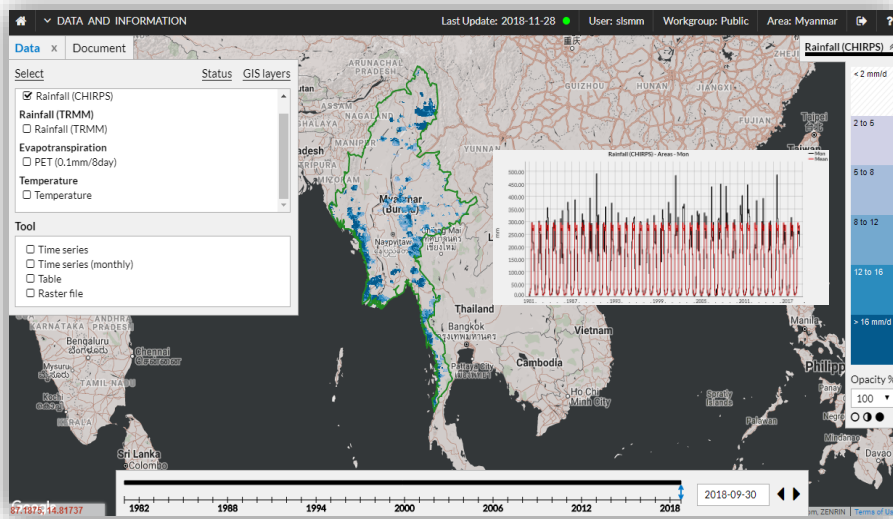


Strengthened drought and flood management through improved science-based information availability and management in Myanmar

Deliverable 3 (activity 1.3) Technology specifications and methodology for validation



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Approved by

28-01-2019

X 

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Strengthened drought and flood management through improved science-based information availability and management in Myanmar

Deliverable 3 (activity 1.3) Technology specifications and methodology for validation

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EXECUTIVE SUMMARY

Myanmar requested technical assistance from the Climate Technology Centre & Network (CTCN) to strengthen water management and increase adaptation to climate variability and climate change, using a web-based portal. The Green Climate Fund (GCF) Readiness and preparatory support funding was allocated to the request and the CTCN established an agreement for cooperation with DHI on the 13th July 2018, for the implementation of Response Plan (CTCN reference number: 2016000035) entitled 'Strengthened drought and flood management through improved science-based information availability and management'. The technical assistance kicked off the 13th of September, running until the 30th of June 2019.

The main outcome and objectives of the technical assistance are 1) to develop a web portal for Myanmar with state of the art remote sensing data and information, tools and reporting abilities; 2) to strengthen the basis for informed flood and drought management action; and 3) to enable stakeholders to use satellite data to support the existing ground station data for climate change adaptation measures.

Other outcomes are: 4) the testing and validation of data using two well documented locations in Myanmar; 5) the building of a strong interconnected user community; and 6) training of local end-users.

It is intended that outputs from the assistance contribute directly to the design of a future project proposal to the GCF.

To carry out this technical assistance, DHI is working together with the Myanmar Institute for Integrated Development (MIID), and as a regional expert the Hydro and Agro Informatics Institute (HAII) of Thailand. The Environmental Conservation Department (ECD) of the Ministry of Natural Resources and Environmental Conservation (MONREC) is the CTCN National Designated Entity (NDE) and is also the GCF National Designated Authority (NDA).

The portal is already deployed (www.flooddroughtmonitor.com). During the technical assistance it will be refined based on stakeholder input. It will be running for a period of five years using DHI's server in Denmark. DHI is committed to keep the portal running and technology updated, fix any bugs that might arise, and maintain the system for the next 5 years at no cost for ECD and the stakeholders and the use of the platform in DHI's server will be free for the institutions in Myanmar for 5 years.

Back-to-back with each of the technical training sessions DHI will carry out a one-day workshop to guide the ECD and stakeholders in Myanmar on planning for a full scale GCF proposal including hosting the platform developed during this technical assistance in a server in Myanmar in the long-term. DHI will support the stakeholders in Myanmar to prepare a concept note for a full scale GCF project proposal ensuring that the technicalities for hosting the server for the platform in Myanmar after the initial period of 5 years will be properly addressed in the full GCF project proposal.

This report is the last written deliverable of Activity 1 containing the technical specifications of the portal and the methodology for validation. It is informed by the round of bilateral meetings with stakeholders followed by the first national workshop held in Naypyitaw on the 4th and 5th of December 2018.

The contents of the report include the aspects listed as follows:

- Portal configuration and user registration; GIS based and workgroup workflow logic;

- Technical description and specifications of the portal applications, namely: Issue Analysis; Water Indicator; Data and information; and, Reporting tool;
- Methodology for the validation of the portal datasets for remote sensing rainfall, flash flood potential index indicator and drought indicators;
- Testing of the portal will be done through a workshop and remotely via weekly interaction with the stakeholders around information sheets (infosheets) prepared by the project team on key datasets and their applications.

Finally, the work plan for Activities 2 and 3 is presented, including proposed dates for the next training sessions.

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ACCRONYMS & ABBREVIATIONS

ASCAT	Advanced SCATterometer Surface Soil Moisture
ASI	Agricultural Stress Index
CCA	Causal Chain Analysis
CFS	Climate Forecast System
CGLS	Copernicus Global Land Service
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
COP	Conference of Parties
CORDEX	Coordinated Regional Climate Downscaling Experiment
CP	Climate of the Past
CTCN	Climate Technology Centre & Network
DHI	http://www.dhigroup.com/
DSS	Decision Support System
ECD	Environmental Conservation Department
EDI	Effective Drought Index
GCF	Green Climate Fund
GPM	Global Precipitation Measurement
HAI	Hydro and Agro Informatics Institute
JAXA	Japanese Aerospace Exploration Agency
LMCS	Land Monitoring Core Service
METOP	Meteorological operation satellite
MONREC	Ministry of Natural Resources and Environmental Conservation
MoU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NDA	National Designated Authority
NDE	National Designated Entity
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
RCM	Regional Climate Model
RCP	Radiative Concentration Pathway
SPI	Standardised Precipitation Index
SSM	Surface Soil Moisture
SVI	Standardised vegetation index
SWI	Soil Water Index
TRMM	Tropical Rainfall Measuring Mission
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention of Climate Change
UNIDO	United Nations Industrial Development Organization
VCI	Vegetation Condition Index
WCRP	World Climate Research Programme
WRIAM	Water Resource Issues Assessment Method

1 Introduction

1.1 Background

The Climate Technology Centre and Network (CTCN) received from the United Nations Framework Convention on Climate Change (UNFCCC) the mandate to promote the accelerated transfer of environmentally sound technologies for low carbon and climate resilient development at the request of developing countries (cf. COP decisions 1/CP.16, 2/CP.17, 14/CP.18, and 25/CP.19). CTCN is hosted by United Nations Environment Programme (UN Environment) and United Nations Industrial Development Organisation (UNIDO).

The CTCN provides technology solutions, capacity building and technical advice on policy, legal and regulatory frameworks tailored to the needs of individual countries based on specific country requests submitted by a National Designated Entity (NDE) of the respective country. In the case of Myanmar, the Environmental Conservation Department (ECD) of the Ministry of Environmental Conservation. NDEs facilitate support to their countries from the CTCN by serving as National Focal Point on CTCN activities, as well as managing the national submission process of technical assistance requests to the CTCN.

The 196 Parties to the United Nations Framework Convention on Climate Change selected a Consortium to work together with the CTCN Centre. UNEP-DHI Partnership – Centre on Water and Environment (DHI) is one of 12 independent organizations with expertise in climate technologies called ‘CTCN Consortium Partners’.

Myanmar requested support from the CTCN to strengthen water management and increase adaptation to climate variability and climate change, through the use of a web-based portal. The objective of the portal is to support the work of several national and subnational levels government ministries and agencies with a strong direct interest in water and its use as part of their work.

The Green Climate Fund (GCF) Readiness and preparatory support funding was allocated to the aforementioned request and the CTCN established an agreement for cooperation with DHI on the 13th July 2018, for the implementation of the Response Plan of the technical assistance with reference number 2016000035 entitled ‘Strengthened drought and flood management through improved science-based information availability and management’ in the framework of the approved project: Joint UNEP-UNIDO Programme to host and manage the CTCN.

This agreement is consistent with the Memorandum of Understanding (MoU) effective on 14 October 2013 between UN Environment and DHI. To carry out this technical assistance, DHI is working together with the Myanmar Institute for Integrated Development (MIID), and as a regional expert the Hydro and Agro Informatics Institute (HAII) of Thailand. The ECD is the CTCN NDE and is also the GCF National Designated Authority (NDA).

1.2 Objectives

The main objectives and outcomes of the technical assistance are:

- A web portal for Myanmar with state of the art remote sensing data and information, tools and reporting abilities; to strengthen the basis for informed flood and drought management action; to enable the

stakeholders to use satellite data to support the existing ground station data for climate change adaptation measures;

- Testing and validation with two use cases to be selected;
- Strong and interconnected user community;
- Training and capacity building workshops on the use of the tool and the development of a full GCF proposal.

As the CTCN network partner implementing the technical assistance DHI builds on the work done during the “Flood and drought management tools” project (GEF and UNEP 2014-2018) which produced a platform, data processing routines, and developed tools for flood and drought assessments (for more information on the project please visit the project homepage at <http://fdmt.iwlearn.org/en>). With the IT infrastructure in place, the technical assistance can further focus on its adaptation to the Myanmar study area, data validation, workshops and training. The portal will be running hosted by DHI’s servers for a period of three to five years.

It is intended that outputs from the assistance contribute directly to the design of a future project proposal to the GCF to strengthen effective climate finance planning and investment decision making for flood and drought management and to include the transfer of the drought and flood management portal’s server to Myanmar after the initial 5 years.

