencies of the Member Countries involved in drought management work have limited understanding of and experiences with drought-related issues, including drought definition and classification, drought monitoring and forecasting, drought risk and vulnerability assessment, drought management and mitigation, etc. With this, the DMS 2019-2023 suggests that capacity building is essential to build capacity and institutional capability for national agencies and can be performed through national and regional training courses, internships, seminars, workshops, and study tours.

Objectives

The main objectives of the capacity building on drought assessment and planning are to:

- Enhance national capacity and institutional capability for line agencies on drought management work including drought forecasting and early warning, drought preparedness and planning, and drought vulnerability assessment, and drought adaptation and mitigation strategy through national and regional trainings.
- Exchange experiences and knowledge on drought management on local and transboundary issues with other regional and international organizations and river basins through regional and international conferences and workshops.
- Build practical experiences on drought management and adaption strategy through exchange visits to drought prone areas of other countries in the region and beyond.

4.1.3.1. National and regional training

Training is the most effective way for building capacity of national line agencies that are dealing directly and indirectly with drought management activities. Within the MRC, training is divided into two distinct levels, specifically national and regional levels. With regard to training courses, the MRC can provide capacity building on specific topics to the trainees with practical exercises to familiarise them with the tools and theories. Field visits can be added to obtain practical experiences for certain areas. The activities for capacity building will be performed in close cooperation with national research institutes and universities in order to enable further dissemination of the knowledge and experiences through national capacity development. Moreover, capacity building on drought should be incorporated in regular curricula in universities.
For the first time of the MRC, the training on drought management work shall focus on some basic tools and understanding of drought-related concepts. They should include the following:

1) Advanced GIS and analysis tools for drought management
2) Drought indicator assessment
   - Standardized Precipitation Index
   - Soil Moisture Index
   - Soil Moisture Deficit Index
   - Drought Severity Index
   - Standardized Runoff Index
   - Normalized Difference Vegetation Index
   - Streamflow forecast
3) Drought risk and vulnerability assessment
4) Water resources planning and drought response measures
5) Drought management and adaptation strategy

Where possible and relevant, capacity building should be done in close cooperation with national research institutes and universities. Possibilities for on-the-job training and internship with the RFDMC should be considered.

In addition to the trainings, regional and international workshops and conferences will be planned and carried out to exchange experiences with experts in the region and beyond. MRC staff at both national and regional levels will have an opportunity to interact, express their concerns, and exchange experiences with other regional and international experts who have different experiences and concepts on drought management issues. It is ultimately essential for MRC staff to learn from other regions and experts, especially on drought early warning systems and drought management and adaptation strategies.

4.1.3.2. Experiences exchange with other river organizations

Study tours are a good practice to learn real things in the field. It is a very common action that most international river organisations usually do to improve understanding in the real world and to validate the theories that have been transferred from one person to another. Study tours can be taken place in one of the Member Countries or other river organizations, where droughts have been an issue of the locality or transboundary and consequently have been addressed with significant results.

4.1.4. Drought mitigation measures

Drought mitigation is the most important action of which the MRC Secretariat should directly support the Member Countries, both in terms of coordination and technical supervision, especially during critical situations of severe droughts, prolonged dry spells, and critical low flows. During the drought hazards in 2016, the MRC could have, had such a mechanism been already in place, on behalf of the Member Countries, played a key role in coordinating with dialogue partners for an immediate water supply from upstream countries, especially China. The MRC could have conveyed the emergency of the water scarcity and severe low flows that were threatening the Member Countries in the LMB, putting at risk agricultural products and domestic water use, which needed an immediate support. Moreover, the MRC could have been able to support the Member Countries by disseminating information on drought conditions and trend analysis at some main locations of the Mekong mainstream for disaster preparedness and prevention.
Under this mitigation section, it is also necessary to have a regional guideline on drought adaptation and to test some of the adaptation options in pilot activities. The Member Countries can learn from the pilot projects how to mitigate some specific impacts and witness the effectiveness of the applied options.

4.1.4.1. Collaboration with Dialogue Partners

MRC’s Dialogue Partners, China and Myanmar, are mainly the driver of regulating flow regimes from upstream parts, which play a key role in reducing and triggering hydrological drought hazards in the LMB. Hence, it is extremely significant for the MRC to enhance cooperation with those dialogue partners for a better Mekong mainstream water management. Data on daily operations of the hydropower dams especially the flow velocity and water levels are also significantly important for the MRC to monitor the changes of the Mekong flows as well as to forecast the trends during upcoming periods.

Objectives

The main objectives of the collaboration with dialogue partners are to:

- Strengthen inter-relationship between the MRC Secretariat and National Mekong Committees with the dialogue partners (China and Myanmar) for future technical collaboration on drought and water resources management issues and data sharing of flows and dam operations especially during dry periods.
- Establish an annual technical exchange workshop and study tours to China and Myanmar and other advanced basins/countries to enhance knowledge and capacity in drought adaptation options and early warning systems.

