



**Mekong River Commission**  
Drought Management Team (DMT)

**Drought Management Strategy**  
**For the Lower Mekong Basin**  
**2019-2023**

**FIRST DRAFT**

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## Executive Summary

In the recent few decades, the Lower Mekong Basin has been experiencing severe drought hazards with serious economic losses due to damages of agricultural crops, negative impacts on environment and effects on people's livelihoods. The impacts have extended from agricultural water use to industry and domestic water consumption. There is a significant increase of the impacts on duration and magnitude if comparing the drought hazards from one event to another. This is a strong indicator showing that our Lower Mekong Region is currently at high risk of droughts and the trend is growing.

In addition, with different climate scenarios, more severe drought is likely to come to our region in the next 30, 60, and 90 years due to less precipitation, high air temperature and high evapotranspiration. The increase of population from current more than 60 million people relying on Mekong water to about 100 million people in 10 years' period is another strong pressure on water demands for all sectors. These are the reasons why the MRC Secretariat was requested by its Joint Committee Members to formulate a regional strategy for drought management and mitigation.

This DMS 2019-2023 was developed based on a series of results of national and regional findings including drought risk assessment of the LMB, national drought impacts and vulnerability assessment, crop modeling and scenarios on land and water availability, and national drought early warning system. The objectives and strategic goals of the DMS 2019-2023 were formulated based on the original objectives and strategic goals of the Drought Management Programme 2011-2015 which were gone through a number of national and regional consultation workshops to incorporate the needs of 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 focusing very much or/and solely on flood and other type of disasters rather than drought. Therefore, until now, there is almost no concrete national drought management policy and mitigation strategy available for reference.

Thus, this DMS 2019-2023 is a regional strategy aiming at addressing national interests and needs in drought management and mitigation. It has been discussed, reviewed, and compiled with all participations by relevant stakeholders and agencies including the MRC Expert Group on "data modeling and forecasting" before being finalized and approved by the JC. To achieve a regional perspective, issues of regional relevance contained in these policies, strategies and plans were compared with MRC policies, strategic priorities and actions as defined in the updated Basin Development Strategy (BDS) 2016-2020 as well as the Mekong Adaptation Strategy and Action Plan (MASAP) 2017.

The DMS 2019-2023 has proposed 6 main priority areas under four main clusters including (i) Indicator monitoring, (ii) Drought early warning, (iii) Capacity building, and (iv) Mitigation actions. Cluster (i) covers (1) hydro-meteorological and reservoir water monitoring, (2) monitoring of procedures for maintenance of flows on the mainstream, (3) ground water monitoring, (4) soil moisture monitoring, and (5) Salinity level monitoring; cluster (ii) covers (1) drought monitoring and forecasting; cluster (iii) focuses

on (1) national and regional training, (2) regional and international workshops and conferences, and (3) study tour to drought prone regions; and cluster (iv) focuses on (1) collaboration with dialogue partners, (2) drought information dissemination, (3) development of guideline on drought mitigation, and (4) pilot activities on drought adaptation measures.

In collaboration with the former MRC Basin Development Programme and Climate Change Adaption Initiative, recommendations are made regarding the alignment of the DMS 2019-2023 Strategic Priorities and Actions with the strategic priorities and actions outlined in the relevant BDS Core River Basin Management Functions and the Mekong Adaptation Strategy and Action Plan.

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## Acronyms

ADPC	Asian Disaster Preparedness Centre
AIT	Agriculture and Irrigation Team
BDP	MRC Core Programme: Basin Development Plan
CCAI	Climate Change Adaptation Initiative
CHIRP	Compressed High Intensity Radiated Pulse (Satellite)
DAE	Department of Agricultural Extension
DDPM	Department of Disaster Prevention and Mitigation
DMH	Department of Meteorology and Hydrology
DMP	Drought Management Programme
DMT	Drought Management Team
DSI	Drought Severity Index
ENSO	El Niño/Southern Oscillation (ENSO)
ESCAP	the Economic and Social Commission for Asia and the Pacific
EU	European Union
FAO	Food and Agricultural Organisation
FMMT	Flood Management and Mitigation Team
GFS	Global Forecast System
GISDA	Geo-informatics and Space Technology Development Agency
GIS	Geographic Information System, software
GMS	Greater Mekong Subregion
GPM	Global Precipitation Measurement (Satellite)
GRACE	Gravity Recovery and Climate Experiment (Satellite)
KBDI	Keetch-Byram Drought Index
IOD	Indian Ocean Dipole
JAIF	Japan ASEAN-Integration Fund
LMB	Lower Mekong Basin
MAF	Ministry of Agriculture and Forestry (Lao)
MAFF	Ministry of Agriculture, Fisheries, and Forestry (Cambodia)
MARD	Ministry of Agriculture and Rural Development (Viet Nam)
MCs	Member Countries
MOD/MODIS	Moderate Resolution Imaging Spectroradiometer (Satellite)
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NASA	National Aeronautics and Space Administration
NASA JPL	NASA Jet Propulsion Laboratory, US Agency
NCEP	National Centers for Environmental Prediction
NCHMF	National Centre for Hydro-Meteorological Forecasting
NDVI	Normalized Difference Vegetation Index
NGO	Non-Government Organisation, Civil Society Organisation
NMCs	National Mekong Committees
NOAA	National Oceanic and Atmospheric Administration
PWUM	Procedure on Water Use Monitoring
RFMMC	Regional Flood Management and Mitigation Center
SRI	Surface Runoff Index
SMI	Soil Moisture Index
SMOS	Soil Moisture and Ocean Salinity (Satellite)
SPI	Standardized Precipitation Index
TD	Technical Division
TRMM	Tropical Rainfall Measuring Mission (Satellite)
USAID	United States Agency for International Development
USGS	United States Geological Survey

# 1. INTRODUCTION

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

The recent studies, undertaken by the four MRC Member Countries on National drought impacts and vulnerability assessment, show that drought events in the LMB have increased in frequency and severity in the past decades. The recent attention of the MRC originated with the regional drought events of 2004 to 2005, 2009 to 2010, and most recently 2015 to 2016 where unusually low flows in the Mekong River and seasonal deficiencies in regional rainfall led to severe agricultural losses in north eastern Thailand and Cambodia, and critical levels of saline intrusion in the Delta of Vietnam.

The latest drought in 2016 has broken the MRC 100-year historical record for Mekong water scarcity, high temperature, and severe level of salinity intrusion in Mekong Delta of Vietnam. The impacts have brought serious economic losses to Thailand which was estimated at USD 1.7 billion (Thai Baht 62 billion).<sup>1</sup> The Government of Thailand has clearly understood the seriousness of the threat posed and has placed immediate drought relief measures and regarded as the highest priority issue being faced by the country. The Thai official national drought status report on 5 Feb 2016 listed 55 districts, 290 counties, 2,666 villages and 14 provinces including thirteen provinces that were lack sufficient water for agriculture. This means that more than 50% of the total Thai area of the Mekong watershed in NE Thailand was already at a critical drought status.

Meanwhile, The Government of Vietnam reported “more than 200,000 tons of rice have been damaged, resulting in a loss of over 1 trillion VND (44.64 million USD) to the region. The ministry reported in early 2016 that saltwater 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, saltwater has intruded upstream 50 – 60km into the mainland, and even 93km in the Vam Co River’s neighbourhood, about 15 – 20km deeper than previous years. That was the worst saltwater intrusion so far in the Delta – the rice hub of Vietnam, the ministry stressed. In the winter-spring crop 2015-2016, more than 339,200ha of rice in coastal Mekong Delta provinces was affected by saltwater intrusion and drought, accounting for 35.5 percent of those localities’ rice area and 21.9 percent of the region’s total rice area. Of them, 104,000 ha have been severely impacted.”<sup>2</sup>

In Cambodia, water scarcity started looming rural areas effecting both agriculture and domestic water consumptions since early 2016. The National Committee for Disaster Management

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<sup>1</sup> Bangkok post article on damage of drought bringing serious economic loss of upto 62 million Thai Baht. <http://www.bangkokpost.com/news/general/849356/drought-may-result-in-b62bn-in-damages>

<sup>2</sup> <http://english.vietnamnet.vn/fms/environment/151331/mekong-delta--salt-intrusion-a-once-in-a-century-disaster.html>



(NCDM) publicly announced on 24 April 2016 that drought was causing water shortages in 18 out of 25 provinces with 2.5 million people lack of water.

This is one of the reasons why MRC needs a regional drought management strategy. It is *“to support Member Countries in managing and mitigating drought impacts and vulnerability in terms of water management and planning to reduce water shortage in dry season”*.

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

Another convincing evidence supporting drought as a trans-boundary issue is that the devastating condition of salinity intrusion in the Mekong Delta of Vietnam was due to insufficient rain water from both local and regional locations which brought less flooding extent to Cambodia flood plain of Tonle Sap area than it usually is. Tonle Sap lake is functioning as a central heart that pumps the flooded water out to lower part/Mekong Delta of Vietnam after end of each rainy season when the flow at the Mekong Mainstream drops down to normal level (Campbell *et al*, 2009). Significant lack of flooded water in Tonle Sap due to either insufficient rain water or inflows from upper part of the mainstream means none or little water will be pumped out from Tonle Sap to Mekong Delta in early next dry season making low flow in the Delta and triggering salinity intrusion from sea water inflows. Thus, insufficient flood plain extent of the Tontel Sap in wet season could cause serious salinity issue in the Mekong Delta, Southern part of Vietnam, in the next dry season showing a trans-boundary connection between the two lower Mekong Countries. To mitigate such trans-boundary impacts of drought, a close coordination and collaboration is ultimately needed with a proper and transparent joint management plan. MRC Secretariat can play a key role in this sense to bring together a regional coordination and collaboration to manage and mitigate the regional threats.

Based on this concept, development of the drought management strategy for MRC for 2019-2023 is to *“support Member Countries in managing water resources in the region to mitigate a regional and trans-boundary drought hazards”*.

On other concept, based on the MRC projection, population keep growing rapidly in our MRC region adding up from 60 million people using the Mekong water to 100 million people in coming years and decades leading to extra demands on water use in different sectors while water resources of the Mekong River are not extending nor increasing to meet with such growing demands. In response to the urgent need of additional water for agriculture during dry season in

2015, for instance, Thai Government decided to operate rain making mission by using chemical substance to spread into thick clouds to form artificial rains in North-eastern part of Thailand. Rainmaking project in Thailand was initiated by King Bhumibol Adulyadej in 1955 and began its operation in 1969 to generate artificial rain water for rural areas of Thailand<sup>3</sup>.

To have a sustainable use of the water resources of the Mekong River especially with the rapid growing pace of the regional population, a regional mechanism on Mekong River water resources management is inevitably needed. This is to ensure that a national plan on water use and diversion from the Mekong mainstream is notified, agreed, and shared among the MRC Member States and incorporated into the regional management plan.

Under this important objective, the regional drought management strategy 2019-2023 is formulated to *“support Member Countries in developing a regional mechanism on water use management and planning for a sustainable and long-term benefits among the Mekong Countries”*.

Last but not least, the climate scenarios performed by the Climate Change Adaptation Initiative have obviously indicated that there will be a dramatic increase in temperature, number of dry days, and more severe low flow in the region for the next 30, 60, and 90 years' periods.<sup>4</sup> This means that the LMB region will be more likely facing more severe drought in the coming decades of which a proper planning and management mechanism of the MRC level needs to be developed and put into practice before the impacts of the climate change take place.

Therefore, the last reason we need to have 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 MRC Member Countries and stakeholders, dating back to 2006, and inspired by high level decisions of the Member Countries' Heads of Government (1<sup>st</sup> MRC Summit), Council, and the Joint Committee. The DMP 2011-2015 was a progressive development of the DMP document (dated 23<sup>rd</sup> March 2007), DMP Start-Up Project 2008, Initial Drought Management Project 2010-2011, and the decision of the 2<sup>nd</sup> 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.

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<sup>3</sup> <http://www.jordantimes.com/news/local/jordanian-team-learns-artificial-rainmaking-thailand-%E2%80%94-jmd>

<sup>4</sup> CCAI Scenarios

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 JC in March 2011 and at its 33<sup>rd</sup> JC Meeting in Cambodia. The project was finally funded by JAIF and launched in January 2015 through 2018 under the Drought Management Team (DMT) of the Technical Division (TD).

The immediate objectives of the document are to strategically provide 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. DMT will work with Member Countries' NMCs and national line agencies to provide knowledge-based operational services and technical assistance on drought preparedness, drought awareness, and management strategy in order to mitigate impacts of drought on livelihoods of vulnerable people in the region.

The Drought Management Programme's Core Functions Project focuses mainly on four main outputs including:

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 Drought Definitions and Indices**

### **1.3.1 Drought Definition**

Drought is one of the least understood natural hazards and most costly ones (Wilhite, 1993); This concept has been acknowledged as a fact in the MRB, and particularly in LMB. 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 ground-water aquifers, and 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 ground water (Gathara *et al*, 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 (i.e., rainfall intensity, number of rainfall events) of the rains. 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 (Wilhite, 2000a). The severity of a drought is dependent not only on its duration, intensity and spatial extent, but also on the specific environmental and the economic activities carried out within it. Hence, drought is the result of many external and internal factors:

- Natural factors - 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 - 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 States during DMP 2011-2015 Programme Document formulation process, 6 drought definitions have been agreed and adopted for the LMB Region. They are known as the most applicable definitions and defined as followings:

1. ***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 from expected or “normal” 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, although other climatic factors (such as high temperatures, high winds, and low relative humidity) are often associated with it in many regions of the LMB and can significantly aggravate the severity of the event. Drought is also related to the 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, ground water levels, and stream flow.
2. ***Hydrological drought*** is best defined by deficiencies in surface and subsurface water supplies (i.e., reservoir and ground water 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 deeper groundwater levels, which make pumped abstraction too expensive or mechanically impossible, and impact

energy productivity level. 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.