The beneficiaries of the project outcomes, are decision makers, planners, managers at the government level as well as the academic community, involved in management of floods, droughts, water resources, climate change adaptation and research.

2 Technical specifications

The following subchapters present the technical specifications of the web portal with data and tools delivered as part of the technical assistance. The introductory subchapter introduces the web portal, already introduced to stakeholders during **Activity 1.2 First National Workshop**. The subchapters that follow the introduction, list and present the specifications of the technical components, namely:

- Issue Analysis;
- Water Indicator;
- Data and information; and,
- Reporting tool.

2.1 Portal configuration and user registration

The web portal titled **Myanmar Flood & Drought Portal**, constitutes the platform provided by the technical assistance used to deliver embedded applications, namely:

- Issue Analysis – used to assist in the identification, understanding and prioritizing key environmental issues;
- Water Indicator – consists of a vast library of different indicators setting up stakeholders on the building of frameworks to monitor and evaluate the key issues identified;
- Data and Information – application providing free access to near real time data and information of relevance for the CTCN assistance;
- Reporting Tool – application to support dissemination of reports or bulletins to stakeholders.

The look and feel of the web portal deployed is intuitive, user friendly and previous projects have been very well received according to our own experience pilot areas.¹ Our focus is on adequate customization of the data in the portal, and together with the ECD and stakeholders, decide on the final detailed aspects such as logos, title, homepage introductory and explanatory texts and reporting templates. Timely input from stakeholders will determine the depth of customization reached by assistance-end.

The backend of the web portal contains the programs developed for each tool and the following data processing workflow:

1. Data download
 - a) Data is downloaded from the source server
 - b) Data is downloaded using an empty string as start and end date
 - c) Entire data series is downloaded the first time
 - d) Only new data is downloaded during the operational use
2. Data processing
 - a) Downloaded data is converted to netcdf² format
 - b) Data is saved in a time varying netcdf file

¹ DHI has been implementing a GEF funded project between 2014 and 2018, for the technical development of a web-based Decision Support System (DSS) and the methodologies and tool based on well-tested and proven technology developed by DHI. The overall objective of the web based DSS is to facilitate the inclusion of information about floods, droughts and future scenarios water resources planning.

² NetCDF (Network Common Data Form) is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. For more check <https://en.wikipedia.org/wiki/NetCDF>

- c) Downloaded data is cropped to the user extent
- 3. Data statistics
 - a) Statistic files for the data set are calculated
 - b) Statistic files are updated every time the data is updated
- 4. Calculation of indices and indicators
 - a) Indices and indicators calculated based on the updated data and the calculated statistics following their defined equations.

User registration takes place from the Login functionality. After signing up, the user receives an email confirming the request. Once the request has been processed and access granted, a second email is received.

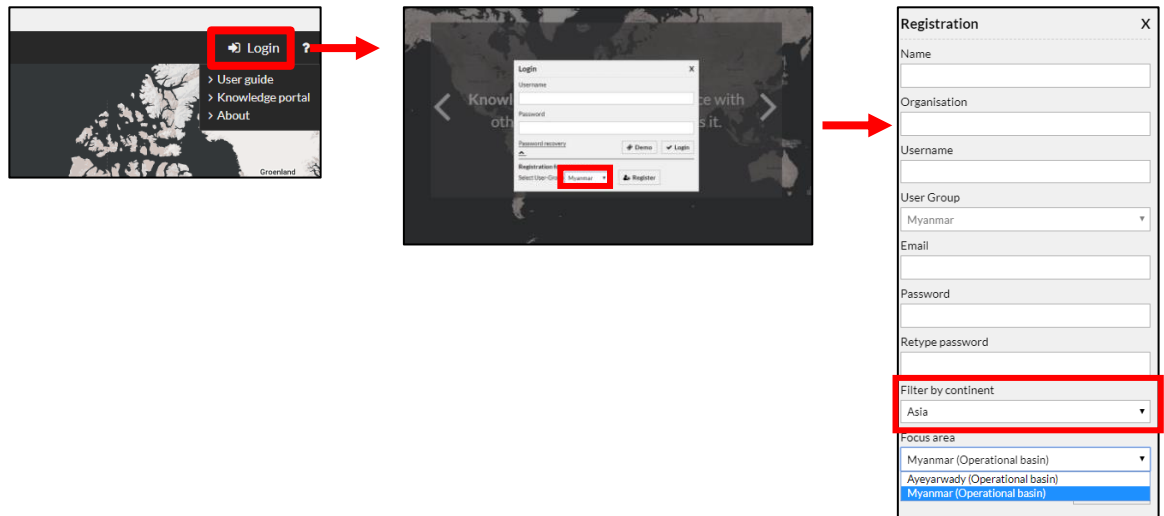


Figure 2.1 Illustration of the user registration process.

All users are linked to the Myanmar area, and the Ayeyarwady basin area. Data and information is restricted to the boundary: the national borders or the basin delineation.

2.2 GIS based configuration

The portal has two area configurations based on two polygon shapefiles: the **Myanmar** national area, and the **Ayeyarwady** river basin area. All data and information are made available based on these two boundaries (see green polygons in Figure 2.2 below).

Within these boundaries, data can be accessed through two different overall methods: points and areas. Point data can be viewed for predefined points, or for a user-selected point. Area weighted data is available for the whole focus area, Myanmar and Ayeyarwady, and two more sublevels.

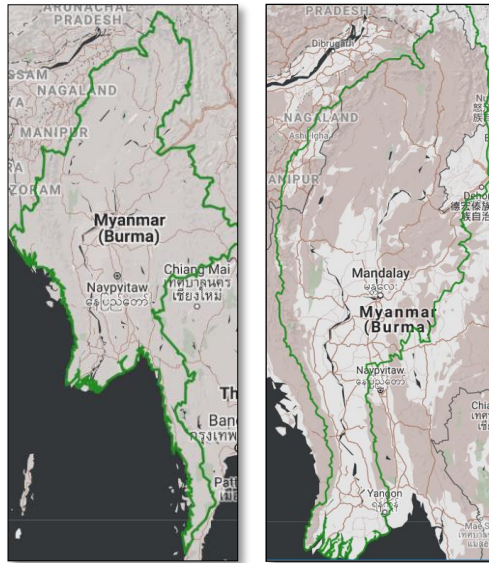


Figure 2.2 Shapefiles of the two areas available to users within the Data and Information application. To the left is the Myanmar area and to right the Ayeyarwady basin area.

In the case of “Myanmar”, the next level is **States/Regions** of Myanmar, followed by the **Districts**; the areas are predefined and cannot be edited by the user. The predefined points correspond to the location of major cities. The areas, subareas, and points for Myanmar can be seen in Figure 2.3 with polygons and points in blue.

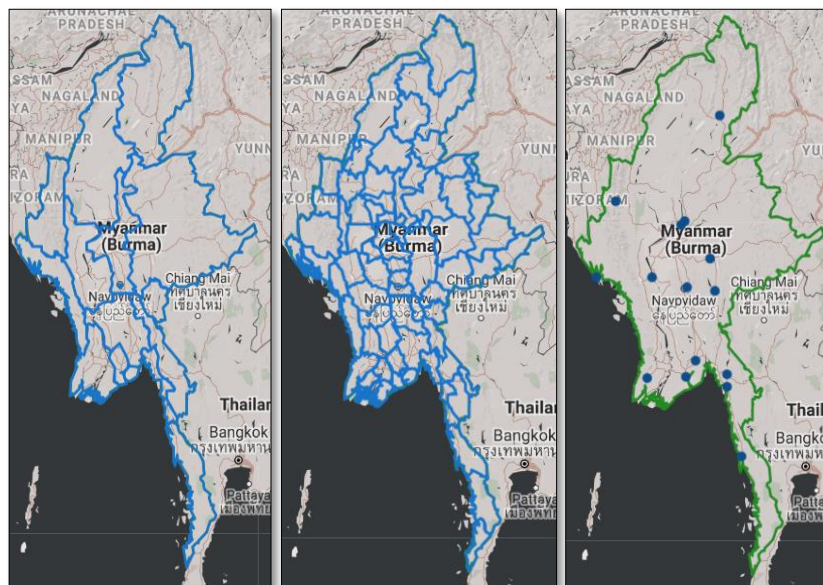


Figure 2.3 Area sublevels polygons and points

For the Ayeyarwady basin area, there are only two options loaded currently, the entire focus area shown in Figure 2.2, and one sublevel corresponding to **sub-catchments** within the basin. There are no station data points as of the time of submission of this report, however the team is expected to obtain points based on suggestions from the stakeholders. The subareas for Ayeyarwady are shown in Figure 2.4.



Figure 2.4 Area sublevel polygons for the Ayeyarwady area.

2.3 Workgroup configuration

Workgroups are used for sharing information between users. When users set up an account, by default they are added to the “Public” workgroup and a “Private” workgroup is automatically created for them. Workgroups are linked to the **Area**.

Users can also create their own workgroups, and they will be creators and group administrators. This means they are the only ones able to add or remove members to the group they created.

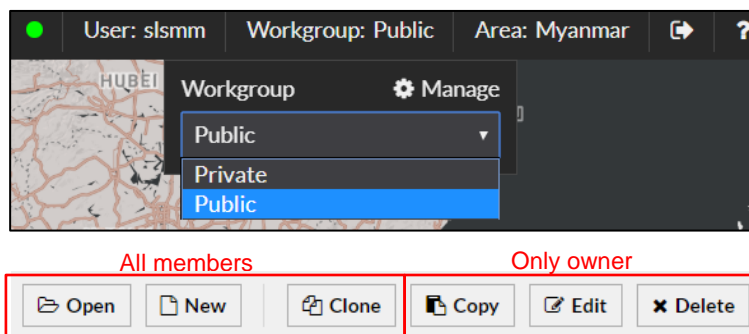


Figure 2.5 Illustration indicating where to create and manage workgroups.