4.1.4.2. Collaboration with national agencies and regional institutions on drought disaster management

Human resources at the national level of the MRC Member Countries are still very limited and need to be enhanced especially on management and technical work such as space application for drought monitoring and forecasting which is the most overriding topic to be improved. With this, a wider collaboration with the national counterparts and regional institutions will play a major role in building up capacity for relevant agencies and institutions in the field of drought management and technology. It will also provide an opportunity for financial support to the drought management team from our collaboration partners.

In response to the request by the Member Countries for a wider collaboration within national territory and outsiders to disseminate and exchange the knowledge and understanding of drought and to build collaboration network, the drought management strategy for the next implementation period seeks to broaden the national collaboration to both national agencies and regional institutions. Those agencies and institutions shall include, but not be limited to, educational institutes, universities, scientific research, regional institutes, regional organizations, academic foundations, etc.

Objectives

The main objectives for bridging the collaboration with national agencies and regional institutions are to:

- Enhance national institutions’ capacity and capability on drought management and disseminate drought disaster and water resources management related work of the MRC to national agencies and regional institutions.
- Strengthen relationship between the MRC and national and regional institutions and involve those agencies and institutions with MRC drought management activities through technical collaborations.
• Broaden academic studies and research at both national and regional institutes in the field of drought management, adaptation, and forecasting systems to improve effectiveness of national and transboundary drought management efforts.

4.1.4.3. Feasibility study on basin water retention through collaboration with Thailand of the Monkey Cheeks (Kaem Ling) projects

Monkey Cheeks or so-called Kaem Ling project in Thailand was a royal project initiated by King Bhumibol Adulyadej, Rama 9. The project aims to develop retention areas that store flood waters and allow drainage of large amounts of water into the monkey cheeks instead of along the streets and roads of cities. The monkey cheeks generate a water reserved area to be used in the dry season. The project has been piloted in many flood and drought provinces of Thailand and evaluated as a successful project for flood prevention and water retention to mitigate drought impacts in the next dry season.

Since Cambodia and Lao PDR are in need of small reservoirs to store water for agricultural irrigation in some severe drought areas, this water retention project, although originally and primarily conceived as a flood management initiative in Thailand, can be explored in terms of effectiveness for drought mitigation as well.

Objectives

The main objectives of this study are to:

• Comprehensively understand the monkey cheeks’ structure and project operation in Thailand, and its effectiveness and recommendations to deal with water scarcity in the dry season.
• Assess feasibility of the project for other MRC Member Countries, mainly Cambodia and Lao PDR.
• Develop a full proposal for fund raising on water retention projects to be implemented in the MRC Member Countries in the-near future.

4.1.4.4. Identification of water demand management measures

With economic development and a growing population, the demand for freshwater will increase. The increased demand for food, energy and industrial products will raise the demand for water significantly and without measures to reduce the water consumption per product, this demand will become too high to sustain. A range of options exist towards reducing the use of water. These include managing water consumption, grey water reuse, water efficient industrial production, rainwater harvesting, innovative irrigation, crops that require less water, etc.

Improved insight is needed in the water use per sector and at the household level, as well as options to reduce the water consumption in each sector. Based on that information, specific measures can be developed.

Objectives

The main objectives of this activity are to:

• Comprehensively study water demand and supply for agriculture and the correlation between national and transboundary issues on crops and water resources.
• Set up threshold values for both national and transboundary water use mainly on agricultural sector to improve drought and water resources management in the future of the lower Mekong countries.

4.1.4.5. Development of a guideline on drought adaption

Considering reducing transboundary drought impacts and vulnerability as the core task in drought management, drought adaption under the MRC strategy needs to be implemented under an appropriate guideline facilitated by the drought management team of the MRC Secretariat. To be effective, drought mitigation should be focused by giving transboundary issues priority before considering national and local issues, so that both transboundary and national impacts can be fully covered and addressed.

Objectives

The main objectives of the development of the drought adaption guideline are to:

- Investigate and gather lessons learnt from the MRC Member Countries on the past practices of drought adaptation and mitigation measures as well as the feedback on those practiced drought adaption and mitigation methodologies.
- Formulate a comprehensive MRC drought adaptation guideline addressing both the needs at the national and transboundary levels to adapt to drought impacts and build up adaptive capacity to drought vulnerability.

4.1.4.6. Pilot activities on drought adaptation measures

To validate the adaptation options that will be identified and listed in the MRC guideline for mitigating drought impacts, some pilot projects need to be put into practice. Each Member Country can select a few mitigation options that match the drought problems in local areas. Ideally, those selected options should be different from one country to another so that more mitigation options can be piloted and tested for their efficiency.

Objectives

The main objectives of pilot activities are to verify the effectiveness of the selected drought adaptation options and develop recommendations based on the actual results from piloting for future improvement of the measures and to support the formulation of the adaptation guideline.