3. ***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 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.
4. ***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.
5. ***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 or abnormal dry periods and equalise the water supply throughout the year (Gathara et al, 2006, Matthai, H.F., 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.
6. ***Land use related drought*** involves two interlocking, complex systems: the natural ecosystem such as periodic stresses of extreme and persistent climatic events – drought, and the human social (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.

\* NOTE: These types of drought may coexist or may occur separately. Though there are quite a number of drought definitions, only 3 indicators are the most commonly used to monitor and detect drought condition. They are meteorological, hydrological, and agricultural indicators. Detailed definition of each indicator type will be explained in the next section.

### **1.3.2 Drought Indicator Indices**

A range of indices have been globally used to detect drought severity and occurrence. The indices are mainly used to monitor three types of drought indicators including 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 (Wilhite et. al 2004). Followings are indices that most commonly used in the region and beyond.

**a) Meteorological drought indices:**

- *Percent of normal rainfall*: A simple calculation suited to the needs of more general audiences (Wilhite, Hayes et al. 2000) and used to prepare easy to understand maps.
- *Standardised Precipitation Index (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 steps to predict the trend of precipitation comparing 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 (EDI)*. This measure (Byun and Wilhite. 1999) 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 is the standard USDA measure for activating drought mitigation and response programmes. Its application in Asia, where observational networks are not extensive, is therefore considered as limited.

**b) Hydrological indices:**

- Daily stream flow (forecasts);
- Average groundwater level;
- Average reservoir storage level; etc.
- Source: Adamson (2005); <http://www.drought.unl.edu/whatis/indices.htm>

**c) Agricultural drought indices:**

- *Crop Moisture Index (CMI)*: The Crop Moisture Index (CMI) 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 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):** 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 the Drought Monitor 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 Field Capacity (FC), Wilting Point (WP), and Soil Moisture (SM). The equation can be given below:

$$SMI = \left[ \frac{5(SM - WP)}{FC - WP} - 5 \right]$$

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 that drought of extreme intensity

- **Normalised Difference Vegetative Index (NDVI):** Represents vegetation condition 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 vulnerability or coping capacity concept. Following an approach suggested by the ADB (2004), 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, 2002b):

1. **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;
2. **Impact Indicators:** Describing the deterioration of water related system functions and economic, social and environmental values. Example may include a loss of income from

reduced land productivity, reduction of food supplies due to a decline in agricultural production resulting from water soil fertility, biodiversity, water quality, ).

3. **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 facilitated formulation of drought response strategies, plans and actions.

## **2. NATIONAL AND REGIONAL FINDINGS**

### **2.1 Drought Risk Assessment for the Lower Mekong Basin**

One of the most important tasks of the Drought Management Programme 2011-2015 was to assess drought risk for the whole Lower Mekong Basin 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 imageries from all open sources.

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

It is important to understand that the model we chose to adopt for this study is relatively simple and only attempt to evaluate the vulnerability of current agriculture systems to drought. To be even 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 risk posed by a major drought such as forest fires, disruption to fisheries, and economic losses in other sectors etc. The model also does not attempt to evaluate any potential future impacts of drought that may occur due to climate change.

The actual impacts of drought in the real world are undoubtedly much more complex, extensive and cross-sectorial 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 predict the possible of



increased salt water intrusion into rice paddies in the Mekong Delta etc. This would be an enormous modelling task.

#### a) **Supporting Dataset and Indicators Required for the Model**

The model has used 6 indicators with 6 weighting factors to assess the drought risk for the LMB area. Those indicators include (1) precipitation; (2) agricultural and irrigation; (3) ground water potential; (4) surface water; (5) soil moisture; and (6) land use.

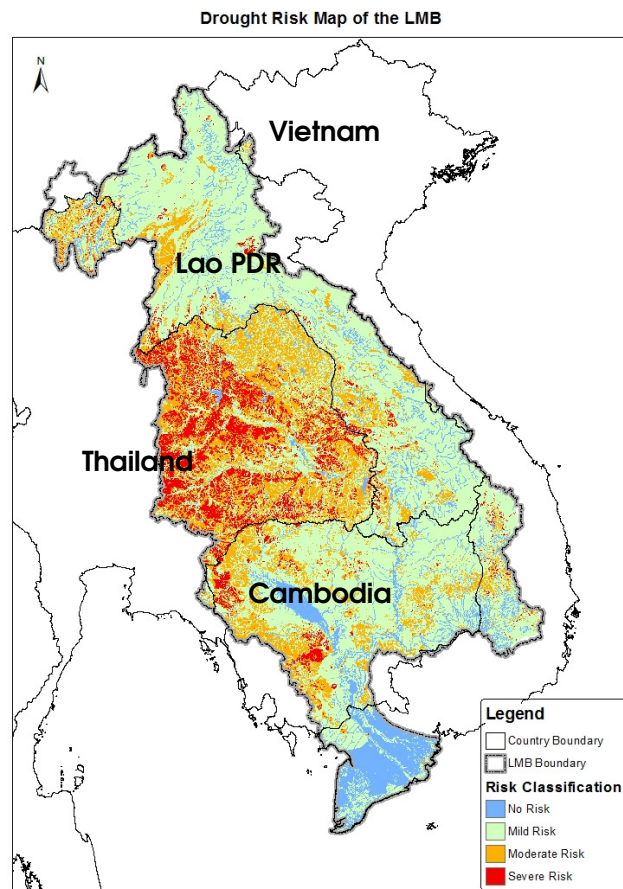
- **Precipitation:** TRMM satellite data was used to obtain monthly rainfall
- **Agricultural irrigation:** GlobCover land cover with 250-meter resolution was used as the MRC land cover 2010-2011 was not yet available when the study took place in early 2013
- **Ground water potential:** Old data of ground water from MRC was used including "Hydrogeological Map of the LMB" by Adisai Chrurattana and Tran Hong Phu, 1992 compiled from various national and sub-national maps (some as old as 1972) re-digitized by the MRC in 2005. Specifically, this map gives "Aquifer Ground Water Potentials (in m<sup>3</sup>/hour)" that 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 zone to identify areas with accessibility to surface water
- **Soil drainage:** the existing soil data of MRC was used for the calculation
- **Land use:** GLOBCOVER 2009 dataset with resolution of 250 meters was used for land use weighing factor.

#### b) **Results of Drought Risk Assessment for the Lower Mekong Basin**

Weighting factors of all six indicators were calculated through the followings:  $(\text{Rainfall} + 2 \times \text{Irrigation} + 1.5 \times \text{Groundwater Rates} + 2 \times \text{Surface Water} + 2.5 \times \text{Soil Drainage} + \text{Land Use}) / 10$ .

Please note: The weighting factors shown are only illustrative purposes and will continue to be modified as necessary to fit changing expert opinion 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:



**FIGURE 1: DROUGHT RISK ASSESSMENT MAP OF THE LMB**

**c) Conclusion and Recommendations**

Northeast of 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 main water sources to 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 scheme. 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 Southern and Northern areas (Champassack and Vientiane province) are also relatively vulnerable to drought due to insufficient amount of rainfall and absence of irrigation system. The areas are too far away from water bodies and the Mekong River where irrigation scheme is most likely undoable.

Unlike other Countries, Vietnam does not have any significant sign of drought vulnerability except some hot areas in the Central Highland. The Mekong Delta is well irrigated with full coverage of irrigation canals. However, the area is seriously vulnerable to salinity intrusion which cannot be presented by the models. This salinity level is mainly caused by hydrological drought when flows at the Mekong mainstream are too low to defend the force of sea currents flowing backwards from the sea mouth.

From the study, we could draw some recommendations as follows:

- Regional drought vulnerability should be re-assessed every 5-10 years to accommodate the changing land use, development of irrigation schemes at National levels, population growth, as well as climate change effects
- For more accurate results, national data should be used with more variables and parameters
- The model of assessment should be reviewed and updated to the most appropriate one in the next assessments.

## **2.2 Drought Impacts and Vulnerability Assessment by the MRC Drought Management Programme**

Besides the statistical data that the Drought Management Programme have accessed from relevant National Line Agencies on historical drought impacts, under financial support by GIZ in 2013 as well as JAIF from 2015 to 2017, DMP conducted its own drought impacts and vulnerability assessment on agriculture, socio-economics, and environment. The assessment timeframe was focusing on 3 different periods including past as **historical (H), current (c), and potential impact or future trend (P)**.

We adopted the methodology of drought preparedness planning which includes drought impact and vulnerability assessment developed by DONALD A. WILHITE, MICHAEL J. HAYES, AND CODY L. KNUTSON of the National Drought Mitigation Center, university of Nebraska, Lincoln, Nebraska, USA. The assessment would follow the sequent steps below:

### **The assessment processes included:**

- 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 from National Level;
- Provincial Departments on Disaster Risk Reduction of the drought prone provinces;
- Relevant Department at Provincial Level;
- Provincial Government of the drought prone provinces; and
- District Administration of the drought prone districts

## Results of the impacts and vulnerability assessment

### a) Cambodia

#### Drought prone area selection:

Cambodia has selected 6 provinces as the most drought prone areas for the assessment including Battambang, Banteay Meanchey, Kampong Cham, Kampong Chhnang, Prey Veng, and Svai Rieng. The selection was based on national agricultural census, food security, historical drought situations, and water resources and irrigation system of the Country.

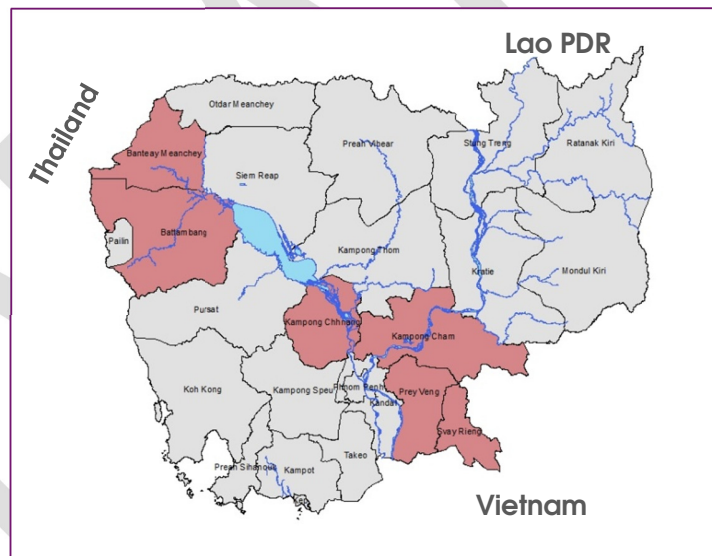


FIGURE 2: DROUGHT PRONE PROVINCES OF CAMBODIA

The overall impacts, trend, and impact ranking are summarized in the table below:

Province/districts	Impact type	Trend	Rank
Battambang	- Annual and perennial crop loss, mainly rice, cassava and corn	Increasing	1
- Thmar Kol	- Insufficient of water for local consumption, upto 80%	Decreasing	2
- Rokhak Kiri			
- Sangkae			
- Samlot	- Losses of agricultural land		3

	- Water use conflict	Increasing	4
	- Losses of income with 32% migration workers	Increasing	5
	- Losses of timber products	Increasing	6
	- Damages of biodiversity	Increasing	7
	- Reduction of fish and animal habitats	Increasing	8
Banteay Meanchey	- Perennial crop losses between Jane-August of rice, bean, corn, and cassava	Increasing	1
- Thmor Pouk	- Environmental damages (losses of forest and wet land)	Increasing	2
- Preahnet Preah	- Losses of income with 60% migration workers	Increasing	3
- Malay	- Decrease of food production and increase of food prices	Increasing	4
- Svay Chek			
- Ou Chrov			
Kampong Cham	- Perennial crop losses of rice, corn, and cassava	Increasing	1
- Kong Meas	- Crop damages by insects	Increasing	3
- Prey Chhor	- Reduction of fish and animal habitats	Increasing	2
- Koh Soutin	- Reduction of ground water	Increasing	4
- Srey Santhor	- Respiratory disease	Normal	5
Kampong Chhnang	- Losses of perennial crop losses of rice, cassava, and corn	Increasing	1
- Kampong Leang	- Decrease of agricultural products and livestock	Increasing	4
- Kampong Tralach	- Decrease of biodiversity	Increasing	5
- Kampong Chhnang	- Losses of income, migration	Increasing	6
- Rolea Bier	- Reduction of fish and animal habitats	Increasing	2
- Sameakki	- Water use conflict	Increasing	7
- Meanchey	- Insufficient water for irrigation	Increasing	3
- Tuek Phos			
Preveng	- Losses of annual and perennial crop	Increasing	1
- Svay Antor	- Reduction of fish and animal habitats	Increasing	3
- Pea Raing	- Losses of income, migration	Increasing	2
- Kamchay Mear	- Respiratory disease	Increasing	5
- Kampong Trabaek	- Decrease of agricultural products	Increasing	4
- Preah Sdach			
- Me Sang			
- Ba Phnom			
- Kanh Chriech			
Svay Rieng	- Losses of annual and perennial crop, mainly rice	Increasing	1
- Kompong Rou	- Increase of insects	Increasing	2
- Svay Chrom	- Increase of migration for jobs	Increasing	3
- Chan Trea	- Decrease of rice production	Increasing	4
- Svay Teab			
- Romeas Haek			