User rights follow this logic below:

- All members can view all information within a workgroup
- A member cannot edit/delete information made by other members
- All members can clone information and then edit/ delete

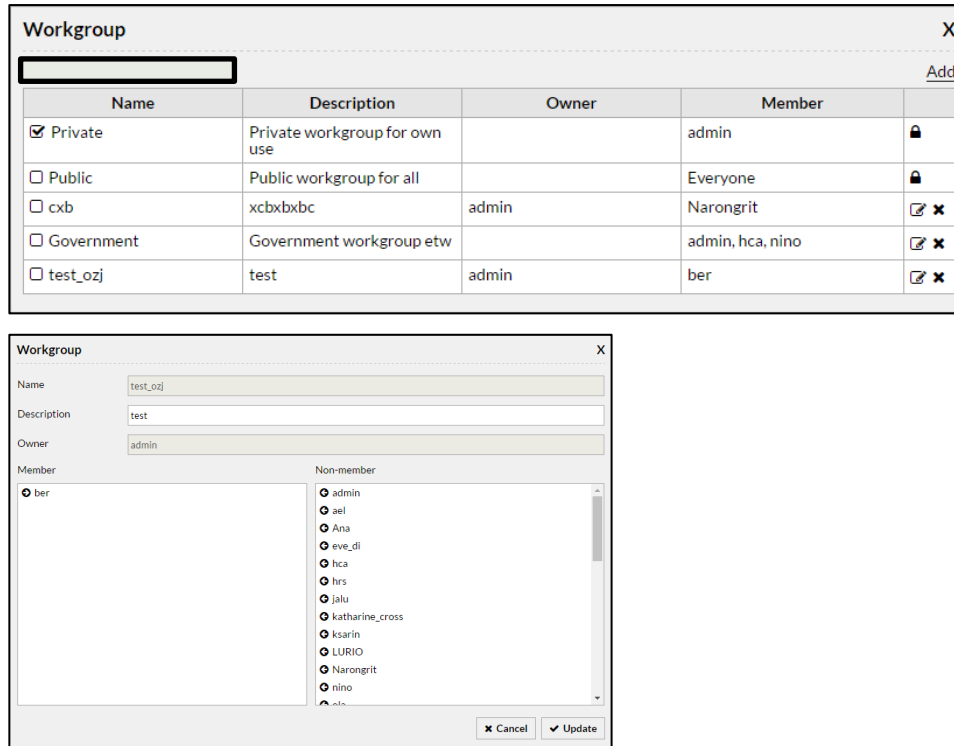


Figure 2.6 Portal areas related to workgroup management

2.4 Issue analysis

This subchapter describes the Issue Analysis application. This is a tool that helps the user quantify and analyse the impacts of a given environmental issue by identifying the underlying causes based on a Causal Chain Analysis (CCA) principle. Additionally, the severity of each impact is assessed according to the Water Resource Issues Assessment Method (WRIAM).

Any number of impacts can be added for an issue. The tool thereby gives a clear overview of

- a) the impacts related to an issue
- b) the causes and severity of each impact

This helps stakeholders and decision makers identify the causes behind the impacts as well as the underlying and root causes, thus enabling the planning to focus on the deeper causes rather than just solving the obvious problem, which may be only a temporary relief.

Quantifying the severity of the impacts also enables stakeholders to prioritise the most serious problems. This increases the efficiency of the planning process and may lead to more effective measures.

The following sections describe CCA and WRIAM in more detail, which also explains how the principles are applied in the portal.

2.4.1 Background to Causal Chain Analysis

CCA is often also called Root Cause Analysis as the approach is to identify underlying and root causes. It is closely related to systems thinking and the DPSIR³ approach.

At its most basic, a causal chain is an ordered sequence of events linking the causes of a problem with its effects, see Figure 2.7. At each link in the chain, it is investigated why this occurs, thus leading to the cause. This means that instead of just looking directly at the cause of the impact, the underlying causes are also considered, which may be more effective as a means to solving the problem. It may also identify that it is not feasible to solve the problem if the root causes are overwhelming, thus enabling decision makers to focus their efforts differently.

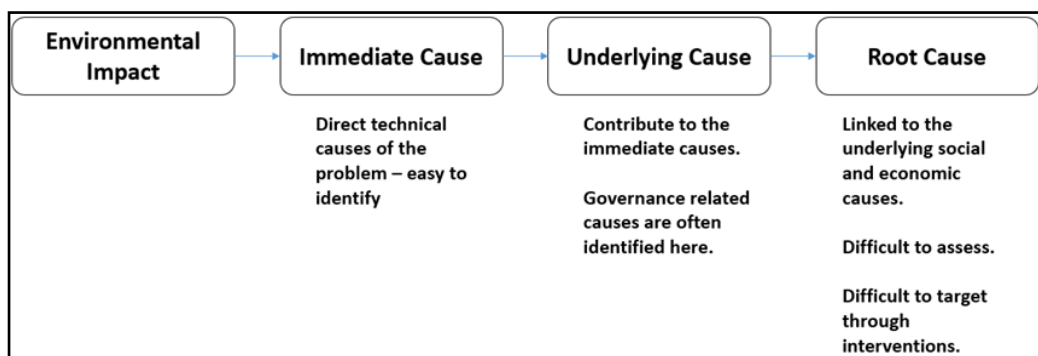


Figure 2.7 Main components of a Causal Chain Analysis.

The following sections explain the different levels of causes in more detail.

2.4.1.1 Immediate Cause

Immediate or **technical causes** (sometimes known as primary causes) are usually the direct technical causes of the problem. They are predominantly tangible (e.g. enhanced nutrient inputs), and with distinct areas of impact (with the exception of causes such as atmospheric deposition or climate change).

Immediate causes, usually being technical in nature are the most straightforward to quantify, prioritise and geographically locate using maps.

2.4.1.2 Underlying Cause

Underlying causes are those that contribute to the immediate causes. They can broadly be defined as underlying resource uses and practices, and their related social and economic causes. Governance related causes are often identified here.

The underlying causes will tend to fall into areas such as:

- Land use (reclamation/drainage operations, deforestation, agriculture etc.)
- Damaging or unsustainable practices (intensive livestock production, lack of treatment technology etc.)
- Uses of water (diversion, storage etc.)
- Lack of investment, operation and maintenance

³ DPSIR is a causal framework that describes the interactions between society and the environment. It works with the terms Driving forces, Pressures, States, Impacts, and Responses (<https://en.wikipedia.org/wiki/DPSIR>)

- Poor awareness or lack of education
- Governance failures, legislation, regulation or enforcement

2.4.1.3 Root Cause

Root causes are linked to the underlying social and economic causes and sectoral pressures, but they are often related to fundamental aspects of macro-economy, demography, consumption patterns, environmental values, and access to information and democratic processes. Many of these may be beyond the scope of project interventions, but it is important to document them as they may determine whether measures to reduce the impact of environmental issue succeed or not, as discussed above.

Root causes can be divided into the following categories:

- Climate change
- Population pressure and demographic change
- Poverty, wealth and inequality
- National, regional and international governance issues
- Education and formulation of values
- Social change and development biases
- Development models and national macro-economic policies

2.4.2 Background to WRIAM

The assessment of the impact of an environmental issue will be based on a subjective judgement. WRIAM has been developed as an attempt to quantify such a subjective assessment by defining some assessment criteria to which different values can be assigned. The output of the method is a single value defining the severity of the impact, which can then easily be compared with other issues and re-assessed in the future if the situation changes.

The method utilises a standard definition of some important assessment criteria. For each of these criteria, semi-quantitative values can be assigned, with the aim of giving a precise and independent score for each issue.

The assessment criteria fall into two groups:

- (A) Criteria related to the importance of the issue or effect, and which can individually change the score obtained considerably;
- (B) Criteria that are of value to the given situation, but individually have a lesser effect on the score obtained.

For group A, the overall score is found by multiplying the scores allocated to each criterion. The principle of the multiplication is very important since it ensures that the weight of each score has a significant impact on the result, whereas a summation of the scores could give identical results for groups of different scores.

Group A contains the following components:

- **Extent of the impact (4 to 0):** Transboundary, national, regional, local to no importance

- **Seriousness of the impact (3 to 0):** Major change, significant change, negative change to no change

For group B, the scoring system consists of adding the scores allotted to each criterion. This ensures that an individual score cannot influence the overall result very much. On the other hand, the summation ensures that the collective importance of all scores in group B is taken fully into account.

Group B contains the following components:

- **Permanence (3 to 1):** Permanent, temporary to no change
- **Irreversibility (3 to 1):** Irreversible, reversible to no change
- **Cumulative character (3 to 1):** Strong, moderate to light

The overall score (OS) for a given issue is calculated by multiplying the result of group A by the result of group B.

A₁ and A₂ represent individual criteria scores for group A;

B₁, B₂ and B₃ represent individual criteria scores for group B;

For each issue the following calculation is made:

$$A_1 \times A_2 = AT$$

$$B_1 + B_2 + B_3 = BT$$

$$AT \times BT = OS$$

In the portal, the overall score is presented along with the assessment associated with this score, see Table 2.1.

Table 2.1 The scores and assessments used in issue analysis

Score	Assessment
0	No importance
1-9	Slight negative impact
10-18	Moderate negative impact
19-35	Negative impact
36-71	Significant negative
72-108	Major negative impact

2.5 Water Indicator

This application holds an extensive list of water-related indicators, including descriptions of the indicators and how to interpret them. The application can be linked to the issue analysis, as issues from that application can be loaded here. Indicators can then be assigned to the impacts and causes identified for the issue.

The indicators can be used to track the state of water resources. Once a relevant indicator has been identified, tracking this can give information about the state.

As an example, a simple and often used indicator in daily life is body temperature to monitor health. Once this indicator has been identified, it can be used for several purposes:

- 1) To identify if there is a problem. The temperature shows whether there is fever or not.
- 2) To know what to do. Depending on whether there is a fever or not, the patient can choose to go to the hospital, take medicine, or do nothing.
- 3) To track changes. If the patient's temperature starts rising, it may be necessary to do something.
- 4) To track the effect of treatment. The patient starts taking medicine. If the temperature does not fall, other steps should be considered.