4.1.5 Information sharing and dissemination

4.1.5.1. Drought information dissemination

Unlike flood, drought is a slow-progressing disaster of which the negative effects do not directly present themselves in physical appearance. The negative impacts of drought are mainly non-structural such as reduction in agricultural products, insufficiency of domestic water use, critical low flow, plant disease, human stress, etc. Therefore, it takes time for us to notice the drought progress, hazards, and threats leading to fewer or slower responses in terms of preparedness and prevention.

Moreover, since some Member Countries, including Cambodia and Lao PDR, do not have a system for drought monitoring and forecasting, support from the MRC in terms of a monthly drought situation analysis and notification will be significantly ideal, useful, and necessary.

Objectives

The MRC’s involvement, under this strategic role, is to produce monthly drought information bulletins and post it on the MRC website to allow public access to the most up-to-date drought situation in the region. The MRC can
distribute the monthly bulletin via email or through mobile App to all representatives of relevant national agencies. This monthly bulletin can later serve as a drought information archive for future reference.

4.1.5.2. Drought data and information documentation

Drought information especially seasonal analysis of drought conditions needs to be well documented as it will be used for future review and cross check. Therefore, an archive system of drought information needs to be developed for the MRC.

Objectives

The main objective of this section is to structure the drought data and information systematically in order to build an MRC drought archive for future reference.
<table>
<thead>
<tr>
<th>Strategic Priority/Outcome &amp; Objectives of Each Activity</th>
<th>Activity/Output</th>
<th>Timeframe</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Indicator Monitoring</td>
<td>1.1. Hydro-meteorological and reservoir Monitoring</td>
<td>2020-2024</td>
<td>Some newly stations of hydro-met and selected reservoirs at National level are constructed and equipped with telemetry function for near-real time monitoring</td>
</tr>
<tr>
<td></td>
<td>• Extend hydro-meteorological monitoring stations for drought monitoring in the drought prone areas of Member Countries in addition to the currently existing stations to support drought condition analysis and ground truth validation in the future for drought management work</td>
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<tr>
<td></td>
<td>• Install water level monitoring stations for the main reservoirs with near-real time function to monitor water level in the reservoirs for drought emergency response, preparedness, and planning</td>
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<td></td>
<td>1.2. Monitoring on dry season flows, Article 6A, under the Procedures for Maintenance of Flows on the Mainstream (PMFM) and Procedures for Water Use Monitoring (PWUM)</td>
<td>2022-2023</td>
<td>Some main locations on the Mekong Mainstream are selected for dry season flows and water use monitoring and the routine work are operational</td>
</tr>
<tr>
<td></td>
<td>• Develop a regional mechanism for monitoring flows on the mainstream, including standard requirements for selection of the main locations to be monitored, time periods for monitoring and notification, and notification procedures based on the PMFM</td>
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</table>