TABLE 1: LIST OF DROUGHT IMPACTS AND RANKING IN CAMBODIA

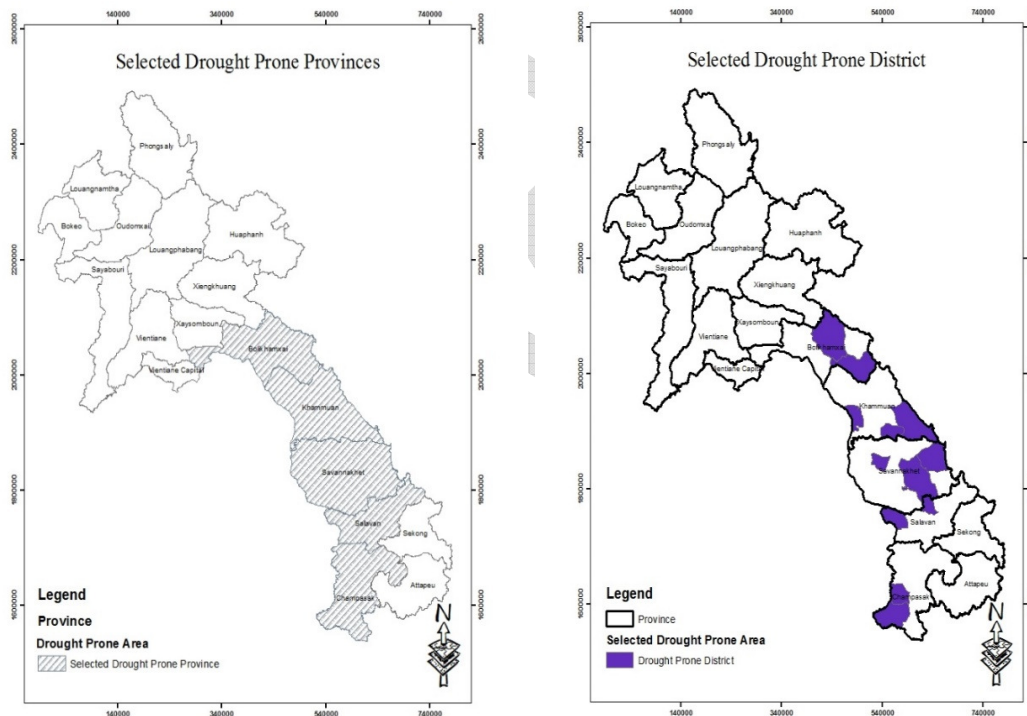
The impact ranking is evaluated based on severity of the impact and economic losses that the impact caused. It varies from one district to another. In the table above, the ranking is calculated by averaging all ranking number by districts, the least number in average is ranked the first.

The study has identified the main causes of the impacts, proposed actions to be taken to mitigate the impacts, and evaluated on the existing mitigation and adaptations strategy and tools which have been applied in those drought prone districts to mitigate the impacts. The study has also provided recommendations for each province on structural and non-structural measures based on the actual needs of local households.

**b) Lao PDR**

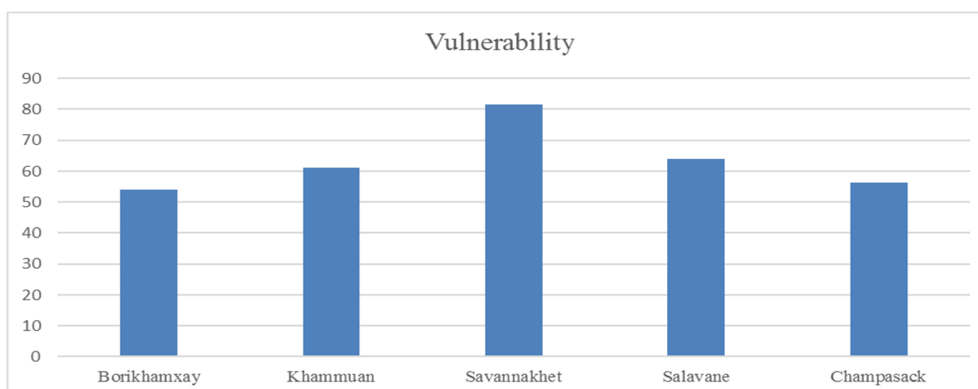
**Drought prone area selection:**

Lao PDR has evaluated and identified 5 provinces to be the most drought prone areas based on historical record of drought occurrence, loss of agricultural economics, population density, and geographical locations and selected for drought impacts and vulnerability assessment in July 2017. Those provinces include Borikhmaxay, Khammuan, Savannakhet, Salavanh, and Champasack.



**FIGURE 2: MAP OF DROUGHT PRONE DISTRICT AND PROVINCES OF LAO PDR**

As result, drought vulnerability level for the selected drought prone provinces can be presented through the graph below:



**FIGURE 3: DROUGHT VULNERABILITY LEVEL, LAO PDR**

The result has showed that Savannakhet is the most vulnerable area among the five provinces and followed by Saravanh and Khammuan. The main problem is the area almost does not has access to surface water where farmers can rely on. Natural ponds become more important during dry season. Yet, it depends on rain water during rainy season how much a natural pond can capture and store for the next dry period.

Based on the report, the main impacts can be listed, evaluated, and ranked in severity order in the table below:

Province	Main Fields	Summary option					
		Cost	Equally Distributed?	Growing?	Public Priority?	Equitable Recovery?	Impact Rank
Borikhamxay	Economic/production sectors impacted by drought	87.5	Yes	Yes	Yes	No	1
	Environment sectors impacted by drought	50	Yes	Yes	Yes	No	3
	Social Sector impacted by drought	100	Yes	No	Yes	No	2
Khammuan	Economic/production sectors impacted by drought	100	Yes	Yes	Yes	No	1
	Environment sectors impacted by drought	75	Yes	Yes	Yes	No	3
	Social Sector impacted by drought	79	Yes	No	Yes	No	2
Savannakhet	Economic/production sectors impacted by drought	100	Yes	Yes	Yes	No	1
	Environment sectors impacted by drought	75	Yes	Yes	Yes	No	3
	Social Sector impacted by drought	100	Yes	No	Yes	No	2
Saravanh	Economic/production sectors impacted by drought	100	Yes	Yes	Yes	No	1
	Environment sectors impacted by drought	100	Yes	Yes	Yes	No	3

	Social Sector impacted by drought	67	Yes	No	Yes	No	2
<b>Champasack</b>	Economic/production sectors impacted by drought	87.5	Yes	Yes	Yes	No	1
	Environment sectors impacted by drought	87.5	Yes	Yes	Yes	No	3
	Social Sector impacted by drought	68.5	Yes	No	Yes	No	2

**TABLE 2: LIST OF DROUGHT IMPACTS AND RANKING ON AGRICULTURAL ECONOMIC, ENVIRONMENTAL, AND SOCIAL SECTORS BY PROVINCE OF LAO PDR**

Value of cost ranges from 1 to 100 representing cost level from low to high. The cost value for Savannakhet, for instance, is 275 for the total of three impact sectors which is the highest value among all the provinces. This means that Savannakhet receives more drought impacts than others and would be the most vulnerable area of Lao PDR.

**c) Thailand**

Within the Lower Mekong Basin part, Thailand considers all areas in the Northeast are 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. Northeast Thailand is facing persistent drought which occurs almost every year with high economic losses mainly on agricultural productions.

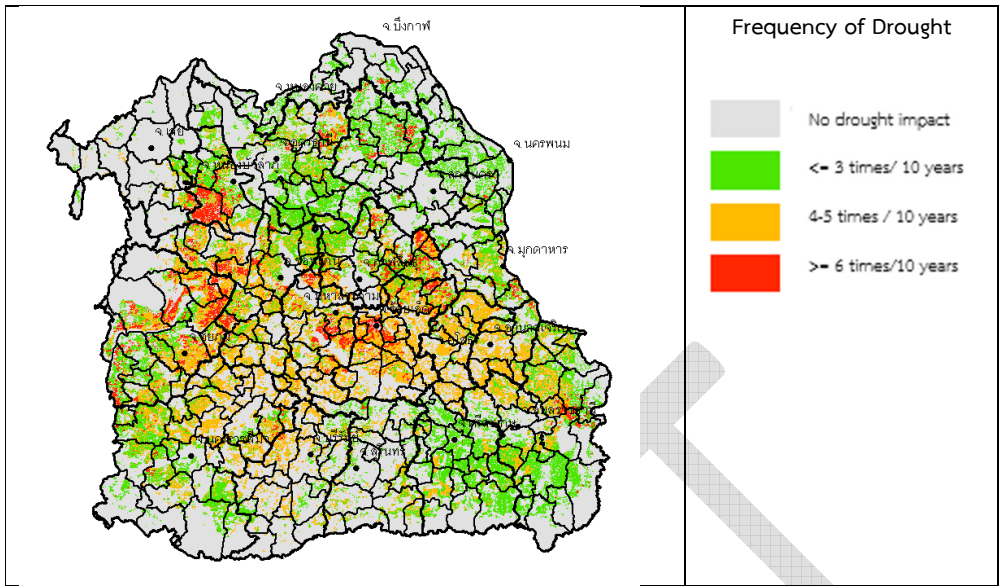
Drought impacts and vulnerability assessment in Thailand in this document was conducted mainly based on historical studies, past reports on damages from drought and water supply management together with consultative approach with relevant line agencies and local stakeholders.

The study carried out from October 2015 to March 2016 under financial support by JAIF of the Drought Management Programme’s Core Functions Project of the MRC Secretariat.

Like other Member Countries in the region, in Thailand drought impact assessment and monitoring are carried out at different national agencies with their own tasks and responsibilities. The main National Line Agencies working on the drought risk management and mitigation include Thai Meteorological Department, Land Development Department (LDD), Department of Disaster Prevention and Mitigation (DDPM), Department of Agricultural Extension, and Geo-Informatics and Space Technology Development Agency (GISDA).

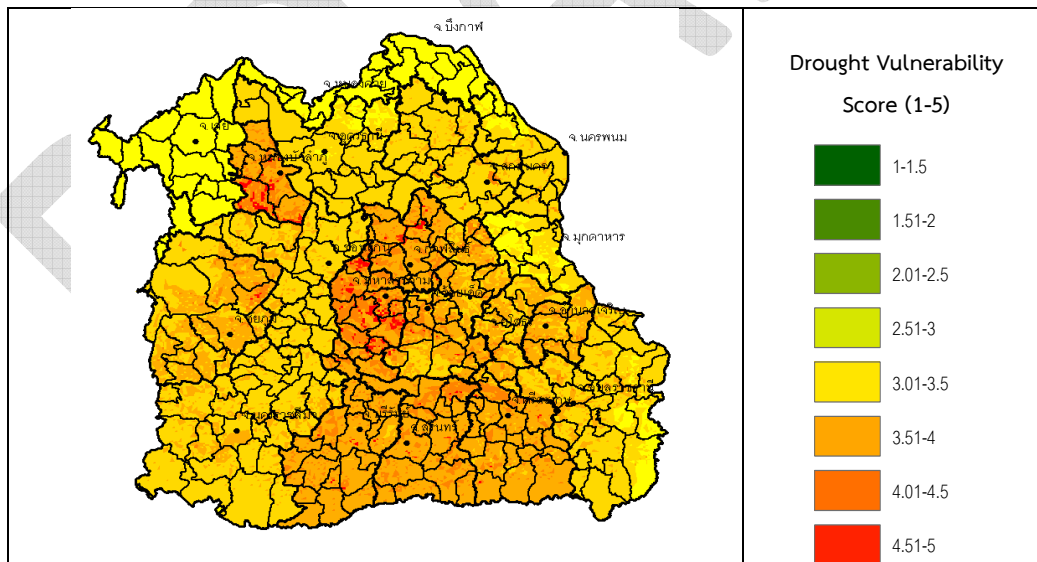
Some significant findings from the national drought impacts and vulnerability assessment are listed with description below:





**FIGURE 4: DROUGHT RISK MAP BY LAND DEVELOPMENT DEPARTMENT (2013)**

The map above shows frequent occurrence of drought mainly on water scarcity during wet and dry seasons in 10 years' period recorded by the Land Development Department. The red areas represent more frequent drought occurrence than the orange and the green ones.



**FIGURE 5: MAP OF DROUGHT VULNERABILITY FOR AGRICULTURAL WATER**

The study also calculated drought vulnerability map for agricultural water. The darker red the more vulnerable area on agricultural water.

The northeast region experiences drought in upper and middle parts of Mun and Chi river basins. High vulnerability areas for both agriculture and domestic water use at present and in future under climate change scenarios are Nongbua Lamphu, Maha Sarakham, Roi Et, Surin, Sisaket, Yasothon, and Chaiyaphum. The main causes of severe drought impacts are low amount of rainfall which produce low runoff and discharge, high population density, and wide agricultural areas. The low adaptive capacity with drought due to low income of farmers is also a major concern making some potential mitigation options cannot be brought into actions in the area. In that concept, groundwater quality needs to be reviewed and enhanced for water scarcity measure.

For provinces in the northeast part, vulnerabilities are moderately high as drought impacts are relatively lower than other parts due to lower density of population and smaller size of agricultural lands.

The northeast area experiences moderate and high levels of vulnerability for both agricultural and domestic water uses. Climate change in this region does not have significant affect only if the rainfall amount decreases in the future.

#### **d) Vietnam**

##### **Drought prone areas of Vietnam**

In the Southern Vietnam, drought prone area is divided into two different parts based on socio economics and geographical locations including Central Highland and Mekong Delta. The assessment on drought impacts and vulnerability was conducted in 2013 under the GIZ financial support to the Drought Management Programme 2011-2015.