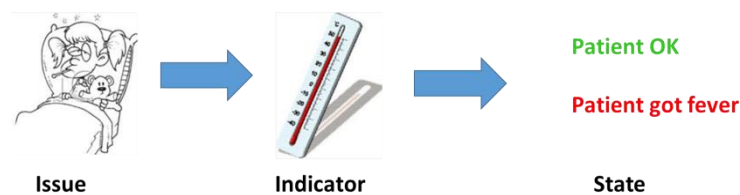


Figure 2.8 Illustration of an indicator example.

For water resources, indicators can be used in the same way. By looking at indicators for a water system, it can be determined whether there is a problem, and by tracking the change in indicators, it can be seen whether a bad system is getting worse. A healthy water system may be tracked as well as this will quickly give information if conditions deteriorate. Finally, if an environmental issue is being treated, indicators can be used to see if the treatment has the desired effect – and can at the same time be used to ensure that other negative impacts are not appearing instead.

The indicator gives an easy way to assess the state of a system. Returning to the fever example, it is hard to measure “fever” or “not fever”, but temperature can be easily measured, and it is known what range this should be in in order to *indicate* “fever” or “not fever”. In the same way, a water indicator should be relative easy to measure and it should be clear when it indicates a state of bad or good (or getting better or worse).

Although indicators are critical to understand what is happening in a system (river basin, water supply system, etc), there are a large number (literally thousands) and information is often not complete. Furthermore, ideal indicators may not be practical; the feasibility of using certain indicators can be constrained by the availability of data and financial and human resources.

A useful indicator should be:

- relevant for monitoring the state or the pressure of the issue
- easy to interpret

- able to give information on the current status and the status in relation to the historical change
- based on available data or information

The more clearly defined an indicator is, the less room there will be for later confusion or complications.

The Water Indicator application provides the following support:

- Assists user in selecting relevant indicators based on a specific issue
- Used as a learning tool for basin or catchment organisations/other users
- Provides a starting point through a default indicator framework that can be adjusted and complemented to match user needs (see example in Figure 2.9)
- Provides an online tool for stakeholders to share their indicator frameworks with others to allow for consistency. This is helpful if there are more people involved in measuring indicators or if the same indicators are measured in several different locations.
- Used as a tool for storing indicator information to support the design of decision support systems (DSS).

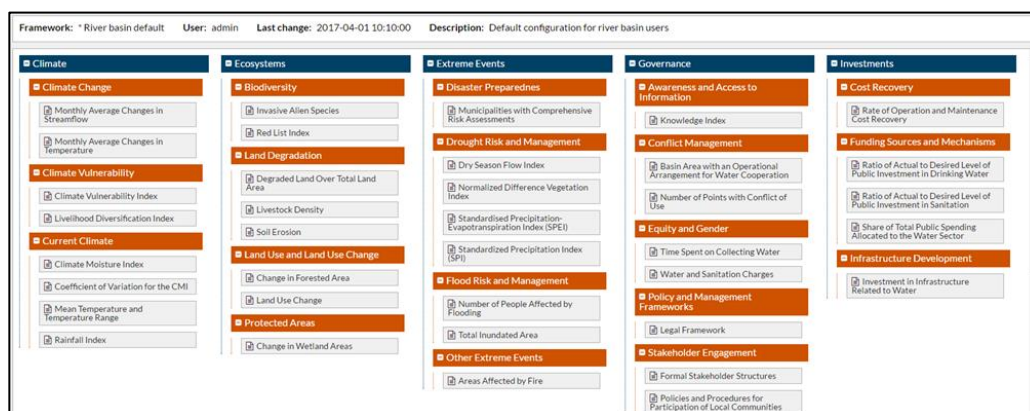


Figure 2.9 Example of default framework for river basin planning.

2.6 Data and information

The purpose of the Data and Information application is to provide spatially distributed, water-related data for Myanmar in near real time. The application holds all the data that is included in the portal. This is mainly data based on remote sensing and several products derived from remote sensing-data sets. Remote sensing data is very useful as it has a large spatial coverage and especially in areas with lack of station-based data, the remote sensing data can be essential for verifying model results or creating a water balance. The web portal ensures that any user will always have a basic data set available for monitoring and for planning activities related to water resources or drought management. The data can be visualised directly in the portal or be downloaded for further processing.

The original datasets are obtained from a number of different data sources, all available in near real time and free. The data is processed to generate different climate variables; climate forecast data, climate change data, drought related indices and flood related data, having in common the following:

- Spatially distributed data (raster data visible on a map)

- Temporal resolution maintained in near real time (data is updated regularly)
- Short time delay (data is published with a maximum delay of 5 days)
- Available for download in commonly used formats (netcdf file)

The following sections contain a description some of the most important datasets from our experience including origin and spatial and temporal resolution. The table below matches certain water related activities carried out by the stakeholders of this technical assistance, with the datasets that can be used to support them (Table 2.2).

Table 2.2 Data and information to support the activities of stakeholders.

Activities	Dataset
Long term planning	Climate change projections
Short term water resources management	Near real time based on satellite or a combination of satellite and ground stations Rainfall deviation (30 days) Land surface temperature Ensemble forecast with several months lead time. Standardised Precipitation index (SPI)
Management of agricultural climate change impacts	Soil Water Index (SWI) SWI deviation SWI percentile SWI percentile change
Land degradation monitoring	Normalized Difference Vegetation Index (NDVI) NDVI anomaly NDVI deviation Vegetation condition index (VCI) Standardised vegetation index (SVI)
Wetland monitoring	Water body data set SWI can be used to monitor the state of wetland NDVI can be used to monitor vegetation changes related to the state of wetlands
Energy production and planning	Climatology Ensemble forecast with several months lead time Climate change data

2.6.1 Rainfall related data

2.6.1.1 TRMM data

The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between the National Aeronautics and Space Administration (NASA) and the Japanese Aerospace Exploration Agency (JAXA). It is the first Earth Science mission dedicated to studying tropical and subtropical rainfall and monitors rainfall using microwave and visible infrared sensors, including the first space-borne rain radar. Using a low-altitude orbit (350km), TRMM is complemented with state-of-the-art instruments providing highly accurate measurements.

TRMM is especially useful in cases where consistency in precipitation data is required over many years, as is the case for hydrological design, flood risk assessment and water resources management. Table 2.3 holds the basic information about this dataset. Based on TRMM rainfall dataset several indicators are generated, which are presented in the following Table 2.4 to Table 2.7.

Table 2.3 Basic information of the TRMM dataset

Spatial extent	From 50 degrees north to 50 degrees south of the equator
Spatial and temporal resolution	Spatial resolution: 0.25 degree Temporal resolution: resampled to daily rainfall product from 2000 to present
Reference	http://trmm.gsfc.nasa.gov
Data requirements and calculation	The original 3-hourly real-time rainfall data in mm/h from NASA is resampled to a daily product in mm/day. This daily product is then downloaded from the TRMM data provider and disseminated via the portal. Negative values are removed during the processing.
Update Frequency	Daily
Related indices	SPI 1-month, SPI 3-month, etc
Data source	TRMM_3B42RT_Daily

The following pages contain

Table 2.4 Description of the TRMM based rainfall deviation dataset.

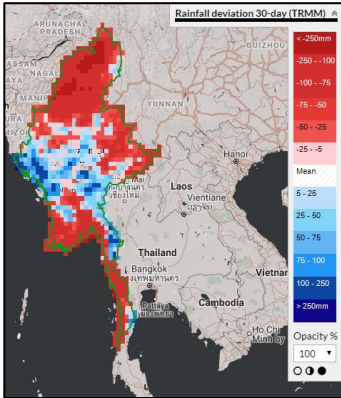
Title	Rainfall deviation (30 days)
Description	Deviation of accumulated rainfall from the long term mean within the last 30 days. Calculated based on the TRMM rainfall where the long-term mean is based on TRMM data since 2000.
INDICATOR USAGE	
Index interpretation	Used to locate areas with rainfall surplus or deficit within the last 30 days.
Spatial extent	As TRMM data
Spatial and temporal resolution	Spatial resolution: 0.25 degree Temporal resolution: Updated daily as TRMM rainfall gets updated.
Reference	Processed based on TRMM data
Example of usage	<p>Illustrates the how the accumulated rainfall deviates from the mean accumulation within a given area. Used to locate areas with rainfall surplus or deficit across the last 30 days.</p> 
INDICATOR CALCULATION	
Data requirements and calculation	Based on daily TRMM rainfall and calculated as $\sum \text{TRMM} - \sum \text{TRMM}_{\text{mean}}$ for the last 30 days
Update Frequency	Updated daily in the web portal
Related indices	-
Data source	Based on TRMM data

Table 2.5 Description of the Effective Drought Index dataset.