To closely monitor and share with Member Countries the dry season flows and water use in some main critical locations and bind up as monthly records.
<table>
<thead>
<tr>
<th>Strategic Priority/Outcome &amp; Objectives of Each Activity</th>
<th>Activity/Output</th>
<th>Timeframe</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Perform periodical assessments and analyses on future trends of the flows during critical situations on a weekly basis</td>
<td></td>
<td>Monthly dry season flows and water use at selected locations are reported in summary</td>
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<tr>
<td>• Notify and disseminate the information and data on dry season flows to Member Countries on a daily and weekly basis</td>
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<tr>
<td>• Review PWUM policy and regulations approved by the MRC Joint Committee</td>
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<tr>
<td>• Develop a regional mechanism and guidelines for national level to follow and implement water use monitoring in dry season</td>
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<tr>
<td>• Carry out implementation on water use monitoring for potentially agreed sectors at National levels</td>
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<tr>
<td>• Develop a comprehensive report on activity assessment with recommendations for future improvement</td>
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<tr>
<td>To assist Member Countries in discovering the ground water resources and setting up some samples of monitoring stations for exploring and making use of ground water potential for future drought impact mitigation</td>
<td><strong>1.3. Groundwater monitoring</strong></td>
<td>2021-2025</td>
<td>Some groundwater monitoring stations are built in agricultural drought prone areas and daily measuring function is operational</td>
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<tr>
<td>• Collaborate with Regional and International Organizations and Academic Research Centers to exchange knowledge and adopt new technology on ground water monitoring</td>
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<tr>
<td>• Develop a standard framework including criteria for site selections and procedures of equipment installation and station construction for new monitoring stations to assist Member Countries</td>
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<tr>
<td>• Support Member Countries to construct groundwater monitoring stations in the appropriately selected drought-prone areas with near-real-time functions; the existing hydro-meteorological stations of the DMT can be equipped with an additional sensor</td>
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<tr>
<td>• Include water quality monitoring sensors, where relevant, to identify salinization and/or other water quality deterioration</td>
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<tr>
<td>• Build data management system including quality control and gaps filling</td>
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<tr>
<td>Strategic Priority/Outcome &amp; Objectives of Each Activity</td>
<td>Activity/Output</td>
<td>Timeframe</td>
<td>Indicator</td>
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<td>----------------------------------------------------------</td>
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<tr>
<td>• Develop management plans for station operation and maintenance, and decentralisation road map for the stations</td>
<td><strong>1.4. Soil moisture and crop condition monitoring</strong></td>
<td>2022-2024</td>
<td>Some soil moisture monitoring stations are built in agricultural drought prone areas and daily measuring function is operational</td>
</tr>
<tr>
<td>• Carry out a comprehensive study on ground water monitoring and use which have been developed in Member Countries and the region</td>
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<tr>
<td>• Seek for collaboration with regional and international organization and agencies on technical advancement of the soil moisture monitoring</td>
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<tr>
<td>• Develop a regional framework and assist Member Countries in building soil moisture monitoring stations with near-real time functions</td>
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<tr>
<td>• Build data management system including quality control and gaps filling</td>
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<td>• Develop management plans for station operation and maintenance, and decentralisation road map for the stations</td>
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<tr>
<td>To support Member Countries in monitoring levels of salinity intruded from sea water mainly during dry period where flows from the Mekong River are at critically low level</td>
<td><strong>1.5. Salinity level monitoring</strong></td>
<td>2022-2024</td>
<td>Salinity intrusion in the critical areas of Member Countries are studied and some daily measuring stations are built with high-tech equipment for daily operation in drought year</td>
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<td>• Carry out a comprehensive study on salinity intrusion in Member Countries and the region</td>
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<td>• Assist Member Countries in setting up the monitoring stations in the appropriate locations</td>
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<td>• Build data management system including quality control and gaps filling</td>
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<tr>
<td>2. Drought Forecasting and Early Warning</td>
<td>2.1. Drought monitoring</td>
<td>2020-2021</td>
<td>A regional drought monitoring and forecasting system is developed and operational with regularly updated tools</td>
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<td></td>
<td>• Select drought indices and tools for monitoring work (nowcasting) under RHEAS</td>
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<td></td>
<td>• Build a standard drought monitoring tool for regional levels and transboundary issues</td>
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<td></td>
<td>• Develop and operate a regional drought monitoring service on selected drought indices (SPI, DSI, SRI, and SMDI)</td>
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<td></td>
<td>• Develop a regional drought data portal to share raw and end-product data with the Member Countries</td>
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<td>• Conduct end-product verification for tools enhancement</td>
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<td>2.2. Drought forecasting and early warning</td>
<td>2020-2021</td>
<td>A regional drought forecasting with early warning information and seasonal outlook is developed and operational</td>
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<tr>
<td></td>
<td>• Select drought indices and tools for drought forecasting work under RHEAS</td>
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<td></td>
<td>• Build a standard drought forecasting and early warning tool for regional level that links to the national levels</td>
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<td>• Develop a seasonal outlook on weather forecast for the next 3-6 months</td>
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<td>• Develop a regional drought data portal to share raw and end-product data with Member Countries</td>
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<td>• Conduct end-product verification for tools enhancement</td>
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<td></td>
<td>• Conduct frequent technology sharing on drought early warning among MRC Member Countries and beyond, especially with the ASEAN region</td>
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<td></td>
<td>• Develop a MRC stand-alone drought forecasting system by customising RHEAS models with customised parameters for the LMB</td>
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<td></td>
<td>• Provide national and regional trainings on drought management and related subjects to national Line Agencies</td>