- **Central Highland**

The impact type on agricultural economic sector can be illustrated by graph below:

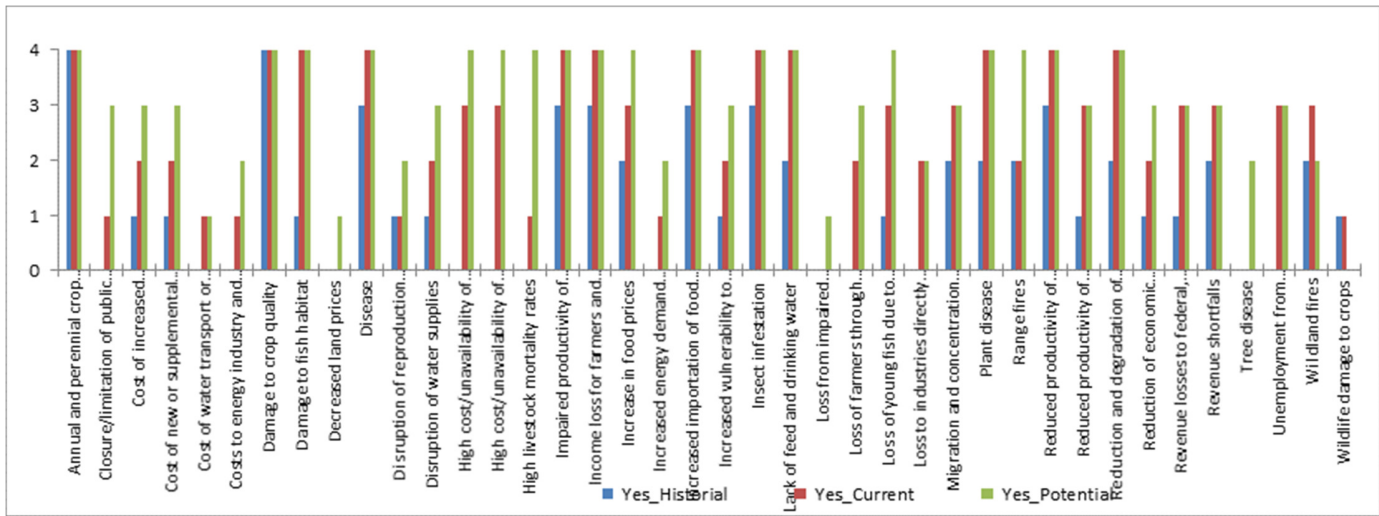


FIGURE 6: IMPACT TYPE ON AGRICULTURAL ECONOMIC SECTOR, CENTRAL HIGHLAND

The impact type on agricultural economic sector through different time period (past, current, and future trend) can be illustrated through graph below:

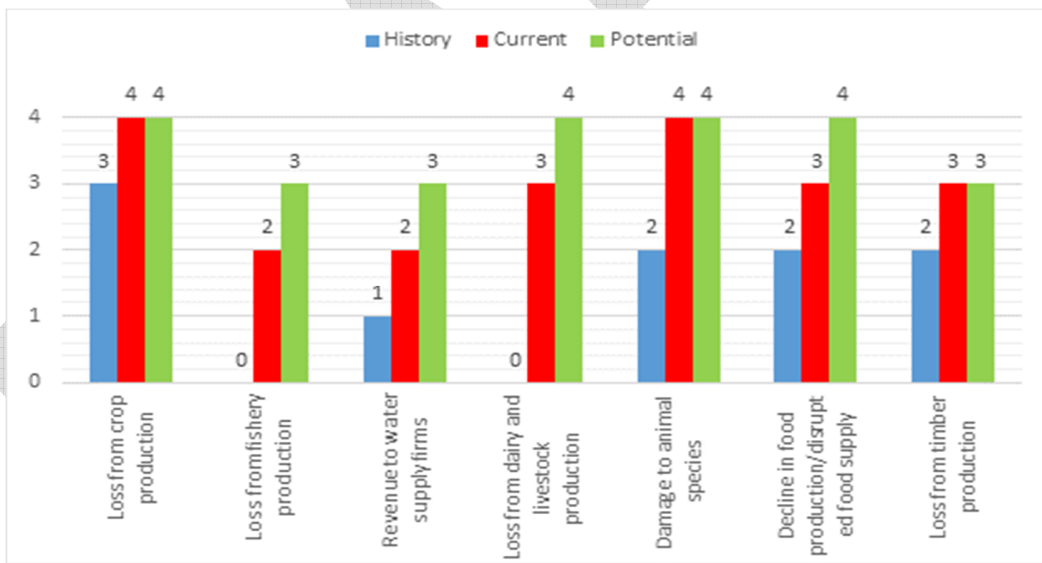


FIGURE 7: IMPACT TYPE ON AGRICULTURAL ECONOMIC SECTOR THROUGH DIFFERENT TIME PERIODS, CENTRAL HIGHLAND

The impact type on environmental sector through different time period (past, current, and future trend) can be summarized in the graph below:

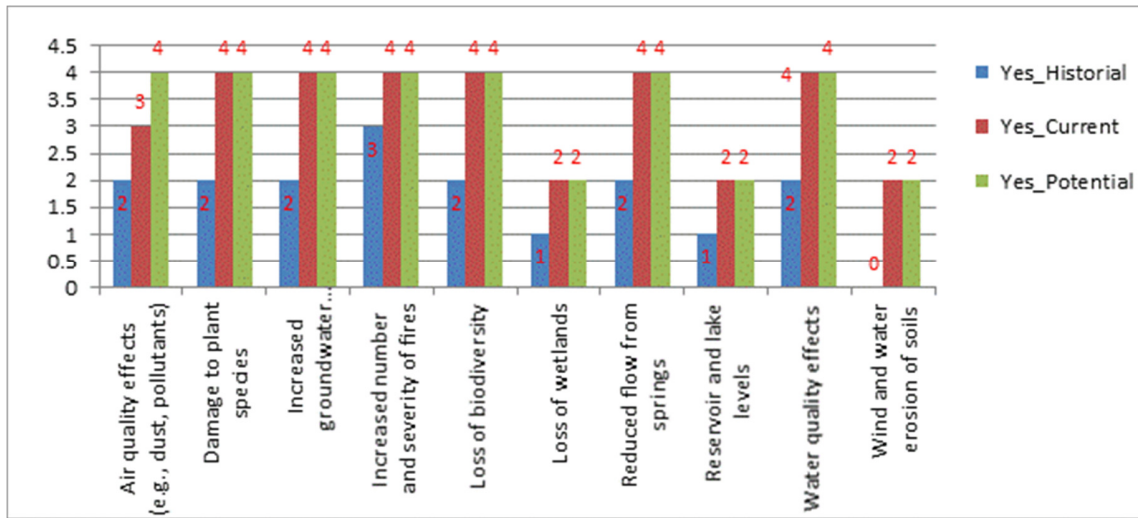


FIGURE 8: IMPACT TYPE ON ENVIRONMENTAL SECTOR THROUGH DIFFERENT TIME PERIOD, CENTRAL HIGHLAND

The impact type on social sector for Central Highland can be summarized in the graph below:

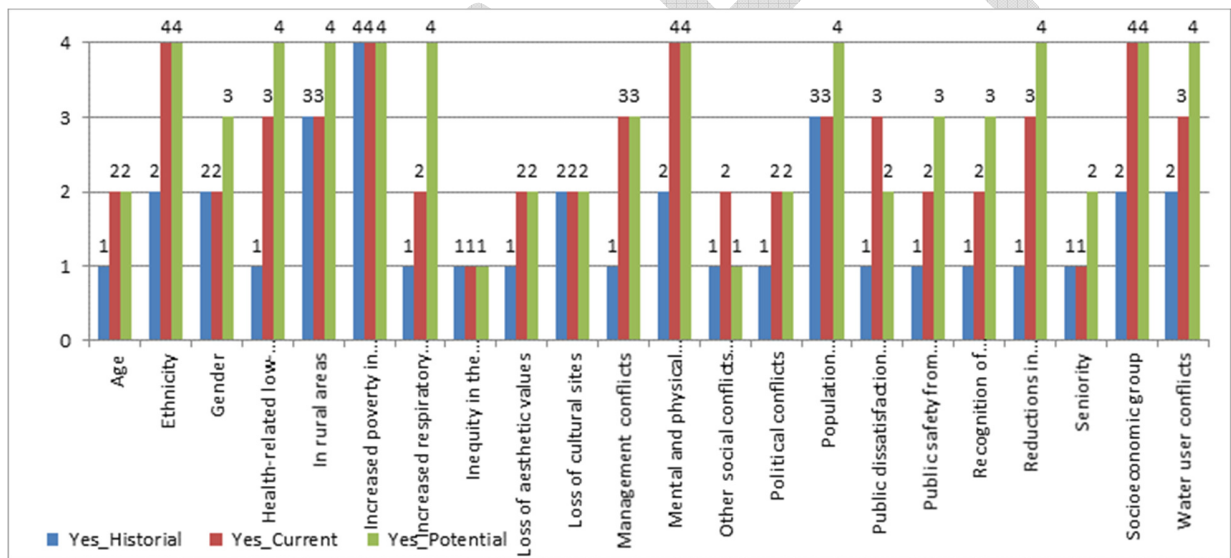


FIGURE 9: IMPACT TYPE ON SOCIAL SECTOR, CENTRAL HIGHLAND

Summary of impact list and ranking on agricultural economic, environmental and social sectors can be presented in the following table:

No	Groups of drought impact types in Central Highlands	Rank
1	Loss from crop production	1
2	Decline in food production/disrupted food supply	2
3	General environment	2
4	Loss from timber production	2

No	Groups of drought impact types in Central Highlands	Rank
5	Reduced quality of life, changes in lifestyle	2
6	Increased conflicts	4
7	Inequity in drought impacts based on:	4

**TABLE 3: LIST OF DROUGHT IMPACTS ON AGRICULTURAL ECONOMIC, ENVIRONMENTAL, AND SOCIAL SECTOR, CENTRAL HIGHLAND**

- **Mekong Delta**

Summary of drought impact ranking on agricultural economic, environmental, and social sectors in Mekong Delta of Vietnam can be summarized in the table below:

No	Groups of drought impact types in Mekong Delta	Rank
1	Loss from crop production	1
2	Loss from dairy and livestock production	3
3	Loss from timber production	3
4	Loss from fishery production	1
5	Decline in food production/disrupted food supply	2
6	Revenue to water supply firms	3
7	Damage to animal species	0
8	General environment	1
9	General society	2
10	Increased conflicts	2
11	Inequity in drought impacts based on:	2
12	Reduced quality of life, changes in lifestyle	2

**TABLE 4: LIST OF DROUGHT IMPACTS AND RANKING ON AGRICULTURAL ECONOMIC, ENVIRONMENTAL, AND SOCIAL SECTORS, MEKONG DELTA**

**e) Conclusion and Recommendations**

- At all nations, there is no recording system or mechanism on annual drought impacts on socio economic, environment, and agriculture
- More small and medium-sized water storage system at local areas needs to be rehabilitated especially for Cambodia, Lao PDR and even Thailand to provide sufficient water in dry season and during dry spells in rainy season
- Ground water 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
- The importance of trans-boundary mechanism for drought impact mitigation has not been applicable yet at the bordering areas

- Drought early warning has not reached rural areas. Farmers are relying on their traditional method when and where to start planting their crops in the beginning of the monsoon

## **2.3 National Drought Early Warning System**

A national survey on existing drought early warning system which includes drought monitoring, forecasting, and early warning services at Country level was carried out from 2015 to 2016. The objective of the survey was to identify the data and knowledge gaps that need to be addressed and 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.

### **a) 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. However, the Committee is not yet equipped with any drought early warning facilities. The Committee focuses mainly on flood and typhoon.

### **b) Lao PDR**

Like Cambodia, Lao PDR does not have any drought early warning system in operation yet. Line Agency in charge needs to build capacity in drought early warning system to be able to handle the system in the near future.

### **c) Thailand**

Thailand is seen to be the most advanced Country in the Lower Mekong Region especially in the field of drought early warning system. National Agencies working related to droughts including hydrology, meteorology, agriculture, irrigation, and water resources are performing their own drought indicator monitoring and forecasting for both dry and wet seasons every year.

In recent years, drought monitoring and forecasting information has been populated in many websites of the Thai National Agencies though the information become available without actually getting any closer to improved monitoring and forecasting droughts which should be better prepared and dealt with.

National Line Agencies working on drought monitoring and forecasting include Land Development Department, Thai Meteorological Department, Department of Disaster Prevention and Mitigation, Department of Agricultural Department, Geo-Informatics and Space Technology Development Agency (GISDA), and Thai Water and Thai Office of the National Water and Flood Management Policy.

In summary, national agencies with their responsibilities and tasks related to drought monitoring and forecasting are listed in the following table:

Department/Agency	Task	Model	Lead Time
Land Development Department	<ul style="list-style-type: none"> <li>- Regional drought management and mitigation strategies</li> <li>- Drought-related capacity development</li> <li>- Land and water resource analysis (crop maps etc.)</li> <li>- Climate impact and vulnerability assessments</li> </ul>	Now cast and forecast based on drought frequency	1 week to months
Thai Meteorological Department	<ul style="list-style-type: none"> <li>- Drought monitoring</li> <li>- Number of consecutive dry days</li> <li>- 3 months rainfall forecast</li> </ul>	GMI, SPI, SMI, PET, dynamical weather prediction models	1 week to 3 months
Department of Disaster Prevention and Mitigation	<ul style="list-style-type: none"> <li>- Collect data on water demand</li> <li>- Monitor drought using climate information with water in reservoirs</li> </ul>	<ul style="list-style-type: none"> <li>- Surveys</li> <li>- Climate information with reservoir levels</li> </ul>	Daily, weekly, and monthly
Department of Agricultural Extension	<ul style="list-style-type: none"> <li>- Very drought indicator indices</li> </ul>	<ul style="list-style-type: none"> <li>- Crop and agricultural status via photos with satellite data</li> </ul>	Weeks and months
Geo-Informatics and Space Technology Development Agency	<ul style="list-style-type: none"> <li>- Earth observation satellite signals</li> <li>- Data archiving and processing, image analysis</li> <li>- Provision of satellite data and GIS</li> <li>- Provide technical support, space technology research and development</li> </ul>	Direct reception of the earth observation satellite signals	Daily, weekly and monthly
Thai Water and Thai Office of the National Water and Flood Management Policy	<ul style="list-style-type: none"> <li>- Real time information about weather and hydro-climatological variables</li> </ul>	Satellite data	Hourly and daily

**TABLE 5: LIST OF LINE AGENCIES OF THAILAND WORKING ON DROUGHT MONITORING AND FORECASTING**

#### **d) Vietnam**

##### **National Hydro-meteorological Service of Vietnam**

The National Hydro-Meteorological Service (HMS), which belongs to Vietnam's Ministry of Natural Resources and Environment (MONRE), provides weather forecasting and other climate services through the National Centre for Hydro-Meteorological Forecasting (NCHMF). NCHMF is a public-profitable organization which:

- Provides hydro-meteorological and marine forecasts for public and private sectors;
- Monitors climate variations and assesses climate trends;
- Outlines the development strategy on research and forecasting of meteorology, hydrology, marine, and climate monitoring and assessment;
- Enhances the community awareness on weather and climate information.