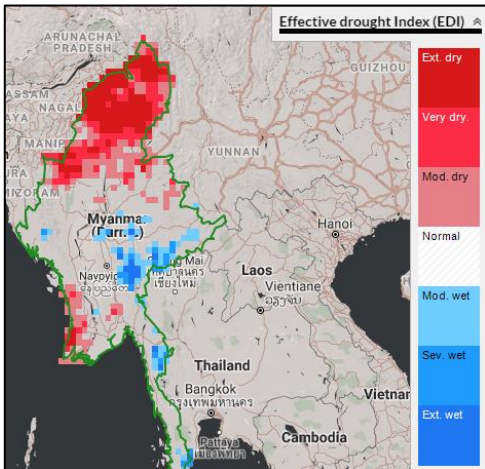
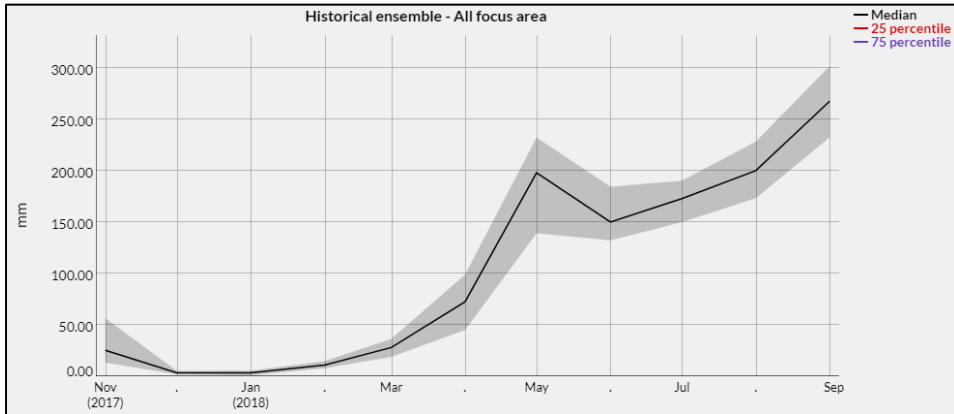
Title	Effective Drought Index (EDI)								
Description	The Effective Drought Index (EDI) was developed by Byun and Wilhite (1999) as a measure that considers daily water accumulation with a weighting function for time passage. More information is available via http://om.ciheam.org/om/pdf/a95/00801330.pdf								
INDICATOR USAGE									
Index interpretation	Used to locate areas that are very dry to very wet as a measure of drought. The "drought range" of the EDI indicated in the following table. <table border="1" data-bbox="646 546 1174 696" style="margin-left: auto; margin-right: auto;"> <tr> <td>-2.0</td> <td>Extreme drought</td> </tr> <tr> <td>[-2.0, -1.5]</td> <td>Severe drought</td> </tr> <tr> <td>[-1.5, -1.0]</td> <td>Moderate drought</td> </tr> <tr> <td>[-1.0, 1.0]</td> <td>Near normal conditions</td> </tr> </table>	-2.0	Extreme drought	[-2.0, -1.5]	Severe drought	[-1.5, -1.0]	Moderate drought	[-1.0, 1.0]	Near normal conditions
-2.0	Extreme drought								
[-2.0, -1.5]	Severe drought								
[-1.5, -1.0]	Moderate drought								
[-1.0, 1.0]	Near normal conditions								
Spatial extent	As TRMM data								
Spatial and temporal resolution	Spatial resolution: 0.25 degree Temporal resolution: Updated daily as TRMM rainfall gets updated.								
Reference	Hi-Ryong Byun and Donald A. Wilhite, Objective Quantification of Drought Severity and Duration, 1999. http://journals.ametsoc.org/doi/full/10.1175/1520-0442%281999%29012%3C2747%3AQQODSA%3E2.0.CO%3B2								
Example of usage	Example of the EDI coverage for Myanmar: 								
INDICATOR CALCULATION									
Data requirements and calculation	Based on daily TRMM rainfall and calculated for the last 30 days as: $EDI = \text{Deviation}(PE) / \text{Std}(PE)$ <p>Here P_E is:</p> $P_{E_i} = \sum_{N=1}^D \left[\frac{\sum_{m=1}^N P_m}{N} \right]$								
Update Frequency	Daily								
Related indices	-								
Data source	Based on TRMM data								

Table 2.6 Description of the standardized Precipitation index.

Title	Standardised Precipitation index (SPI)														
Description	<p>The SPI is based on the probability of precipitation for any time scale. The probability of observed precipitation is then transformed into an index. It is being used in research or operational mode in more than 70 countries. More information is available via http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf</p>														
INDICATOR USAGE															
Index interpretation	<p>SPI is typically categorized using the following classification:</p> <table border="1" data-bbox="705 580 1121 837"> <tbody> <tr> <td>> 2.0</td> <td>Extremely wet</td> </tr> <tr> <td>1.5 to 2.0</td> <td>Very wet</td> </tr> <tr> <td>1.0 to 1.5</td> <td>Moderately wet</td> </tr> <tr> <td>-1.0 to 1.0</td> <td>Near normal</td> </tr> <tr> <td>-1.5 to -1.0</td> <td>Moderately dry</td> </tr> <tr> <td>-2.0 to -1.5</td> <td>Severely dry</td> </tr> <tr> <td>< -2</td> <td>Extremely dry</td> </tr> </tbody> </table> <p>A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude".</p> <p>Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI. However, it must be stressed that the SPI is not suitable for climate change analysis because temperature is not an input parameter.</p>	> 2.0	Extremely wet	1.5 to 2.0	Very wet	1.0 to 1.5	Moderately wet	-1.0 to 1.0	Near normal	-1.5 to -1.0	Moderately dry	-2.0 to -1.5	Severely dry	< -2	Extremely dry
> 2.0	Extremely wet														
1.5 to 2.0	Very wet														
1.0 to 1.5	Moderately wet														
-1.0 to 1.0	Near normal														
-1.5 to -1.0	Moderately dry														
-2.0 to -1.5	Severely dry														
< -2	Extremely dry														
Spatial extent	As TRMM data														
Spatial and temporal resolution	<p>Spatial resolution: 0.25 degree Temporal resolution: Updated daily as TRMM rainfall gets updated.</p>														
Reference	http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf														
Example of usage	<p>The following SPI products are available:</p> <ul style="list-style-type: none"> - SPI 1-month: the 1-month SPI provides a comparison of the precipitation over a specific 1-month period with the precipitation totals from the same period for all the years included in the historical record. 1-month SPI reflects relatively short-term conditions and its application can be related closely with short-term soil moisture and crop stress, especially during the growing season. - SPI 3-month: the 3-month SPI provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. - SPI 6-month: the 6-month SPI compares the precipitation for that 														

	period with the same 6-month period over the historical record. The 6-month SPI indicates medium-term trends in precipitation.
	INDICATOR CALCULATION
Data requirements and calculation	The original 3-hourly real-time rainfall data in mm/h from NASA is resampled to daily product in mm/day. Negative values are removed during the processing.
Update Frequency	Daily
Related indices	SPI 1-month, SPI 3-month, etc
Data source	TRMM 3B42RT

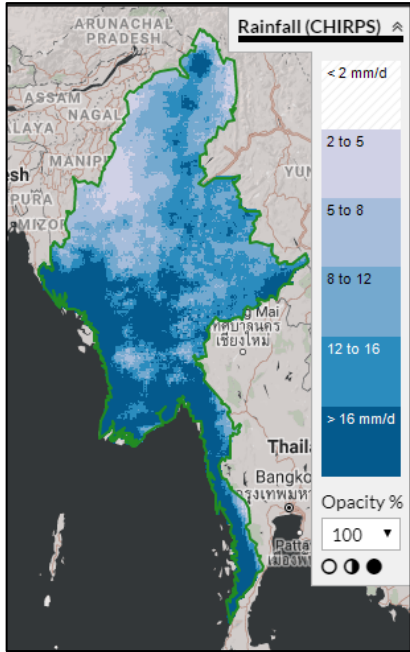
Table 2.7 Basic information about the climatology ensembles, which are based on TRMM data.

Title	Climatology or historical ensembles
Description	Climatology or historical ensembles is a way to generate ensembles based on the historical rainfall to be used as a “prediction” of how the future rainfall will evolve. Climatology is very useful if forecasted rainfall is not available or the skill of the forecasted rainfall is poor.
	INDICATOR USAGE
Index interpretation	Provides ensemble input of forecasted rainfall based on the historical observations.
Spatial extent	From 50 degrees north to 50 degrees south of the equator (similar to TRMM data)
Spatial and temporal resolution	Spatial resolution: 0.25 degree Temporal resolution: daily
Reference	TRMM data
Example of usage	Ensemble members are used as climate input for hydrological, water resource or crop models for evaluation of a future situation. These can also be used to produce statistical monthly envelope charts as shown below. 
	INDICATOR CALCULATION
Data requirements and calculation	Based on TRMM data from 2000 until today. Climatology is yearly time series of the historical TRMM rainfall.
Update Frequency	Daily
Related indices	SPI 1-month, SPI 3-month, etc. based on forecasted rainfall
Data source	TRMM data

2.6.1.2 CHIRPS data

CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) is a 30+ year quasi-global rainfall data set. It combines satellite imagery with a resolution of 0.05° with in-situ station data. The output is gridded rainfall time series which can be used for trend analysis and seasonal drought monitoring. Some basic information about this data set can be found in Table 2.8.

Table 2.8 Basic information about the CHIRPS dataset

Title	CHIRPS
Index interpretation	CHIRPS is mainly used for drought monitoring to produce rainfall maps, especially where surface data is sparse.
Spatial extent	Spanning 50°S-50°N (and all longitudes)
Spatial and temporal resolution	Spatial resolution: 0.05 degree Temporal resolution: daily rainfall product from 1981 to near-present
Source	http://chg.geog.ucsb.edu/data/chirps/
Example of usage	Drought early warning and environmental monitoring. The image shows a rainfall event in Myanmar on 20-08-2018. 
	INDICATOR CALCULATION
Data requirements and calculation	No calculation required
Update Frequency	Monthly
Related indices	None
Data source	http://chg.geog.ucsb.edu/data/chirps/

2.6.2 Medium range rainfall forecasts

There are two different medium range forecast datasets available in the portal. The next datasheets present their description.

Table 2.9 Dataset description of medium range forecast EGFS10.