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<td></td>
<td>• Create a study tour package to other drought prone Countries in the region and beyond</td>
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<td></td>
<td>• Provide on-the-job training to riparian professionals to learn about drought management work at the MRC Secretariat</td>
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<td>3.2. Regional and international workshops and conferences</td>
<td>2020-2025</td>
<td>Annual workshops and conferences for knowledge exchange are conducted at regional and international levels with experience sharing forum enabled</td>
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<td></td>
<td>• Conduct annual conferences and workshops with regional and international experts to exchange experiences and new advancement</td>
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<td></td>
<td>• Generate a drought-exchange-experience forum for knowledge sharing</td>
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<td></td>
<td>3.3. Experience exchanges with other river organizations</td>
<td>2020-2025</td>
<td>More collaboration with other river basin organizations extended and field visits to drought prone Countries in the region and beyond are conducted</td>
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<td>• Build collaboration with other organizations in the region and beyond</td>
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<td></td>
<td>• Carry out experience exchanges with other organizations by Country visit to the drought prone areas with drought adaptation measure applied</td>
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<td>4. Mitigation Measures</td>
<td>2021-2025</td>
<td>Collaboration with dialogue partners, China and Myanmar, on data and technology exchanged are conducted</td>
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<td>4.1. Collaboration with dialogue partners</td>
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<td></td>
<td>• Enhance cooperation with dialogue partners on drought management</td>
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<td></td>
<td>• Propose hydrological data exchange in the dry season, especially from the two stations in China</td>
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<tr>
<td>• Propose an annual technical exchange workshop and study tour to China and Myanmar to learn from drought adaption options and early warning systems used in the Countries</td>
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<td>2021-2025</td>
<td>National agencies and academic institutes working on drought management are directly involved in some of the drought management activities of the RFDMC</td>
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<td>To build a network with national and regional counterparts to extend knowledge and experiences on drought management with more study researchers</td>
<td>4.2. <strong>Collaboration with national agencies and regional institutions on drought disaster management</strong></td>
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<tr>
<td>• Invite relevant national and regional institutions and agencies who are working very closely with drought activities to the MRC drought conferences and seminars</td>
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<td>• Discuss with those relevant national and regional institutions and agencies for collaboration opportunities</td>
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<td>• For academic institutes and research, send them notification letter on our on-going and proposed project with a request for statement of interest</td>
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<td>• Prepare an agreement and MOU for the interested collaboration partners stating clearly scopes of work and financial contribution</td>
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<td>• Jointly implement the collaboration activities with monitoring and evaluation on the progress and outcomes.</td>
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<td>4.3. <strong>Feasibility study on basin water retention through collaboration with Thailand of the Monkey Cheeks or Kaem Ling Project</strong></td>
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<td>• Build collaboration with Royal Irrigation Department (RID) of Thailand on the Monkey Cheeks project through a TOR</td>
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<td>2021-2022</td>
<td>Feasibility study report on basin-based water retention project is developed for future development projects at national levels and a proposal on national pilot projects is drafted with consultations with Member Countries.</td>
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<td>• Hold a discussion meeting with RID on teamwork formulation and action plan</td>
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<td>• Carry out field visit to the project sites for physical study and project understanding</td>
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• To comprehensively understand the monkey cheeks’ structure and project operation in Thailand, and its effectiveness and recommendations to deal with water scarcity in dry seasons
• To assess feasibility of the project for other MRC Countries mainly Cambodia and Lao PDR
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| To develop a full proposal for funding on water retention projects to be imposed in MRC Member Countries in the near future. | • Develop a comprehensive report with recommendations based on feasibility assessment of the Monkey Cheeks project by Thailand side  
• Conduct a regional consultation meeting with MRC Member Countries to discuss on proposed pilot projects at National levels  
• Formulate a proposal for pilot projects on basin-based water retention for drought mitigation at national levels. | 2023-2025 | Water demand and options for crops is comprehensively studied |
| To comprehensively study water demand and supply for agriculture and the correlation between national and transboundary issues on crop and water resources | **4.4. Water demand management measures**  
• Conduct studies into the reduction of water use of different sectors and households  
• Carry out inventories of water demand management options that are relevant for the LMB region  
• Identify priority water demand management options to be included in the DMS | 2023-2025 | |
| To assist Member Countries in developing a national guideline on drought adaptation for certain drought impacts | **4.5. Development of guideline on drought adaptation**  
• Formulate national teams for developing a drought adaptation guideline  
• Conduct a national study on data collection of drought management policy and mitigation strategy, agricultural land use and irrigation, and crop yield for all types of agricultural land use  
• Together with the results of crop modelling and scenarios of land use with water availability, develop a guideline on drought adaptation for the MRC | 2020-2022 | A regional guideline on drought adaptation measures reflecting both national and transboundary perspectives is studied and developed |
| To verify some adaptation guidelines through implementing pilot projects at Member Countries as a lesson learnt | **4.6. Pilot activities on drought adaptation measures**  
• Identify hotspot areas where drought has been a severe problem  
• Select the most suitable adaptation options listed in the MRC Guideline for drought mitigation for the hotspots | 2020-2021 | A pilot project at each Member Countries is carried out to test the adaptation measures being identified for certain drought impacts |
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|                                                          | • Formulate a national team to carry out the pilot project and commence the implementation  
• Write a national report on the pilot project with recommendations for lessons learned | 2020-2022 | A regional mechanism on data sharing between the countries and the region is developed, monthly drought bulletin with seasonal weather outlook is established and operational, and an online drought forecast bulletin library is built |