The HMS has a sophisticated weather and hydrological monitoring and forecasting system that is based on observational station networks (telemetry and automatic weather stations), satellite data and information available from global weather forecasting systems (e.g. the United States of America (USA) National Oceanic and Atmospheric Administration (NOAA) Global Forecast System (GFS, [www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forecast-system-gfs](http://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forecast-system-gfs))). This provides a useful indication of the meteorological drought situation for the whole of Vietnam (see Figure 10: Photos of Vietnam's National Hydro-Meteorological Service (HMS))

). Satellite-based products such as the Drought Monitoring and Early Warning System (DMEWS) and Keetch-Byram Drought Index (KBDI) available from the University of Tokyo are also used (see <http://webgms.iis.u-tokyo.ac.jp/KBDI/> and Section **Error! Reference source not found.** for further details). Ongoing work is also exploring the use of remotely sensed vegetation information (i.e. Normalised Difference Vegetation Index (NDVI)) to track changes to crop coverage and health in agricultural regions to gain insights into current drought conditions (and hopefully also use this information to if/how drought conditions might develop/intensify/weaken in upcoming months).

In some parts of Vietnam (mainly southern Vietnam and the Mekong Delta) hydrological, agricultural and socioeconomic drought are also monitored and forecast via parameters such as observed water level in the rivers and reservoirs, observed flow rates and volumes, observed salinity and soil moisture at a small number of locations where soil moisture information is available.



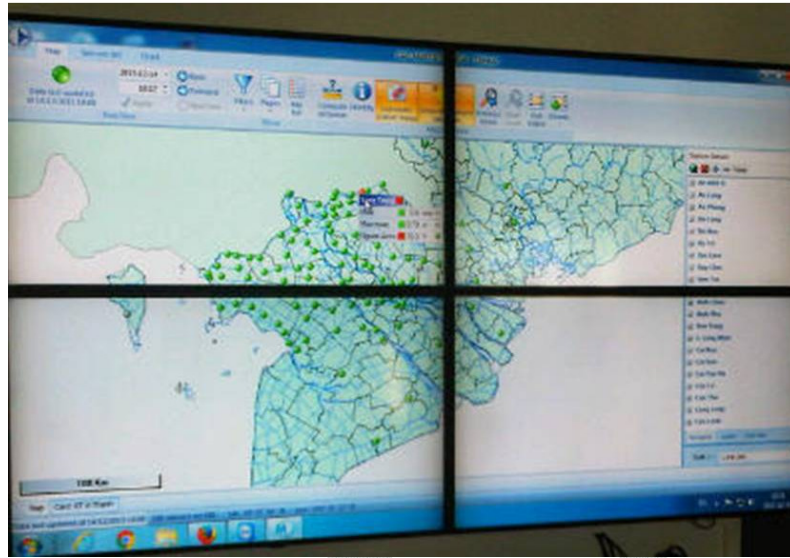


FIGURE 10: PHOTOS OF VIETNAM'S NATIONAL HYDRO-METEOROLOGICAL SERVICE (HMS)

(SOURCE: ANTHONY KIEM, 14<sup>TH</sup> DECEMBER 2015).

Large-scale ocean-atmospheric processes (e.g. El Niño/Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) etc.) influence Vietnam's hydroclimate but the current and forecast state of these processes are not explicitly taken into account in HMS seasonal forecasts – using ENSO or IOD conditions to inform seasonal hydroclimatic forecasts is routinely done in other countries and represents one area where significant improvements could be made to drought monitoring and forecasting in Vietnam.

Other requirements and areas for potential improvement in drought monitoring and forecasting systems in Vietnam include the need for better country-wide forecasts for all categories of drought, better availability and use of things other than rain to forecast drought (e.g. soil moisture (currently only two stations exist in the whole of Vietnam with observed soil moisture data), evapotranspiration, vegetation, non-natural influences on streamflow (i.e. due to irrigation or reservoir operations), socioeconomic and political influences (e.g. decisions to use take water from rivers or reservoirs for hydropower or irrigation may increase the chance or severity of drought impacts).

#### e) Conclusion and recommendations

Thailand is the most advanced Country in the region in terms of drought monitoring, forecasting, and early warning with multi-analysis of drought indicators. With supports from the Geo-Informatics and Space Technology Development Agency, Thailand is capable in performing space observation through satellite by themselves enabling more frequent access with better resolution to climatic indicators including air temperature, rainfall, humidity, and vegetation condition, etc., for detailed drought analysis. Various Agencies are working on drought condition

analysis with different responsibilities and tasks. However, there's a missing communication channel among those responsible departments before the final judgement and announcement is made for drought forecasting and early warning.

For Vietnam, drought monitoring and forecasting mainly focuses on meteorological and hydrological indicators using observational station networks (telemetry and automatic weather stations) and satellite data and information available from global weather forecasting systems including NOAA, GFS, ENSO, and IOD. The National Centre for Hydro-Meteorological Forecasting is using KBDI to detect changes in temperature and onset and offset of monsoon season.

Based on the findings, MRC Secretariat should support Member Countries 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 levels
- Conduct capacity building on drought monitoring, forecasting and early warning focusing all available and essential tools
- Produce monthly bulletin on drought condition of the LMB and share with Member Countries and National Line Agencies
- Develop a drought information and data sharing among Member Countries and MRC Secretariat to exchange emergency information and data on drought and water use conditions

## **2.4 Water Demands and Availability for Crops and Future Scenarios**

The study on water availability for LMB catchment and water demand for crops was carried out from July to October 2017 under output 3 of the DMP's Core Functions Project. The study aimed at analyzing water use gaps for each main catchment of the Lower Mekong Basin. The objectives of the study are:

- a) Determine crop water requirement volume in each catchment within the LMB in term of annual, wet and dry season need;
- b) Estimate the area of crop in each catchment;
- c) Identify areas where the method could be improved to inform future water plan allocations.

MRC Decision Support Framework (DSF) which includes IQQM/E-water Source was used to run crop models for all MRC catchment. Land cover 2003 data with MRC standard land cover classification was main input data for the models.

Analysis results:

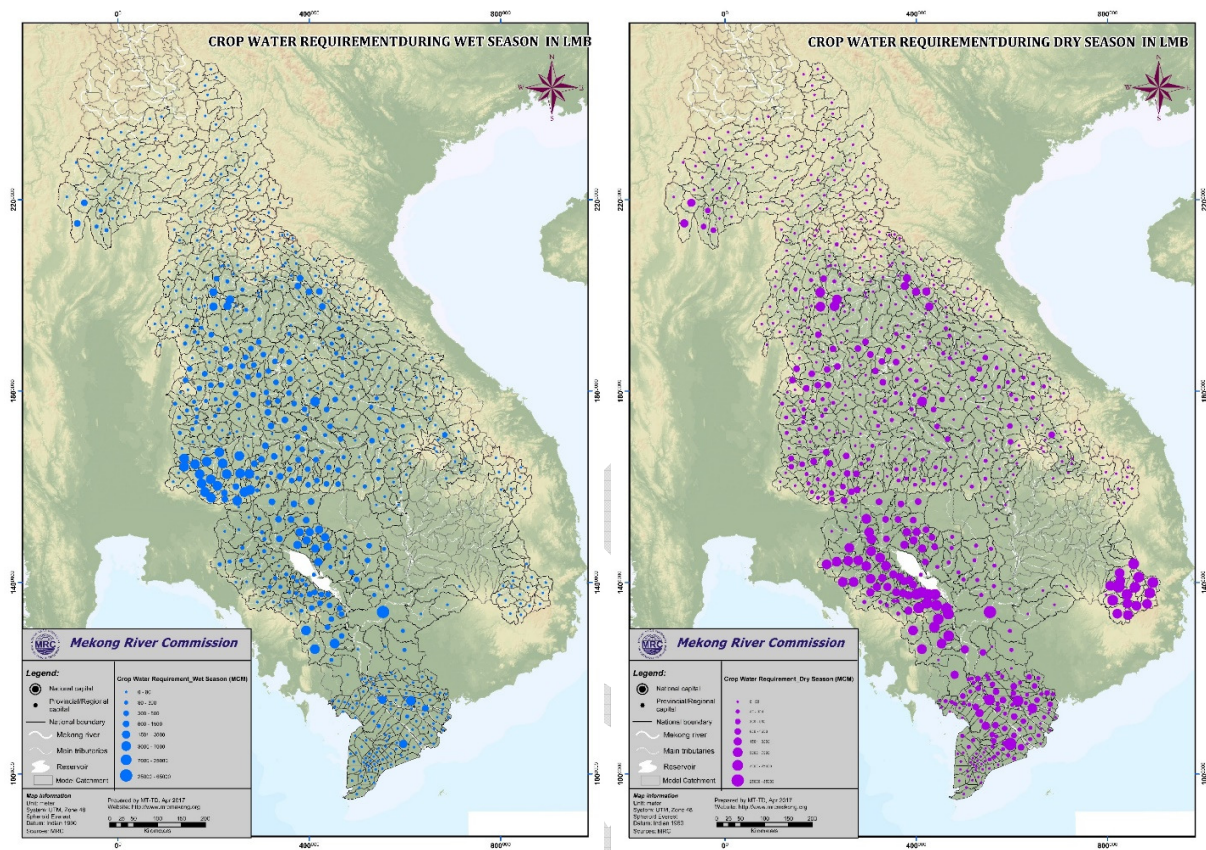


FIGURE 11: WATER REQUIREMENT FOR CATCHMENT IN WET AND DRY SEASON

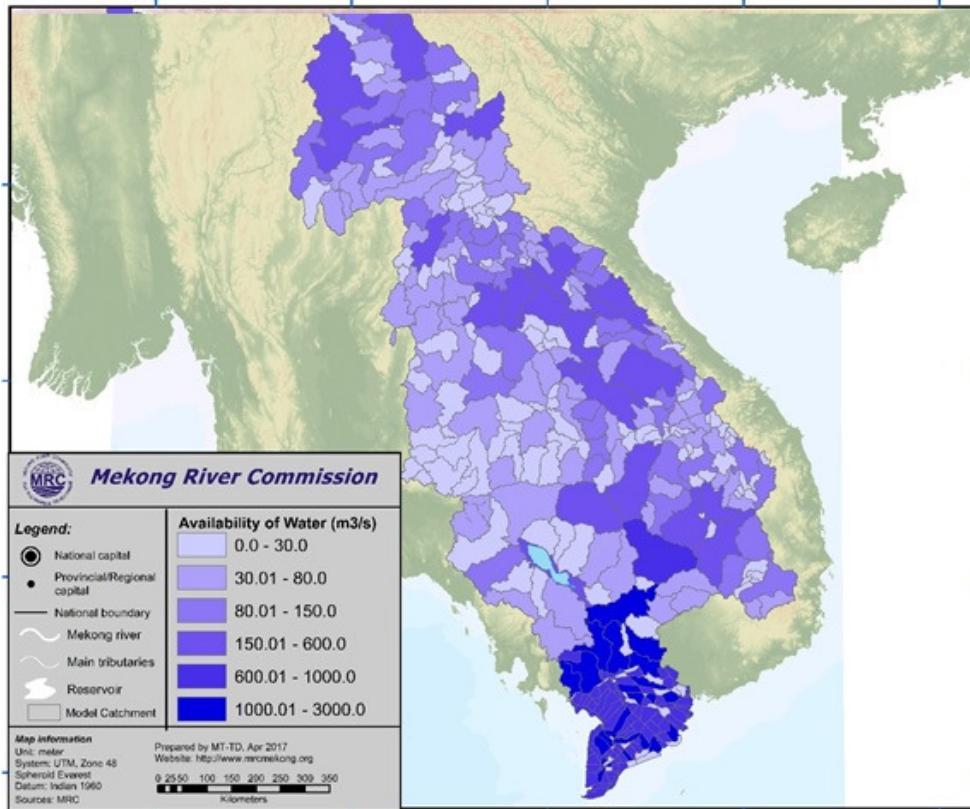


FIGURE 12: WATER AVAILABILITY OF THE CATCHMENT

To be completed after  
the study

## 2.5 Problems Identification from the Findings

After a series of national and regional studies, weaknesses of drought management at both national and regional levels can be summarized in the table below:

Problem	Drought Management	Drought Early Warning
<b>National Issue</b>		
Cambodia	<ul style="list-style-type: none"> <li>- No drought impacts reporting mechanism</li> <li>- Poor capacity in drought management concept</li> <li>- Lack of information on hydrological change regime from upstream</li> <li>- No proper seasonal water planning</li> </ul>	<ul style="list-style-type: none"> <li>- No early warning system</li> <li>- Line Agencies are lack of human resources on both drought monitoring and forecasting</li> <li>- The information on drought impacts are sending from villages and district levels</li> </ul>
Lao PDR	<ul style="list-style-type: none"> <li>- No drought impacts reporting mechanism</li> <li>- Poor capacity in drought management concept</li> <li>- Lack of information on hydrological change regime from upstream</li> <li>- No proper seasonal water planning</li> </ul>	<ul style="list-style-type: none"> <li>- No early warning system</li> <li>- Line Agencies are lack of human resources on both drought monitoring and forecasting</li> <li>- The information on drought impacts are sending from villages and district levels</li> </ul>
Thailand	<ul style="list-style-type: none"> <li>- No drought impacts reporting mechanism</li> <li>- Lack of information on hydrological change regime from upstream</li> </ul>	<ul style="list-style-type: none"> <li>- Have problem with water use monitoring from small-called water use sectors</li> <li>- No seasonal forecast used</li> </ul>
Vietnam	<ul style="list-style-type: none"> <li>- No drought impacts reporting mechanism</li> <li>- Lack of information on hydrological change regime from upstream</li> </ul>	<ul style="list-style-type: none"> <li>- Monitoring indicators are limited to only hydro and meteorological indicators.</li> <li>- No early warning to end-users</li> </ul>
<b>Regional Issue</b>		
	<ul style="list-style-type: none"> <li>- No information and data sharing mechanism on trans-boundary water use and planning</li> </ul>	<ul style="list-style-type: none"> <li>- No information and data exchange on drought monitoring and forecasting</li> <li>- No data exchange on trans-boundary water use and planning</li> <li>- No regional early warning system with all water use conditions shared by MCs</li> <li>- No frequent or timely drought dissemination to MCs</li> </ul>

TABLE 6: SUMMARY OF PROBLEMS IDENTIFICATION ON DROUGHT MANAGEMENT

### **3. OBJECTIVES AND GOALS OF THE DROUGHT MANAGEMENT STRATEGY**

#### **3.1 Development Process**

The 'Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin' - or the '1995 Agreement' as it is informally known - documents the commitment of the four Member States Cambodia, Laos, Thailand and Vietnam 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 pledges the Member States 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 River Agreement provides a broad mandate for the MRC in relation to drought management that could generate a sustainable and basin-wide benefit of Mekong River resources by reducing the impacts of drought on agriculture, socio-economics, and environment.

During the 1st MRC Summit in Hua Hin 2010, high level of the Member Countries' Heads of Government reiterated the needs of the Drought Management Work in the MRC Programmes and requested MRC Secretariat to initiate the formulation of the programme's document aiming at developing the drought management strategy for the MRC.

At the 2nd Regional Meeting which took place in Ho Chi Minh City on March 4, 2011, the four MRC Member Countries reaffirmed their need for moving forward in developing an effective regional drought risk management strategy to cope with meteorological, hydrological, agricultural and socio-economic drought vulnerability. The suggested strategic focus for drought management in the LMB is well aligned with the Heads of MRC Member Country Governments decision at the MRC Summit in April 2010 mentioned above. One of the nine priority areas of action identified by the Heads of Governments in the Summit Declaration as the focus of the MRC in the coming years is related to drought and other disasters.

Since then the MRC Secretariat has been given a mandate to develop a regional drought management strategy to support Member Countries in mitigating and managing drought risk and impacts in an effective way.

The process for formulating the MRC drought management strategy consists of the following distinct stages:

- Regional study on drought risk assessment for the LMB in 2013
- National study on drought impacts and vulnerability assessment (2013-2017)
- National fact-finding missions to the four riparian countries on drought early warning system (2015-2016)
- Regional study on land and water resources analysis
- Regional consultation workshop on the Draft Strategy Report at a regional consultation workshop on 12 December 2017 in Siem Reap, Cambodia, where all four countries have the opportunity to comment on the proposed priority actions.
- National consultation workshops for further get comments and feedbacks from member Countries for the strategy in February and March 2018
- Regional consultation workshop on ...

If the draft Drought Management Strategy 2019-2023 is approved at the Council Meeting, the following tasks will follow:

- Based on the strategy preparatory works, formulate a draft 5-year project workplan including detailed bankable project components - Elaborate the details of the action plan;
- Review of the draft workplan and action plan by the four countries;
- Conduct a Regional Workshop to discuss the detailed workplan and Action Plan;
- Finalise the Action Plan and the detailed project components;
- Incorporate the DMT 5-year workplan into the MRC Annual Work Programme under the new structure of RFMMC.

## **3.2 Scope and Focus**

### **Scope**

The scope of the Drought Management Strategy (DMS) 2019-2023 is to provide an “overall framework to support Member Countries in developing sustainable capabilities and capacity for managing drought vulnerabilities in the LMB in an effective sustainable, and equitable manner” in line with the IWRM and Integrated Risk Management principles.

### **Focus**

The first DMS 2019-2023 of the MRC focuses on sustainable use, management and planning the Mekong River water resources with stakeholder participation in managing drought risk and vulnerability of the Mekong Countries.

### **3.3 Vision, Mission, Goal, and Objectives**

The Vision, Mission, Goal, Objectives and Outcomes of the Drought Management Strategy 2019-2023 are as follows:

#### **Vision**

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

#### **Mission**

To support Member Countries in building capacity and providing new technology for detecting and managing drought risk and hazards in the Mekong Basin with sustainable use of Mekong water resources.

#### **Strategic Goal**

To stimulate responsible and sustainable use and management of water resources in the Mekong River in drought management and mitigation.

#### **Objective**

National and basin-wide drought risk is better managed with equitable and transparent Mekong water resources management and planning facilitated through dialogue and consultative approaches.

### **3.4 Principles**

The DMS 2019-2023 recognizes the General Principles of the 1995 Mekong Agreement:

1. Principle of Protection of Environment and Ecology Balance (Art. 3).
2. Principles of Reasonable and Equitable Utilisation (Art. 5).
4. Principle of Maintenance of Flows on the Mainstream (Art. 6).
5. Principle of avoiding, minimizing and mitigating harmful effects (Art. 7).
6. Principle of State Responsibility for Damages (Art. 8).
7. Principle of Freedom of Navigation (Art. 9).
8. Principles governing response to Emergency Situations (Art. 10).



The DMS 2019-2023 observes the following IWRM principles:

- Provide an enabling environment for sustainable management.
- Responsibility of all parties concerned according to their roles and responsibilities.
- Good technical management tools.
- Transparent stakeholder participation.
- Gender sensitivity.

The DMS 2019-2023 also observes the MRC following procedures:

- 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 and Prior Consultation Action (PNPCA)

## 4. MRC DROUGHT MANAGEMENT STRATEGY

### 4.1 Key Strategic Priorities and Related Priority Actions

Through all the studies and surveys carried out in Member Countries on drought management issues in recent years, we can infer that Countries are still slow in responding to drought hazards of which capacity in the field needs to be enhanced and developed.

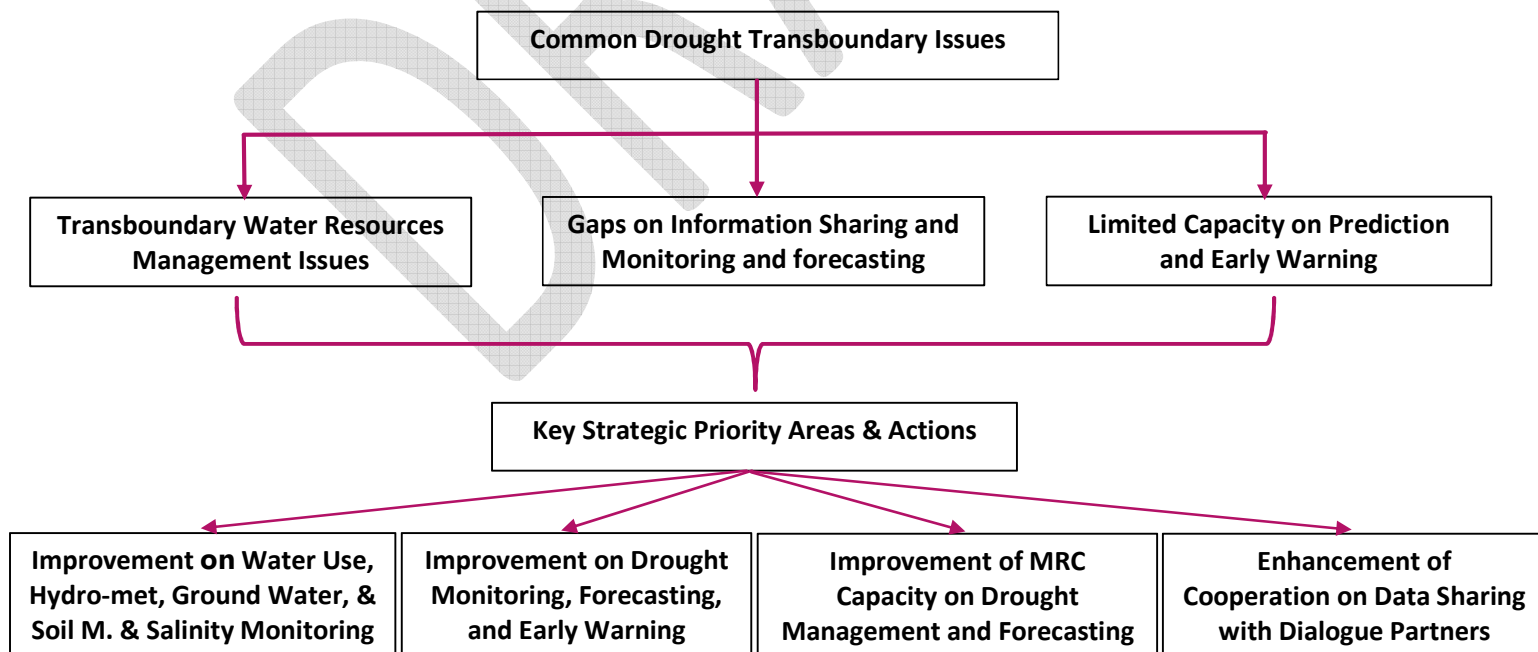


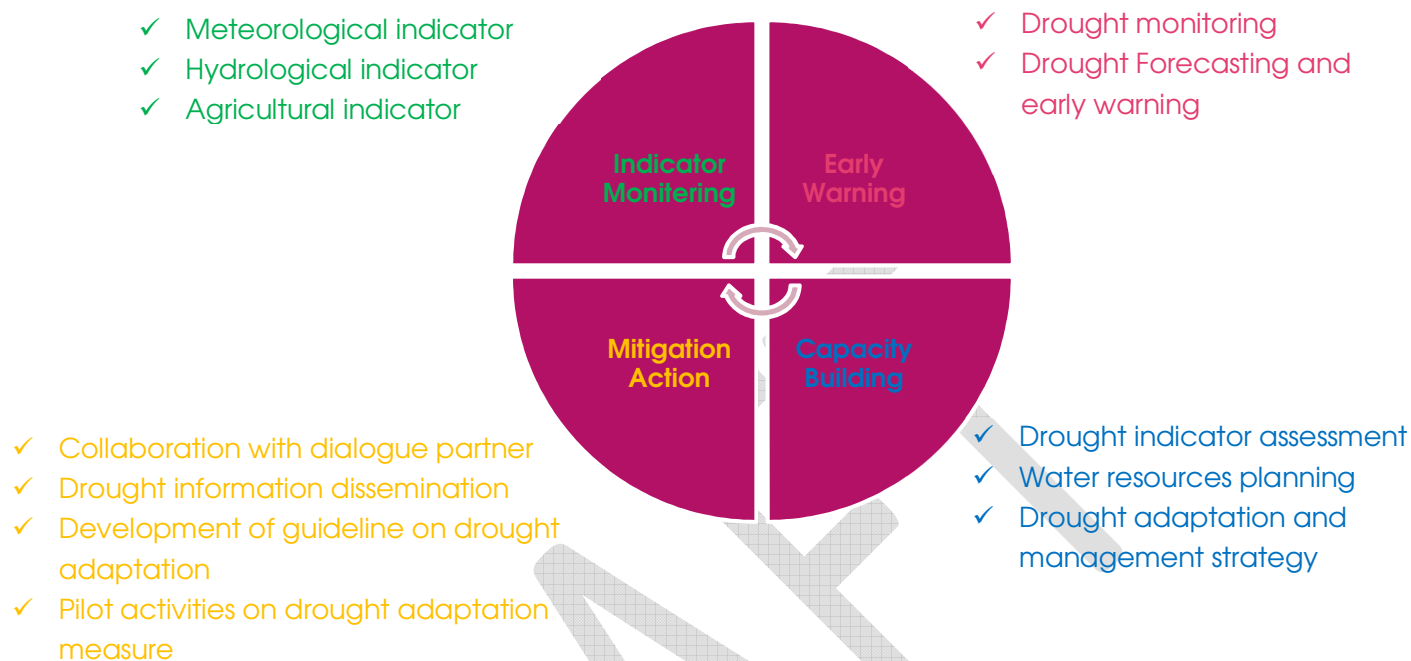
FIGURE 13: COMMON DROUGHT TRANSBOUNDARY ISSUES FOR KEY STRATEGIC PRIORITY AREAS

Our Lower Mekong Basin is lack of a regional mechanism on drought condition and related data sharing in 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 of upstream collaboration on data sharing and support on water resources sharing during severe drought condition.