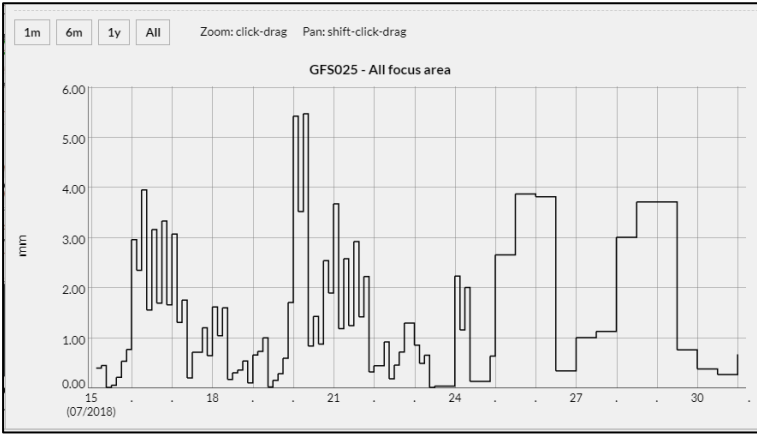
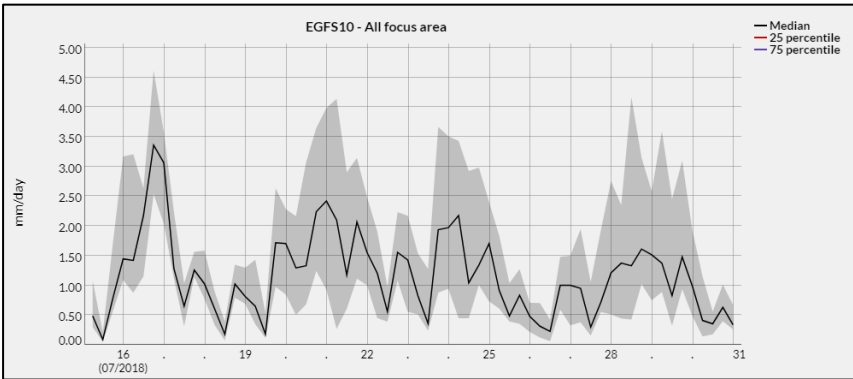
Title	GFS025
Description	A 16-day deterministic forecast of rainfall. From the NCEP Global Forecast Model. Has forecast every 3 hours for the next 10 days and 12-hour forecasts for days 10-16
	INDICATOR USAGE
Index interpretation	Gives a forecast of rainfall for the next 16 days at varying temporal resolution.
Spatial and temporal extent	Spatial extent: Global, longitude 0-360. Temporal extent: Next 16 days.
Spatial and temporal resolution	Spatial resolution: 0.25° Temporal resolution: 3-hourly for the next 10 days, 12-hourly for days 10-16.
Source	http://www.nco.ncep.noaa.gov/pmb/products/gfs/
Example of usage	Forecast starting 16 th of July 2018 for the entire focus area of Volta. 
	INDICATOR CALCULATION
Data requirements and calculation	Deterministic forecast based on a coupled model with atmosphere, ocean, land/soil, and sea ice components
Update Frequency	Daily
Related indices	None
Data source	http://www.nco.ncep.noaa.gov/pmb/products/gfs/

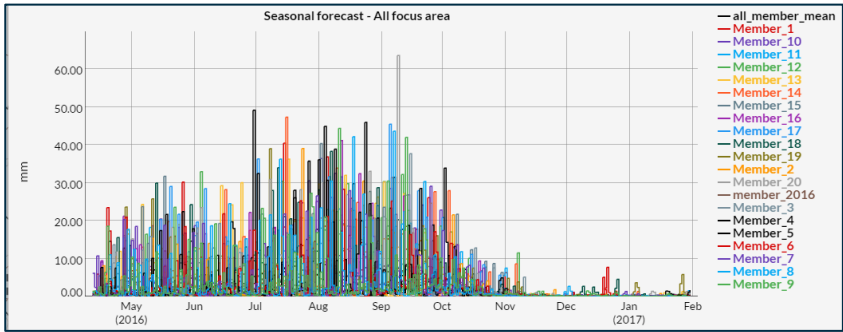
Table 2.10 Dataset description of medium range forecast EGFS10.

Title	EGFS10
Description	A 16-day probabilistic forecast of rainfall. From the NCEP Global Forecast Model. Has forecast every 6 hours for the next 16 days.
	INDICATOR USAGE
Index interpretation	Gives a forecast of rainfall for the next 16 days at varying temporal resolution.
Spatial and temporal extent	Spatial extent: Global, longitude 0-360. Temporal extent: Next 16 days.
Spatial and temporal resolution	Spatial resolution: 1.0° Temporal resolution: 6-hourly
Source	http://www.nco.ncep.noaa.gov/pmb/products/gfs/
Example of usage	Envelope plot of forecast from the 16 th of July 2018. 
	INDICATOR CALCULATION
Data requirements and calculation	Probabilistic forecast based on a coupled model with atmosphere, ocean, land/soil, and sea ice components
Update Frequency	Daily
Related indices	None
Data source	http://www.nco.ncep.noaa.gov/pmb/products/gfs/

2.6.3 Seasonal forecasts

The Climate Forecast System (CFS) version 2 is run by the Environmental Modelling Center at National Centers for Environmental Prediction (NCEP), National Oceanic and Atmospheric Administration (NOAA) and became operational in March 2011. It is a fully coupled model representing the interaction between the Earth's atmosphere, oceans, and land. The variables available include precipitation and surface temperature. The forecast data is made available in a form of an ensemble forecast with several months' lead time and provides ensemble input of forecasted rainfall.

Table 2.11 Basic information about seasonal forecasts.

Spatial extent	Global coverage (Longitude Range: 180W to 180E, and Latitude Range: 90S to 90N)
Spatial and temporal resolution	Spatial resolution: 1 degree Temporal resolution: daily
Reference	http://cfs.ncep.noaa.gov/
Example of usage	Ensemble members used as climate input for hydrological, water resource or crop models for evaluation of a future situation. 
Data requirements and calculation	The computation consists of construction of the 20-member ensemble forecast. The original product is resampled from 6-hourly to daily.
Update Frequency	Daily
Related indices	SPI 1-month, SPI 3-month, etc. based on forecasted rainfall
Data source	NCEP CFS v2

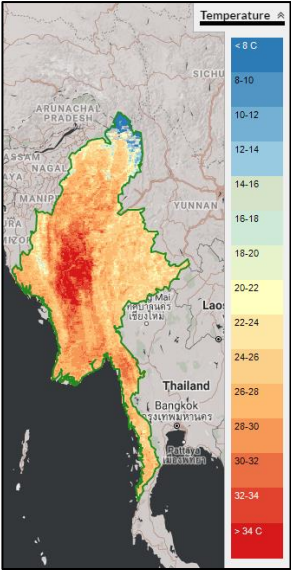
2.6.4 Temperature

The level-3 MODIS⁴ global Land Surface Temperature (LST) and Emissivity 8-day data (MOD11A2) is composed from the daily 1-kilometer LST product (MOD11A1) and stored on a 1-kilometer Sinusoidal grid as the average values of clear-sky LSTs during an 8-day period.⁵

Measurement by the satellite is based on a passive sensor, this means that **this is a cloud sensitive product** as others are within the portal. In particular, the temperature dataset, has a lot of gaps during rainy season due to the interference caused by the presence of clouds.

LST and especially the change in temperature over time is a valuable indicator for climate change and drought events. Basic information about this dataset is included in Table 2.12. The temperature condition index is described in Table 2.13.

Table 2.12 Basic information about the MODIS temperature data.

Spatial extent	Global coverage
Spatial and temporal resolution	Spatial resolution: 1 km but resampled to 5 km Temporal resolution: 8-daily product from 2000 to present
Reference	https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod11a2
Example of usage	Temperature itself is NOT an index but can be used to detect changes in the temperature pattern from year to year. 
Data requirements and calculation	Download of MOD11A2 1 km 8-day product. Data resampled to 5 km resolution using a simple mean of the grid cells.
Update Frequency	8-daily
Data source	MOD11A2

⁴ The Moderate Resolution Imaging Spectroradiometer

⁵ https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod11a2

Table 2.13 Basic information about the temperature condition index.

Title	Temperature condition index (TCI)
Description	TCI is estimated relative to the maximum and minimum temperatures and modified to reflect different vegetation responses to temperature.
	INDICATOR USAGE
Index interpretation	Used to determine stress on vegetation caused by temperatures and excessive wetness.
Spatial extent	Global coverage
Spatial and temporal resolution	Spatial resolution: 5 km Temporal resolution: 8-daily
Reference	Daytime land surface temperature based on the 1 km MOD11C2 product. https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod11c2
Example of usage	<p>Example of the TCI coverage over Myanmar:</p>
	INDICATOR CALCULATION
Data requirements and calculation	TCI is calculated as: $TCI = 100 \cdot \frac{T_{max} - T}{T_{max} - T_{min}}$
Update Frequency	8-daily
Related indices	-
Data source	MOD11C2

2.6.5 Vegetation related data

The Normalized Difference Vegetation Index (NDVI) is used as an index of vegetation health and density.

$$NDVI = \frac{\lambda_{NIR} - \lambda_{red}}{\lambda_{NIR} + \lambda_{red}}$$

where λ_{NIR} and λ_{red} are the reflectance in the near infrared and red bands, respectively.

MODIS vegetation indices are produced on 16-day intervals and at multiple spatial resolutions. NDVI is closely correlated to vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure, and can be used as a base data set for monitoring of crop and vegetation status.

Similarly to the temperature dataset, the measurement is based on a passive sensor, resulting in a **cloud sensitive product**. It varies between -1 and +1 and has a strong correlation with leaf area index and biomass. The vegetation conditions related to different NDVI values are shown in Table 2.14.

Table 2.14 The vegetation conditions related to different NDVI values.

NDVI values	Vegetation condition
0.1 to 0.7	Vegetated land
> 0.5	Dense vegetation
< 0.1	Near zero vegetation such as barren area, rock, sand or snow

NDVI itself does not reflect drought or non-drought conditions but can be used to detect change in vegetation cover from year to year which may be related to drought.

Table 2.15 Basic information about the NDVI dataset, based on MODIS measurements.