5. Information Sharing and Dissemination

To develop a data and information sharing network from the MRC Secretariat to National levels on monthly drought condition

5.4. Drought information dissemination

• Develop a data sharing mechanism between Member Countries and MRC Secretariat for routine data sharing network  
• Develop a monthly bulletin on drought condition forecast with 3-6 months seasonal outlook and share with concerned national agencies  
• Establish an online archive system for the monthly drought forecast bulletin

2021-2025  
A regional data storage on drought monitoring and forecasting for sharing with Member Countries is developed with proper classifications of drought indices

To develop a regional data and information library on drought indicator monitoring and forecasting to share with National Counterparts

5.5. Drought data and information documentation

• Develop data management system at the MRC Office with different categorizations of drought information e.g. by different drought indicator indices and time periods  
• Build archive webpage under the MRC drought forecasting and early warning system  
• Develop a simple guideline on how to access and review the information and share it with both MRC division and Member Countries

Table 13: List of priority areas and related actions
4.2. Challenges for implementing the Drought Management Strategy

The MRC will face opportunities and challenges while implementing the DMS 2020-2025 in the beginning stage. The main difficulty will be adopting new technology on drought early warning systems, including drought monitoring and forecasting, which requires a combination of knowledge and experiences, including advanced GIS, computer programming, water resources planning, as well as drought information analysis. The capacity of MRC staff will need to be further built if the MRC is to facilitate capacity building and technology transfer to riparian countries. These challenges might raise the following issues:

- **Technology transfer to NMC secretariats and line agencies**: The MRC needs to build its own capacity at the secretariat level before the technology can be transferred to riparian countries.
- **Personnel**: Consideration of the necessary personnel within MRCS with regards to drought needs to be addressed.
- **Funding**: Funding is presumably secured when drought activities are managed and operated under the RFDMC. Otherwise, alternative funding sources need to be identified.

Additionally, the cooperation between the Member Countries may pose challenges to implementing the DMS. The different levels of drought monitoring and of experience and capacities in the line agencies may hinder smooth implementation of the actions. Therefore, capacity building to get relevant people at a common level of understanding is needed urgently.

4.3. Monitoring and evaluation of the strategy implementation

In order to monitor and evaluate the progress of the strategy implementation against the set milestones and expected outcomes, which will be clearly written in the annual work plans of the five-year implementation document, the MRC’s standard mechanism of monitoring data collection, documentation, and reporting will be applied, including a six-monthly performance review, an annual performance review and mid-term and final independent evaluation. Each review, and the mid-term and final evaluation will focus on the level to which the proposed actions as listed in Table 13 have been implemented in line with the proposed time-schedule. An annual work plan will be prepared for each calendar year (2020-2025) within the framework of the MRC work planning, in accordance with the MRC Secretariat procedures for advancement of regional and transboundary cooperation.

Next to that, technical reports at the MRC level will be produced.

The MRC will be responsible for budget management and planning and preparation of the annual work plans for both national and regional levels. The annual work plans will be approved by the MRC Joint Committee. The budget statement will be reviewed every six months and addressed in the bi-annual progress report. The bi-annual reports will be submitted to the Member Countries and development partners.

The MRC will audit our activities annually. The audit will cover budget planning, procurement, administration, financial reporting, accounting documents, and statements of transfer/disbursements.
5. ANNEX

Bibliography


MRC. (2010). *MRC Hua Hin Declaration “Meeting the Needs, Keeping the Balance: Towards Sustainable Development of the Mekong River Basin”*. Mekong River Commission Secretariat


Drought definitions and indices

Drought definitions

Drought is one of the least understood natural hazards and most costly ones (Donald A. Wilhite, 1993). This concept has been acknowledged as a fact in the Mekong River Basin, and particularly in its lower parts. The definition of drought varies on the basis of the situation or area for which drought is being defined. In a simple definition, it is understood as a period of water shortage that can range from a few days or weeks for some crops to a few months and years for large reservoirs or groundwater aquifers, e.g., as little as an inch of precipitation for shallow root crops to as much as several feet of precipitation for water supplies that rely on stream-flow or groundwater (Gathara, Gringof, Mersha, Sinha-Ray, & Spasov, 2006). Drought is conceptually relative to some long-term average conditions of the balance between precipitation and evapotranspiration (i.e., evaporation + transpiration) in a particular area. It is also related to the timing (principal season of occurrence, delays in the start or early end of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness of the rains (i.e., rainfall intensity, number of rainfall events). However, it is required to move beyond conceptual definitions to give an operational definition of drought (Gathara et al., 2006).

Drought risk is a product of a region’s exposure to the natural hazard and its vulnerability to extended periods of water shortage (Donald A. Wilhite, 2000). The severity of a drought is dependent not only on its duration, intensity, and spatial extent, but also on the specific environmental and economic activities carried out within it. Hence, drought is the result of many external and internal factors:

- Natural factors, including climate of the area; antecedent conditions as exemplified by the amounts of soil moisture, rain, and snow; the distribution of rain and snow in time and space; water table levels during the drought; water quality; and soil type; and
- Human factors, including socio-economic development; degree of development of water storage and distribution systems; patterns of water use and per capita consumption; legal and policy aspects; project operating rules; relevant water quantity and quality standards; economic considerations; availability of required technology and resources; and many more (Gathara et al., 2006).