Based on the graphic above, the following key areas are found to be more or less poor functioning and should be given priority for receiving technical support from MRC Secretariat in the next coming period 2019-2023:

- (i) Indicator Monitoring
  - (a) Hydrological and Reservoirs Monitoring
  - (b) Monitoring of Procedures for Maintenance of Flows on the Mainstream
  - (c) Ground Water Monitoring
  - (d) Soil Moisture Monitoring
  - (e) Salinity Level Monitoring
- (ii) Drought Early Warning
  - (a) Drought monitoring
  - (b) Drought forecasting and early warning
- (iii) Capacity Building
  - (a) Drought indicator assessment
  - (b) Water resource planning
  - (c) Drought adaptation and management strategy
- (iv) Mitigation Action
  - (a) Collaboration with dialogue partner
  - (b) Drought information dissemination
  - (c) Development of guideline on drought adaptation
  - (d) Pilot activities on drought adaptation measure

The mentioned 4 priority areas are significantly important for Member Countries to be prepared for seasonal drought disaster especially with the first MRC drought management strategy which will be implemented from 2019 to 2023.



**FIGURE 14: FOUR PRIORITY CLUSTERS FOR DROUGHT MANAGEMENT STRATEGY 2019-2023**

#### **4.1.1 Indicator Monitoring**

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

For meteorological and hydrological indicators, MRC currently has HYCOS stations being operated together with our new 15 stations supported by DMT being constructed in the drought prone areas of Member Countries. In addition, the DMS 2019-2023 would like to recommend 2 more essential elements to be monitored for hydrological indicator including reservoir levels and ground water. Reservoirs play an important role in water resources planning during severe and prolonged drought period when rainfall amount is inadequate and water level is at considerably low level. Then the final option will come to ground water where farmers can rely on for both

drinking water and agricultural irrigation to rescue desperate crops that are in need of water to survive.

With regards to agricultural indicator, soil moisture and salinity intrusion are currently the most important indicators in the region. Soil moisture presents level of moisture in the soil ranging from surface to different layers in the ground showing preferable and un-preferable conditions for agricultural crops. Based on national survey, Member States are lack of soil moisture coverage at ground level to monitor agricultural indicator. They tend to rely very much on available satellite data with no ground truth. Meanwhile, salinity intrusion is the primary issue in the Mekong Delta of Vietnam where level of salinity in Mekong mainstream is too high for irrigation harming agricultural crops in the surrounding areas during dry season.

#### 4.1.1.1 Hydro-meteorological and Reservoir Water Monitoring

In the planning process, rainfall and water level are the most fundamental factors to be looked at. During dry year, 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. Therefore, to prevent such situation from happening, policy makers need to consider storing water at main, small and medium sized reservoirs so that water will be available for farmers when facing severe drought.

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

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

***Therefore, the proposed priority actions under hydro-meteorological monitoring are:***

- Investigate on appropriate sites in the drought prone areas for new extending locations of hydro-met stations
- Extend hydro-meteorological stations in the drought prone areas of Member Countries with near-real-time function
- Study on potential reservoirs for water level monitoring stations in the drought prone areas of Member Countries

- Support Member Countries construct water level monitoring station at the selected reservoirs with near-real-time function
- Build a data connection and transferring from the stations for both hydro-met and reservoir stations
- Develop a standard QA/QC tool for quality control and biased correction
- Develop management plan for stations operation and maintenance
- Develop a decentralization road map for the stations

#### 4.1.1.2 Monitoring of Procedures for Maintenance of Flows on the Mainstream

By acknowledging that drought is a trans-boundary water management issue, a minimum flow, which has been analyzed and standardized under PWUM and 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 MRC 1995 Agreement.

To do that, a regional mechanism on monitoring of the flows at some main locations during dry season needs to be in place. Notification needs to be made to all Member States when the flows drop below the minimum/critical level of the MRC standard making sure that all parties are officially informed so that they will be able to come up with appropriate actions and regulations for their own prevention of water scarcity in the area during critical periods.

*The proposed priority actions under monitoring of PMFM are:*

- Develop a regional mechanism on monitoring flows on the mainstreams including standard requirement for selection of the main locations to be monitored, time periods for monitoring and notification, and notification procedures based on PMFM
- Evaluate and select main locations for monitoring and notification actions
- Perform periodical assessment and analysis on future trends of the flows during critical situation as weekly basis
- Notify and disseminate the information and data to Member Countries on daily and weekly basis

#### 4.1.1.3 Ground Water Monitoring

In the developed countries, ground water has been widely explored to support all water utilization sectors. Ground water 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, over exploitation of ground water will lead to subsidence situation with serious impacts on people's livelihood and environment. Therefore, for a sustainable use, groundwater needs to be well managed and appropriately regulated.

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

*For the benefits of MRC Member States on groundwater use, the Drought Management Strategy 2019-2023 would like to propose the following priority actions as follows:*

- Study on appropriate ground water sites for agricultural and livelihood
- Reactivate collaboration with NASA on ground water project where IKMP had in 2015 to support underground layers study
- Support Member Countries construct ground water monitoring stations in the appropriately selected drought prone areas with near-real-time function; it can be an additional sensor to be equipped with the existing hydro-met stations of DMT
- Build data connection and transferring from the stations
- Develop a standard QA/QC tool for quality control and biased correction
- Develop management plan for stations operation and maintenance
- Develop a decentralization road map for the stations

#### 4.1.1.4 Soil Moisture Monitoring

Soil moisture is the main agricultural indicator for drought. Yet, ground monitoring stations of soil moisture are still very limited in the LMB region. As normal practice, Member Countries use satellite data to analyze agricultural drought such as the Normalized Difference Vegetation Index from either MODIS or TM Landsat, and SMOS satellite data.

The soil data for drought analysis is divided into two classes including top soil and sub soil. Sub soil is more important to monitor soil moisture as it is rich in minerals and plays an important part of plant growth.

Like other indicators, ground data of soil moisture is significant for indicator monitoring and satellite products calibration. In the long run, the ground data will generate 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 MRC now for this Strategy 2019-2023 to start building our ground truth stations.

*Therefore, the proposed priority actions under soil moisture monitoring are:*

- Study on potential sites for soil moisture monitoring stations in the drought prone areas of Member Countries
- Support Member Countries construct soil moisture monitoring station with near-real time monitoring function at the selected locations

- Build data connection and transferring from the stations
- Develop a standard QA/QC tool for quality control and biased correction
- Develop management plan for stations operation and maintenance
- Develop a decentralization road map for the stations

#### 4.1.1.5 Salinity Level Monitoring

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

The devastating condition can be alleviated in some extent if the flow regime upstream is increased to sufficient level generating high flow in the Mekong Delta and pushing back the sea water infiltration in the river. This is a regional mechanism and MRC might need a cooperation support from our 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 during disaster period are significantly important for decision makers. DMT would like to propose the following actions under this priority area to support Vietnam in mitigating salinity intrusion:

- Study on locations where salinity intrusion is the major concern for agricultural crops
- Install salinity level monitoring stations in the selected areas
- Build data connection and transferring from the stations
- Develop a standard QA/QC tool for quality control and biased correction
- Develop management plan for stations operation and maintenance
- Develop a decentralization road map for the stations

#### 4.1.2 Drought Early Warning

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

Through national study, among the four Member States only Thailand and Vietnam are operating drought early warning system. Yet, the warning services do not provide full nor comprehensive information as the departments involved are working independently without close cooperation nor information sharing among those relevant agencies, thus providing only one-side drought analysis.

A complete drought early warning system would include:

- Drought monitoring: on at least three main drought indicators including hydrological, meteorological, and agricultural indicators
- Drought forecasting: for a period of weeks and months ahead with at least three main indicators including hydrological, meteorological, and agricultural indicators
- Early warning: drought situation and trend analysis based on both monitoring and forecasting which is 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 USAID project which was signed in October 2015, DMT of MRCS has been fully granted 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).

MRC Secretariat through the Drought Management Team will support Member States in providing weekly and monthly drought monitoring products via a public information sharing tool under the MRC Information Portal.

*The proposed priority actions under this drought monitoring priority area are:*

- Select drought indices and tools for monitoring work (now-casting) under RHEAS
- Build a standard drought monitoring tool for National and Regional levels
- Develop and operate a regional drought monitoring service on selected drought indices (SPI, DSI, SRI, and SMI)
- Develop a regional drought data portal to share raw and end-product data with MCs
- Conduct end products verification for tools enhancement



#### 4.1.2.2 Drought forecasting and early warning

Drought forecasting is built in with the drought monitoring service of the RHEAS tool. The forecasting function is developed using Ensemble Stream Flow Prediction (ESP) that resamples climatology for hydrological indicator and IRI/NMME meteorological forcing that resamples climatology based on the probabilities for meteorological indicator. The forecasting function allows us to predict 90 days ahead for base flow, runoff, soil moisture, evaporation, water balance, etc. Based on the monitoring and forecasting products, a drought early warning service can be produced and made available to public through MRC Website.

With that DMT will support Member States in providing weekly and monthly drought forecasting products and early warning service via a public information sharing tool under the MRC Information Portal. For the time of this document being formulated, the drought early warning system is under development process with 70% progress by an International Consultant with technical support from ADPC and NASA JPL teams.

*The proposed priority actions under drought forecasting and early warning are:*

- Select drought indices and tools for drought forecasting work under RHEAS
- Build a standard drought forecasting and early warning tool for National and Regional levels
- Develop a regional drought data portal to share raw and end-product data with MCs
- Conduct end products verification for tools enhancement
- Conduct frequent technology sharing on drought early warning among MRC Member Countries and beyond especially with ASEAN region
- Develop MRC stand-alone drought forecasting system by customizing RHEAS models with customized parameters for the LMB region

#### 4.1.3 Capacity Building

Drought management is still new to MRC of which the Drought Management Programme was only formulated and operated under MRC Framework in 2012. Moreover, the programme was having funding issue from donors since it first started its operation making the progress of capacity building activities slow.

Referring to the national findings on capacity needs assessment, most National Line Agencies of MRC Countries involved in drought management work have low understanding and experiences on drought related issues including drought definition and classification, drought monitoring and forecasting, and drought management and mitigation etc. With this, the Drought Management Strategy 2019-2023 suggests that capacity building is essential for DMT and can be

performed through national and regional training courses, internships, seminars, workshops, and study tours.

#### 4.1.3.1 National and regional training

Training is one of the best choices for building capacity to National Line Agencies that are dealing directly and indirectly with drought management activities. In MRC, training is divided into 2 distinct levels specifically national and regional levels. With training courses, MRC can provide intensive capacity building on specific topics to the trainees with some practical exercises to make them familiarized with the tools and theories. Field visit can be added to obtain practical experiences for certain areas.

***For the first time of MRC, the training on drought management work shall focus on some basic tools and understanding of drought related concepts. They should include:***

- 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) Water resource planning
- 4) Drought management and adaptation strategy

The proposed activities for capacity building on drought management are listed below:

- Based on the national reports on capacity needs assessment develop capacity development plan for MRC in response to the needs for capacity building at National level
- Conduct national and regional training courses on advanced GIS and analysis tools for drought management
- Conduct national and regional training courses on drought indicator assessment for hydrological, meteorological, and agricultural indicators
- Conduct national and regional training courses on water resources planning concept
- Conduct national and regional training course on drought adaptation and mitigation strategy

#### 4.1.3.2 Regional and International workshops and conferences

Regional and International workshops and conferences are one of the most effective ways of exchanging 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 with different concepts on drought management issues. Drought is new to LMB region, thus it is ultimately essential for MRC staff to learn experiences from other regions and experts especially on drought early warning system and drought management and adaptation strategy.

*The proposed activities under workshops and conferences are as follows:*

- Work to identify areas for improvement and needs of practical experiences from outsiders
- Identify main stakeholders for both MRC sides and guests for the workshops/conferences
- Conduct workshops/conferences and map out lessons learned and experiences from invited international experts
- Apply newly learned practical experiences to the implementation, for instance, apply the adaptation options on drought impacts to pilot projects for verification and tools validation.

#### 4.1.3.3 Study tours to drought prone regions

Study tour is a good practice to learn real things in the field. It is a very common action that most international organizations usually do to improve understanding in the real world and to validate the theories that have been transferred from one person to another. Study tour can be made to one of the Member Countries or outside of the region such as the Philippines or China where droughts have been the issues and consequently addressed with significant results.

*Therefore, the proposed priority actions under capacity building are:*

- Collaborate with other regional organization or Countries on certain areas for technical and experiences exchange
- Develop or invent exchanging programme with collaborating partners to improve our capacity for both national and regional levels
- Plan and apply the newly learned experiences to our project implementation such as pilot projects to validate the lessons learned.

#### 4.1.4 Mitigation Actions

Mitigation is the most important action for MRC Secretariat to directly support Member Countries in both coordination and technical supervision especially during critical situation of severe drought, prolonged dry spells, and low flows. During the drought hazard 2016, on behalf of the Member States, if the regional mechanism was already in place MRC could play a key role in coordination with dialogue partners for an immediate water supply from upstream Countries especially China by conveying the emergency on water scarcity and severe low flows threatening Member Countries of the LMB on agricultural products and domestic water use which needed an immediate support. Moreover, MRC could be able to support Member Countries by disseminating drought condition and trend analysis at some main locations of the Mekong mainstream to Member Countries for disaster preparedness and prevention.

Under this mitigation section, it is also necessary to have a regional guideline on drought adaptation developed and tested some of the adaptation options in pilot activities. MCs can learn from the piloting project the modality of how to mitigate some specific impacts and witness the effectiveness of the applied options.

#### 4.1.4.1 Collaboration with dialogue partner

Dialogue partners mainly China is the main driver for regulating flow regime from upstream part which plays a key role in reducing and triggering hydrological drought hazard to our LMB region. Hence, it is extremely significant for MRC to enhance cooperation with them for a better Mekong Mainstream water management. Data on daily operation of the hydro-power dams are also significantly important for us to monitor the changes of the Mekong flows as well as to predict the trends in short-coming periods.