Spatial and temporal extent	Global coverage
Spatial and temporal resolution	Spatial resolution: from 5600 m to 250 m Temporal resolution: Updated every 16 days based on two daily passes. The value is based on the maximum value during the 16-day period (available from 2000 to present)
Reference	http://modis-land.gsfc.nasa.gov/vi.html and http://e4ftl01.cr.usgs.gov/MOLT/
Data requirements and calculation	Converted to netcdf format
Update Frequency	16-daily
Related indices	Vegetation based indices
Data source	Terra-MOD13C1 (5600 m)

The following Table 2.16 to Table 2.19 define the indicators that are calculated based on the NDVI dataset.

Table 2.16 Basic information about the NDVI deviation dataset.

Title	NDVI deviation										
Description	NDVI deviation is calculated as the deviation from the long-term mean. It expresses the current vegetation growth compared to the long term mean for the same period.										
	INDICATOR USAGE										
Index interpretation	<p>NDVI deviation can be used to define a drought as it is defined as the difference between the NDVI for the current time step and the long term mean NDVI for the same month.</p> $DEV_{NDVI} = NDVI_i - NDVI_{mean,m}$ <p>Here: $NDVI_i$ is NDVI for the current time step and $NDVI_{mean,m}$ is the long term mean NDVI for the same month</p> <p>When DEV_{NDVI} is negative, it indicates the below-normal vegetation condition/health and, therefore, suggests a prevailing drought situation. The greater the negative departure the greater the magnitude of a drought.</p> <p>The limitation is that the deviation from the mean does not take into account the variability in the vegetation within the region. Hence a negative DEV_{NDVI} could be caused by a different crop type.</p> <table border="1"> <thead> <tr> <th>DEV_{NDVI} values</th> <th>Condition</th> </tr> </thead> <tbody> <tr> <td>≤ 0.2</td> <td>Severe drought (extremely dry)</td> </tr> <tr> <td>-0.05 to -0.2</td> <td>Drought (moderately dry)</td> </tr> <tr> <td>-0.05 to 0.1</td> <td>Near normal</td> </tr> <tr> <td>> 0.1</td> <td>Above optimal (extremely wet)</td> </tr> </tbody> </table>	DEV_{NDVI} values	Condition	≤ 0.2	Severe drought (extremely dry)	-0.05 to -0.2	Drought (moderately dry)	-0.05 to 0.1	Near normal	> 0.1	Above optimal (extremely wet)
DEV_{NDVI} values	Condition										
≤ 0.2	Severe drought (extremely dry)										
-0.05 to -0.2	Drought (moderately dry)										
-0.05 to 0.1	Near normal										
> 0.1	Above optimal (extremely wet)										
Spatial extent	Global coverage										
Spatial and temporal resolution	Spatial resolution: 5600 m to 250 m Temporal resolution: 16-daily										
Reference	Processed based on the NDVI data										
Example of usage	<p>Location of areas with a vegetation growth below the long-term average.</p>										

INDICATOR CALCULATION	
Data requirements and calculation	$DEV_{NDVI} = NDVI_i - NDVI_{mean,m}$ <p>where $NDVI_i$ is NDVI for the current time step and $NDVI_{mean,m}$ is the long term mean NDVI for the same month</p>
Update Frequency	16-daily
Related indices	Vegetation based indices
Data source	Based on the NDVI data

Table 2.17 Basic information about the Vegetation Condition Index dataset.

Title	Vegetation condition index (VCI)								
Description	The vegetation condition index (VCI) shows how close the NDVI of the current month is to the minimum NDVI calculated from the long-term record.								
	INDICATOR USAGE								
Index interpretation	<p>VCI values reflects the following:</p> <table border="1"> <tr> <td>50 to 100 %</td> <td>Optimal or above normal conditions</td> </tr> <tr> <td>35 to 50%</td> <td>Fair vegetation conditions</td> </tr> <tr> <td>0 to 35%</td> <td>Severe drought (local trigger values apply)</td> </tr> <tr> <td>0%</td> <td>Extremely dry and equal to the long-term minimum</td> </tr> </table>	50 to 100 %	Optimal or above normal conditions	35 to 50%	Fair vegetation conditions	0 to 35%	Severe drought (local trigger values apply)	0%	Extremely dry and equal to the long-term minimum
50 to 100 %	Optimal or above normal conditions								
35 to 50%	Fair vegetation conditions								
0 to 35%	Severe drought (local trigger values apply)								
0%	Extremely dry and equal to the long-term minimum								
Spatial extent	Global coverage								
Spatial and temporal resolution	<p>Spatial resolution: 5600 m to 250 m</p> <p>Temporal resolution: 16-daily</p>								
Reference	Kogan, F. N. F. Remote sensing of weather impacts on vegetation in non-homogeneous areas. International Journal of Remote Sensing 1990, 11, 1405–1419.								
	INDICATOR CALCULATION								
Data requirements and calculation	<p>VCI shows how close the NDVI of the current month is to the minimum NDVI calculated from the long term record.</p> $VCI_j = \frac{(NDVI_j - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \cdot 100$ <p>Here $NDVI_{min}$ and $NDVI_{max}$ are calculated for the same month from a long-term record.</p>								
Update Frequency	16-daily								
Related indices	Vegetation based indices								
Data source	Based on the NDVI data								

Table 2.18 Basic information about the Vegetation Health Index dataset.

Title	Vegetation health index (VHI)										
Description	VHI is combination of vegetation condition index (VCI) and temperature condition index (TCI).										
	INDICATOR USAGE										
Index interpretation	The following classification is used for drought related vegetation stress: <table border="1" data-bbox="491 533 1043 701"> <tr> <td><10</td> <td>Extreme drought</td> </tr> <tr> <td>10-20</td> <td>Severe drought</td> </tr> <tr> <td>20-30</td> <td>Moderate drought</td> </tr> <tr> <td>30-40</td> <td>Mild drought</td> </tr> <tr> <td>40-100</td> <td>No drought</td> </tr> </table>	<10	Extreme drought	10-20	Severe drought	20-30	Moderate drought	30-40	Mild drought	40-100	No drought
<10	Extreme drought										
10-20	Severe drought										
20-30	Moderate drought										
30-40	Mild drought										
40-100	No drought										
Spatial extent	Global coverage										
Spatial and temporal resolution	Spatial resolution: 5600 m to 250 m Temporal resolution: 16-daily										
Reference	Processed based on the NDVI data										
	INDICATOR CALCULATION										
Data requirements and calculation	Calculated as based on VCI and TCI: $VHI = 0.5 \cdot VCI + 0.5 \cdot TCI$										
Update Frequency	16-daily										
Related indices	Vegetation based indices										
Data source	Based on the NDVI data										

Table 2.19 Basic information about the vegetation condition dataset which is based VHI.

Title	Agricultural Stress Index (ASI)
Description	The ASI is an index based on the integration of the Vegetation Health Index (VHI) in two dimensions that are critical in the assessment of a drought event in agriculture: temporal and spatial.
	INDICATOR USAGE
Index interpretation	Provides the combination of the intensity and duration of dry periods occurring during the crop cycle and spatial extent.
Spatial extent	Global and available since 2000
Spatial and temporal resolution	Spatial resolution: 1 km Temporal resolution: 16-daily
Reference	Based on the VHI data
	INDICATOR CALCULATION
Data requirements and calculation	<p>The first step of the ASI calculation is a temporal averaging of the VHI at pixel level.</p> <p>The second step determines the spatial extent of drought events by calculating the percentage of pixels in arable areas with a VHI value below 35 per cent (this value was identified as a critical threshold in assessing the extent of drought in previous research by Kogan, 1995).</p> <p>Finally, each administrative area is classified according to its percentage of affected area to facilitate the quick interpretation of results by analysts.</p>
Update Frequency	16-daily
Related indices	Vegetation based indices
Data source	http://www.fao.org/giews/earthobservation/asis/index_1.jsp

2.6.6 Soil moisture related data

The Soil Water Index (SWI) product contains daily synthesis of SWI derived from Advanced Scatterometer Surface Soil Moisture (ASCAT SSM) data at 25 km resolution (then resampled to 0.1 degree).

SWI is based on an active sensor, which **means measurements are not cloud sensitive**.

The SWI algorithm, originally developed at Vienna University of Technology (TU Wien) and later improved by other research groups, uses an infiltration model describing the relation between surface soil moisture and profile soil moisture as a function of time. The algorithm is based on a two-layer water balance model.

The data value uses the largest characteristic time length, thereby giving the deepest penetration within the soil layers. The values represent an average SWI across 0.5 to 1 meter of the topsoil.

SWI is used as an indicator for the water availability in the upper part of the root zone. It is not a drought index but can be used to detect changes in the soil moisture pattern from year to year, which may be related to drought. Some basic information about this index can be seen in Table 2.20. Table 2.21 and Table 2.22 present indicators based on SWI which are included in the portal.

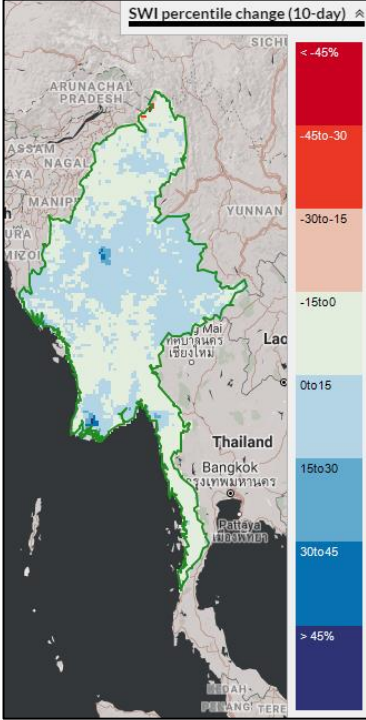
Table 2.20 Basic information about the Soil Water Index

Spatial extent	Global
Spatial and temporal resolution	Spatial resolution: 0.1 degree Temporal resolution: 10-day METOP-ASCAT satellite, from 2007 – present
Reference	http://land.copernicus.vgt.vito.be/PDF/datapool/ and http://land.copernicus.eu/global/products/swi
Update Frequency	10-day
Related indices	Soil moisture-based indices

Table 2.21 Basic information about the SWI percentile dataset.