Through a series of national and regional consultation workshops with the four MRC Member Countries during the DMP 2011-2015, under the programme document formulation process, six drought definitions have been agreed upon and adopted for the LMB. They are known as the most applicable definitions and defined as follows:

**Meteorological or climatologic drought** focuses on the degree of “dryness” in terms of accumulated rainfall deficit and is principally defined by a deficiency of precipitation compared to expected or “normal” levels over an extended period of time. Drought is the consequence of a natural reduction in the amount of precipitation received over an extended period of time, usually a season or more in length. Other climatic factors (such as high temperatures, high winds, and low relative humidity) are also often associated with drought in many regions of the LMB, and such factors can significantly aggravate the severity of the event. Drought is also related to delays in the start of the rainy season, early end of the rainy season, and/or prolonged dry spells during the rainy season, as well as occurrence of rains in relation to principal crop growth stages and the effectiveness of the rains (i.e., rainfall intensity, number of rainfall events). Meteorological drought is the prime mover in the sequence. The first consequence of an accumulated rainfall deficit is a reduction in soil moisture storage, which, once it reaches a critical level, has impacts upon crops and animal grazing. Hence, it is critical to better understand the drought climatology (i.e., the probability of drought at different levels of intensity and duration) and establish comprehensive and
integrated drought indicators that incorporate climate, soil, and water supply factors such as precipitation, temperature, soil moisture, snow pack, reservoir and lake levels, groundwater levels, and stream-flow.

**Hydrological drought** is best defined by deficiencies in surface and subsurface water supplies (i.e., reservoir and groundwater levels, stream-flow, and snowpack). As the rainfall and moisture deficit continues to accumulate, hydrological drought begins to manifest itself. Firstly, natural stream-flow decreases and falls below normal, ultimately causing a water resources shortfall. This can take the form of critically low river flow, drawn-down reservoir storage, and it can impact energy productivity levels. If the event has a long duration, and particularly in the case of multi-year droughts, groundwater levels fall, and abstraction can become too expensive, too damaging, or even mechanically impossible.

**Agricultural drought** is best characterised by deficiencies in soil moisture and is a critical factor in defining crop production potential. It generally applies to rain-fed agriculture, though irrigated crops can be affected when accessing other water resources become restricted or too expensive. Agricultural impacts are, therefore, the first to appear and, in most cases, provide the first confirmation that there is in fact a drought of any sort at all. These impacts can vary from crop to crop, farm to farm, region to region and depend upon the crop and its resistance to moisture stress, the stage in its growth, whether there are alternative water supplies other than rainfall, and whether livestock can be provided with alternative grazing.

**Socio-economic drought** is associated with the supply and demand consequences for economic goods. Drought becomes apparent as a socio-economic process of water shortages and their impacts. There may be food price increases due to reduced domestic agricultural output and (possibly) their replacement with more expensive imports. There may be power rationing due to reduced generating capacity, and some industries that are high consumers of water (petrochemicals, metallurgical, bottling plants) have to reduce production, with secondary consequences for employment, prices, the availability of goods, and national economic growth.

**Water management drought** is characterised as water-supply shortages caused by the failure of water management practices or facilities, such as an integrated water-supply system and surface or subsurface storage, to bridge normal and abnormal dry periods and equalize the water supply throughout the year (Gathara et al., 2006; Matthai, 1979). It is associated with curtailment of water resources from competitive uses during droughts. There are industrial, agricultural, environmental, and social consequences from such curtailment.

**Land use-related drought** involves two interlocking, complex systems: the natural ecosystem, including periodic stresses of extreme and persistent climatic events such as droughts, and the human factor, i.e., human use and abuse of sensitive and vulnerable dry land ecosystems (WMO, 2005). Long-term food productivity is threatened by soil degradation, which is now severe enough to reduce agricultural yields in many critical regions in the LMB.

These types of droughts may coexist or may occur separately. Though there are quite a number of drought definitions, only three types of indicators are the most commonly used to monitor and detect drought condition. They are meteorological, hydrological, and agricultural indicators. Detailed definitions of each indicator type will be given in the next section.
Drought indicator indices

A range of indices has been globally used to detect drought severity and occurrence. The indices are mainly used to monitor three types of drought indicators, namely meteorological, hydrological, and agricultural indicators.

The trend is to rely on multiple drought indices with a range of threshold values that trigger mitigation and response actions depending on the intensity and stage of a drought. Here are the indices that are most commonly used in the region and beyond:

**Meteorological drought indices:**

- *Percent of normal rainfall:* A simple calculation suited to the needs of more general audiences (D A Wilhite, Hayes, Knutson, & Smith, 2000) and used to prepare easy to understand maps.

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• **Standardized Precipitation Index (SPI):** SPI is based on the probability of precipitation over any duration of interest (weeks, months, growing season, etc.). It can provide early warning that meteorological drought conditions are developing and aid in the assessment of drought severity. To date, SPI is finding more applications in Asia than other drought indices due to its practical data requirements, flexibility, and simple calculation. Ideally SPI shall be used for 1-, 3-, 6-, and 12-month time periods to forecast the trend of precipitation compared to statistical records.