*The proposed actions for collaboration with dialogue partners include:*

- Enhance cooperation with dialogue partners especially China on drought management
- Propose hydrological data exchange in dry season especially from the two stations in China
- Propose an annual technical exchange workshop and study tour to China to learn from drought adaption options and early warning system used in China

#### 4.1.4.2 Drought information dissemination

Unlike flood, drought is a slow-progressing natural disaster of which the negative effects do not present in physical appearance. The negative impacts of drought are mainly nonstructural elements 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 less or slow responsiveness of preparedness and prevention.

Moreover, due to the fact that some Member Countries of the MRC including Cambodia and Lao PDR are not yet capable in monitoring and forecasting the drought progress, supports from MRC on monthly based drought situation analysis and notification are ideally useful and necessary.

MRC involvement under this strategic role, thus, is to produce monthly drought information bulletin and host it under MRC Website to allow public access to the most update drought situation in the region. MRC can distribute the monthly bulletin to all representatives' email of relevant National Agencies. This sort of monthly bulletin later will be built as drought information archive for future reference.

*Therefore, the proposed priority actions under this drought information dissemination are:*

- Build a data connection network with national agencies of MCs on monthly drought analysis
- Develop a monthly bulletin on drought condition and trends and sharing with concerned national agencies

#### 4.1.4.3 Development of guideline on drought adaptation

By considering as the core task in drought management to reduce trans-boundary drought impacts and vulnerability, drought adaption under the MRC Strategy needs to be implemented under an appropriate guideline facilitated by DMT of the MRC Secretariat. To be effective, drought mitigation should be focused through top down approach meaning transboundary issues should be given priority before considering national and local issues, so that both transboundary and national impacts can be fully covered and addressed.

*The proposed actions to develop a guideline on drought adaptation are listed below:*

- Formulate national teams on MRC guideline development for drought adaptation
- Conduct 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 modeling and scenarios of land use with water availability, develop a guideline on drought adaptation for the MRC

#### 4.1.4.4 Pilot activities on drought adaptation measure

To validate the adaptation options which have been identified and listed in the MRC guideline for mitigating drought impacts, some piloting projects need to be put into practice. Each MC can

select a few mitigation options that match with 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.

*The proposed activities for pilot projects can be listed below:*

- Identify hotspot areas which drought has been a severe problem
- Select the most suitable adaptation options for the hotspots which are listed in the MRC Guideline for drought and mitigation
- Formulate a national team to carry out the pilot project and commence the implementation
- Write a national report on the pilot project with recommendation for lessons learned.

**List of Priority Areas and Proposed Actions:**

Priority Area	Proposed Action	Task
1. Indicator Monitoring	Hydro-meteorological and reservoir water monitoring	<ul style="list-style-type: none"> <li>▪ Investigate on appropriate sites in the drought prone areas for new extending locations of hydro-met stations</li> <li>▪ Extend hydro-meteorological stations in the drought prone areas of Member Countries with near-real-time function</li> <li>▪ Study on potential reservoirs for water level monitoring stations in the drought prone areas of Member Countries</li> <li>▪ Support Member Countries construct water level monitoring station at the selected reservoirs with near-real-time function</li> <li>▪ Build a data connection and transferring from the stations for both hydro-met and reservoir stations</li> </ul>
	Monitoring of Procedures for Maintenance of Flows on the Mainstream	<ul style="list-style-type: none"> <li>▪ Develop a regional mechanism on monitoring flows on the mainstreams including standard requirement for selection of the main locations to be monitored, time periods for monitoring and notification, and notification procedures based on PMFM</li> <li>▪ Evaluate and select main locations for monitoring and notification actions</li> <li>▪ Perform periodical assessment and analysis on future trends of the flows during critical situation as weekly basis</li> <li>▪ Notify and disseminate the information and data to Member Countries on daily and weekly basis</li> </ul>
	Ground water monitoring	<ul style="list-style-type: none"> <li>▪ Study on appropriate ground water sites for agricultural and livelihood</li> <li>▪ Reactivate collaboration with NASA on ground water project where IKMP had in 2015 to support underground layers study</li> <li>▪ Support Member Countries construct ground water monitoring stations in the appropriately selected drought prone areas with near-real-time function; it can be an</li> </ul>

		<p>additional sensor to be equipped with the existing hydro-met stations of DMT</p> <ul style="list-style-type: none"> <li>▪ Build data connection and transferring from the stations</li> <li>▪ Develop a standard QA/QC tool for quality control and biased correction</li> <li>▪ Develop management plan for stations operation and maintenance</li> <li>▪ Develop a decentralization road map for the stations</li> </ul>
	Soil moisture monitoring	<ul style="list-style-type: none"> <li>▪ Study on potential sites for soil moisture monitoring stations in the drought prone areas of Member Countries</li> <li>▪ Support Member Countries construct soil moisture monitoring station with near-real time monitoring function at the selected locations</li> <li>▪ Build data connection and transferring from the stations</li> <li>▪ Develop a standard QA/QC tool for quality control and biased correction</li> <li>▪ Develop management plan for stations operation and maintenance</li> <li>▪ Develop a decentralization road map for the stations</li> </ul>
	Salinity level monitoring	<ul style="list-style-type: none"> <li>▪ Study on locations where salinity intrusion is the major concern for agricultural crops</li> <li>▪ Install salinity level monitoring stations in the selected areas</li> <li>▪ Build data connection and transferring from the stations</li> <li>▪ Develop a standard QA/QC tool for quality control and biased correction</li> <li>▪ Develop management plan for stations operation and maintenance</li> <li>▪ Develop a decentralization road map for the stations</li> </ul>
<b>2. Drought Early Warning</b>	Drought monitoring	<ul style="list-style-type: none"> <li>▪ Select drought indices and tools for monitoring work (now-casting) under RHEAS</li> <li>▪ Build a standard drought monitoring tool for National and Regional levels</li> <li>▪ Develop and operate a regional drought monitoring service on selected drought indices (SPI, DSI, SRI, and SMI)</li> <li>▪ Develop a regional drought data portal to share raw and end-product data with MCs</li> <li>▪ Conduct end products verification for tools enhancement</li> </ul>
	Drought forecasting and early warning	<ul style="list-style-type: none"> <li>▪ Select drought indices and tools for drought forecasting work under RHEAS</li> <li>▪ Build a standard drought forecasting and early warning tool for National and Regional levels</li> <li>▪ Develop a regional drought data portal to share raw and end-product data with MCs</li> <li>▪ Conduct end products verification for tools enhancement</li> <li>▪ Conduct frequent technology sharing on drought early warning among MRC Member Countries and beyond especially with ASEAN region</li> </ul>

		<ul style="list-style-type: none"> <li>Develop MRC stand-alone drought forecasting system by customizing RHEAS models with customized parameters for the LMB region</li> </ul>
<b>3. Capacity Building</b>	National and Regional training	<ul style="list-style-type: none"> <li>Based on the national reports on capacity needs assessment develop capacity development plan for MRC in response to the needs for capacity building at National level</li> <li>Conduct national and regional training courses on advanced GIS and analysis tools for drought management</li> <li>Conduct national and regional training courses on drought indicator assessment for hydrological, meteorological, and agricultural indicators</li> <li>Conduct national and regional training courses on water resources planning concept</li> <li>Conduct national and regional training course on drought adaptation and mitigation strategy</li> </ul>
	Regional and International workshops and conferences	<ul style="list-style-type: none"> <li>Work to identify areas for improvement and needs of practical experiences from outsiders</li> <li>Identify main stakeholders for both MRC sides and guests for the workshops/conferences</li> <li>Conduct workshops/conferences and map out lessons learned and experiences from invited international experts</li> <li>Apply newly learned practical experiences to the implementation, for instance, apply the adaptation options on drought impacts to pilot projects for verification and tools validation</li> </ul>
	Study tours to drought prone regions	<ul style="list-style-type: none"> <li>Collaborate with other regional organization or Countries on certain areas for technical and experiences exchange</li> <li>Develop or invent exchanging programme with collaborating partners to improve our capacity for both national and regional levels</li> <li>Plan and apply the newly learned experiences to our project implementation such as pilot projects to validate the lessons learned</li> </ul>
<b>4. Mitigation Actions</b>	Collaboration with dialogue partners	<ul style="list-style-type: none"> <li>Enhance cooperation with dialogue partners especially China on drought management</li> <li>Propose hydrological data exchange in dry season especially from the two stations in China</li> <li>Propose an annual technical exchange workshop and study tour to China to learn from drought adaptation options and early warning system used in China</li> </ul>
	Drought information dissemination	<ul style="list-style-type: none"> <li>Build a data connection network with national agencies of MCs on monthly drought analysis</li> <li>Develop a monthly bulletin on drought condition and trends and sharing with concerned national agencies</li> </ul>
	Development of guideline on drought adaptation	<ul style="list-style-type: none"> <li>Formulate national teams on MRC guideline development for drought adaptation</li> <li>Conduct national study on data collection of drought management policy and mitigation strategy, agricultural</li> </ul>



		<p>land use and irrigation, and crop yield for all types of agricultural land use</p> <ul style="list-style-type: none"> <li>▪ Together with the results of crop modeling and scenarios of land use with water availability, develop a guideline on drought adaptation for the MRC</li> </ul>
	Pilot activities on drought adaptation measures	<ul style="list-style-type: none"> <li>▪ Identify hotspot areas which drought has been a severe problem</li> <li>▪ Select the most suitable adaptation options for the hotspots which are listed in the MRC Guideline for drought and mitigation</li> <li>▪ Formulate a national team to carry out the pilot project and commence the implementation</li> <li>▪ Write a national report on the pilot project with recommendation for lessons learned</li> </ul>

TABLE 7: LIST OF PRIORITY AREAS AND PROPOSED ACTIONS

## 4.2 Challenges for Implementing the Drought Management Strategy

MRC might face some challenges while implementing the Drought Management Strategy 2019-2023 in the beginning stage. The main difficulty would be adopting new technology on drought early warning system 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 built if MRC is to facilitate capacity building and technology transfer to Riparian States. These challenges might raise the following issues:

- **Internal management and implementation at MRC Secretariat:** MRC requires a sufficiently qualified staff to manage and implement the activities instructed by this Strategy to support Member States. With the new Structure, MRC allows to have only one fixed-term professional staff which requires multiple skills, knowledge and experiences for drought analysis and advanced technology.
- **Technology transfer to NMCs and Line Agencies:** MRC needs to build its own capacity at Secretariat level before the technology can be transferred to Riparian Countries.
- **Funding:** Funding is the final and most important issue to be considered. In case drought activities are managed and operated under the RFMMC, funding might not be the issue. After this Strategy being formulated, earmarked fund JAIF will no longer be available from Japan to support drought activates anymore unless new phase of funding is submitted to the donors and gets approval before end of 2018.

## 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 5-year project document, the MRC standard mechanism of monitoring data collection, documentation, and reporting will be applied, and the following documents will be produced:

- Inception report with Project Implementation Plan (PIP);
- Annual work plans;
- Bi-annual progress reports at the project level;
- Annual progress report at the project level; and
- Technical reports at the MRC level.

The DM Team will produce a detailed project implementation plan (PIP) and a detailed budget, and perform the recruitment for all key positions of the project. The detailed implementation plan will specify the sequential/parallel steps for project implementation. An annual work plan will be prepared for each calendar year (2019-2023) in accordance with MRCS procedures for advancement of regional and transboundary cooperation.

In principle the monitoring and evaluation on the progress of the project implementation in 2019-2023 will be performed through the following activities:

- (i) Six month performance review:** Lessons learned and recommendations made during the first quarter performance review will be reported in a bi-annual report to project management as part of the six month performance review. The performance review will evaluate the process of the component with respect to the principles of transparency, stakeholder participation and contestability with subsequent sharing of the resulting reports with those who are involved. The common MRC-wide format will be used and the performance review results will be recorded on the MRC PMS database.
- (ii) Annual performance review:** The annual performance review is conducted with a greater degree of independence for the review team than the bi-annual review. The results will be available for development partners' evaluation purposes. All outcomes from project components will be evaluated and commented on for improved implementation.
- (iii) Mid-term and Final Independent Evaluation:** The final independent evaluation is expected to be carried out upon the completion of the component. At the request of the Donors, a mid-term review may be produced. The relevance, effectiveness, efficiency, and sustainability of the project will be evaluated. Lessons learned, as well as recommendations made, will allow for future project improvement and development. The results of this final independent evaluation of the project will be officially recorded in the MRC database system and the executive summary documents will be made available to the public online through the MRC website.

MRC will be responsible for budget management. The CEO is responsible on behalf of the MRC Secretariat for the MRC Joint Committee and MRC Council. DMT will prepare an annual work plan including the disbursement plan. The annual work plan will be approved by the MRC Council. The

DMT Manager will carry out budget planning for the project. All expenses and financial activities will be reviewed and assessed by the MRCS Finance and Administration Section (FAS). The budget statement will be reviewed every 6 months and addressed in the bi-annual progress report. The bi-annual reports will be submitted to the donors.

MRC will audit out projects and programmes annually. The audit will cover budget planning, procurement, administration, financial reporting, accounting documents and statements of transfer/disbursements.

## 5. ANNEX

### Document History

No.	Task	Status
<b>Inception Phase</b>		
1	Concept note	Submitted to The Task Force in Sept 2017 in VTE
2	First draft V1 of DMS 2019-2023	05 December 2017
<b>Consultation Phase</b>		
3	First draft V1 of DMS 2019-2023	Discussed on 12 Dec 2017 in Siem Reap, Cambodia
4	First draft V1.2 of DMS 2019-2023	Discussed with Lao PDR on February 2018 in Thalat
5		

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