• **Rainfall Deciles:** This index is the current Australian standard for identifying the onset of meteorological drought. Monthly rainfall is organised into deciles.

• **Effective Drought Index:** This measure (Byun & Wilhite, 1998) also uses only rainfall data, but in this case focuses upon the amount of precipitation needed to return to “normal” conditions and overcome the accumulated shortfall deficit. The concept is straightforward in principle, but requires careful interpretation.

• **Palmer Drought Severity Index (PDSI):** The first comprehensive drought index developed in the US (Palmer, 1965). It is a soil moisture procedure calibrated for regions that are relatively homogenous in terms of climate, landscape, soil, geology, vegetation, and land use, and it is the standard US Department of Agriculture measure for activating drought mitigation and response programmes. Its application in Asia, where observational networks are not extensive, is therefore considered limited.

**Hydrological indices:**

• **Standardized Runoff Index (SRI):** Like SPI, SRI is using monthly stream-flow data to assess hydrological drought. The calculation method is fitting of suitable distribution to flow records of the study area then assessing probability density function and cumulative distribution function before transforming to standardized Gaussian distribution with 0 value of the mean. SRI is usually calculated with 3, 6, 9 and 12 month-time steps (Pathak & Channaveerappa, 2016).

• **Stream-flow Drought Index (SDI):** SDI is used to assess comparison of hydrological conditions of a stream or set of streams in spatial and temporal dimensions (Vicente-Serrano, López-Moreno, Beguería, & Lorenzo-Lacruz, 2012). Stream-flow data with time series are needed for the index. The weakness of the model is that it uses only stream-flow data and does not count no-flow days, which can create problems when calculating.

• **Groundwater Resource Index (GRI):** It is a water balance model, which is found to be useful in a multi-analysis approach for drought monitoring and forecasting (Mendicino, Senatore, & Versace, 2008). The analysis of the GRI has shown it to have high spatial variability and significant sensitivity to the lithological characterisation of the analysed area when comparing to the SPI. It is considered a useful tool for groundwater analysis with capability of forecast in the dry season.

**Agricultural drought indices:**

• **Crop Moisture Index (CMI):** The Crop Moisture Index uses a meteorological approach to monitor week-to-week crop conditions. It is based on the mean temperature and total precipitation for each week within a climate division, as well as on the CMI value from the previous week. The CMI responds rapidly to changing conditions, and it is weighted by location and time.

• **Soil Moisture Index (SMI):** SMI is a quantitative indicator of drought which is used to compare the drought duration and severity for various sites. The spatial SMI maps can be used with drought monitoring maps to assess the local drought conditions more effectively. SMI is calculated based on the soil characteristics, soil moisture conditions, two other soil parameters, including e.g., field capacity, wilting point, and soil moisture.
• The SMI values range from -5 to 0. An SMI of 0 indicates no drought but could be heading toward drought or recovered from drought. An SMI of -1 indicates the drought of least intensity, while -5 suggests drought of extreme intensity.

• Normalized Difference Vegetative Index (NDVI): NDVI represents vegetation conditions that can be monitored by comparing to a long-term average condition of the same time period.

While indices for metrological, agricultural, and hydrological drought are frequently used, this is not the case for other droughts, such as socio-economic, land use, and water management drought. Nevertheless, it appears that the concept of a socio-economic drought is increasingly being linked to the concepts of vulnerability or coping capacity. Following an approach suggested by the Asian Development Bank, levels of vulnerability for social groups can be determined through two broad categories: First, vulnerability score, which is associated with physical remoteness from markets, infrastructure, social services, and cultural insulation (including degree of access to information and participation in decision making beyond the local community); and second, the poverty status: poverty is assumed to cause social, cultural, and economic risks to people, presenting few or no alternatives for improving current livelihood systems. The risk rating is achieved by multiplying the vulnerability score with the estimated level of (poverty) stress. Together, these give relative but subjective vulnerability scores.

Earlier work identified the need for indicators that would sufficiently describe cause-effect relations and impacts with regards to three dimensions (MRC, 2002):

• Status indicators: Indicating the properties of the system. These may refer to the severity level indicated by the above described drought indices or include socio-economic parameters;

• Impact indicators: Describing the deterioration of water-related system functions and economic, social, and environmental values. Examples may include a loss of income from reduced land productivity, reduction of food supplies due to a decline in agricultural production resulting from deteriorating water soil fertility, biodiversity, and water quality.

• Response indicators: Measuring effects resulting from strategies to offset and/or mitigate the negative impact of an activity (e.g., water conservation, increasing water storage, improving land use planning and cropping patterns, afforestation, etc.).

Building upon this valuable conceptual framework, an opportunity arises for the DMT to develop a consistent suite of clear drought definitions and appropriate indicators, in order to provide a coherent platform and terminology for judging and evaluating drought conditions in various parts of the basin. This is seen as a precondition for facilitating formulation of drought response strategies, plans, and actions.