Title	SWI percentile
Description	SWI percentile expresses the percentage of soil moisture that is equal to or below a certain amount for each year in the entire record.
	INDICATOR USAGE
Index interpretation	A drought or water scarcity is often defined when the soil moisture percentile drops below 30 or 20 %.
Spatial extent	Global coverage
Spatial and temporal resolution	Spatial resolution: 0.1 degree Temporal resolution: daily or 10 daily
Reference	Processed based on SWI data
Example of usage	<p>Example of SWI percentile map</p>
	INDICATOR CALCULATION
Data requirements and calculation	Calculated as the percentile value for the same period as the observed data (based on data from 2007 to present).
Update Frequency	Daily or 10-daily
Data source	Based on SWI data

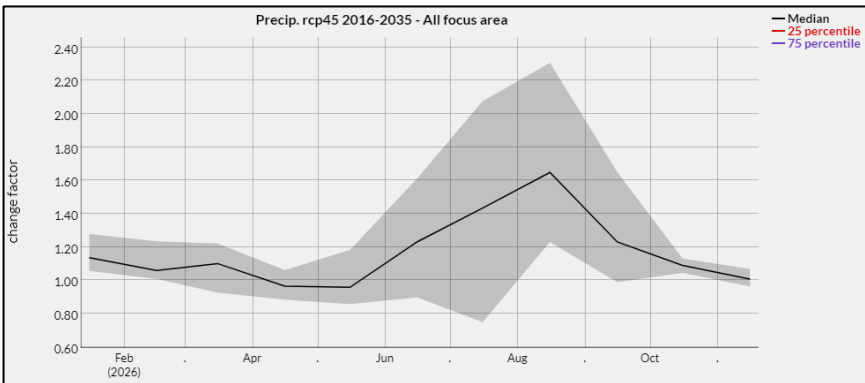
Table 2.22 Basic information about the SWI percentile change dataset.

Title	SWI percentile change
Description	Change in soil moisture percentile is used to evaluate the trend over a given period and locate areas where the soil moisture is increasing or decreasing. The SWI percentile is calculated for change over 10, 20, and 30 days.
	INDICATOR USAGE
Index interpretation	Positive values indicate an increase in soil moisture across the period while negative values indicate a decrease in soil moisture across the period.
Spatial extent	Global coverage
Spatial and temporal resolution	Spatial resolution: 0.1 degree Temporal resolution: Daily or 10 daily
Reference	Processed based on SWI data
Example of usage	<p>Example of SWI percentile change (10 days) showing areas where the soil is getting wetter or dryer over the last 10 days.</p> 
	INDICATOR CALCULATION
Data requirements and calculation	Calculated as the change in percentile value.
Update Frequency	Daily or 10-daily
Data source	Based on SWI data

2.6.7 Climate change data

Coordinated Regional Climate Downscaling Experiment (CORDEX) is a World Climate Research Programme (WCRP) project with the goal to produce coordinated sets of regionally downscaled climate projections worldwide. For each continent a model domain was defined to run a set of Regional Climate Models (RCMs). The initiative responsible for the generation of RCMs for Myanmar is called CORDEX South Asia. The RCMs are driven by the new generation radiative concentration pathway (RCP) scenarios at a horizontal resolution of 0.44 degree.

The RCM outputs are processed into so-called delta change factors for monthly mean rainfall in order to indicate projected changes in monthly mean rainfall. For each month, the factors represent the ratio between the average in the control model run (1986-2005) and the projection model run (2081-2100). Changes are estimated for the medium radiation forcing scenario RCP4.5 and the extreme radiation forcing scenario RCP8.5.

Spatial extent	Global
Spatial and temporal resolution	Spatial resolution: 0.44 degree Temporal resolution: resampled to monthly METOP-ASCAT satellite, from 2007 – present
Reference	https://esg-dn1.nsc.liu.se/search/esgf-liu/ (ESGF Data Node)
Example of usage	Monthly envelope chart of precipitation delta change factors showing expected increase or decrease in precipitation over a certain basin. 
Update Frequency	Static dataset
Related indices	-

Based on the delta change factors series of climate change projection of rainfall for Myanmar are calculated. These time series are named and identified after the carbon dioxide emissions scenarios and the projection time-period:

- Precip. rcp45 2016-2035
- Precip. rcp85 2016-2035
- Precip. rcp45 2081-2100
- Precip. rcp85 2081-2100

Based on the precipitation datasets listed, an index is generated, which expresses the number of dry days per month for each RCP scenario and projection time-period. Finally, alongside precipitation, the datasets of temperature and potential evapotranspiration for Myanmar will also be generated and named as follows:

- PET rcp45 2016-2035
- PET rcp85 2016-2035
- PET rcp45 2081-2100
- PET rcp85 2081-2100
- TEMP rcp45 2016-2035
- TEMP rcp85 2016-2035
- TEMP rcp85 2081-2100
- TEMP rcp45 2081-2100

These datasets are static and available through the web portal.

2.6.8 Water Body data

The Water Body data produced by the Copernicus Global Land Service (CGLS) is a component of the Land Monitoring Core Service (LMCS) of Copernicus, the European Earth Observation programme. With this dataset it is possible to detect areas covered by inland water along the year providing the maximum and the minimum extent of the water surface as well as the seasonal dynamics.

Table 2.23 Basic information about the Water Body dataset

Spatial extent	Global
Spatial and temporal resolution	Spatial resolution: 300 m Temporal resolution: 10-daily composite product. PROV-B sensor, from January 2014 – present
Reference	http://land.copernicus.eu/global/products/wb
Update Frequency	10-daily
Related indices	-

2.6.9 Flood related data

There are two datasets in the portal that can be used to assess flood potential in an area. One is static and based on topography, the Height Above Nearest Drainage (HAND). The other is a dynamic index, based on time varying datasets, the Flash Flood Potential Index.

Table 2.24 Flood potential static index HAND description

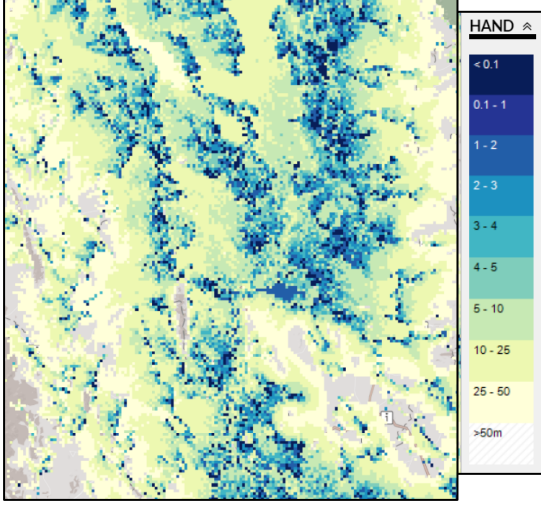
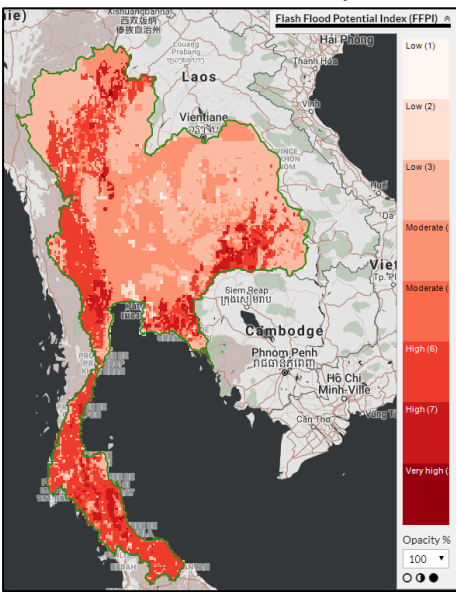
Title	Height Above Nearest Drainage (HAND)
Description	Map showing the height above the nearest drainage point.
	INDICATOR USAGE
Index interpretation	Can be used for a first assessment of whether an area is likely to be flooded. It does not give information on the likelihood of an area being flooded.
Spatial and temporal extent	Global static layer (one-time step)
Spatial and temporal resolution	based on a 90-meter DEM
Source	
Example of usage	<p>HAND index for a study area</p> 
	INDICATOR CALCULATION
Data requirements and calculation	Derived from a detailed DEM only
Update Frequency	None
Related indices	None
Data source	Derived from a detailed DEM only

Table 2.25 Flash Flood Potential Index description

Title	Flash Flood Potential Index (FFPI)
Description	Quantifying a basin's risk of flash floods based on its inherent properties, such as slope, land cover, together with external dynamic indicators such as SWI. As the SWI is also included in the calculation of the FFPI, not only the properties (slope and vegetation cover) are important, but also the current state (soil moisture content) of the basin.
INDICATOR USAGE	
Index interpretation	Gives information on how likely it is for a basin to be flooded based only on the basin's inherent properties
Spatial and temporal extent	Global coverage, data from 2007-present
Spatial and temporal resolution	Spatial resolution: 0.1 degree Temporal resolution: 10-daily
Source	https://land.copernicus.eu/global/products/swi
Example of usage	<p>Potential for flash floods in Myanmar</p> 
INDICATOR CALCULATION	
Data requirements and calculation	<p>The indicator is calculated from the slope, soil water index (SWI), and NDVI as</p> $FFPI = \frac{slope \cdot weight(slope) + SWI \cdot weight(SWI) + NDVI \cdot weight(NDVI)}{sum\ of\ weights}$ <p>The slope is calculated from a DEM and has weight 0.35. SWI is 10-day SWI data and has weight 0.35. NDVI is the long-term average and has weight 0.3.</p>
Update Frequency	10-day
Related indices	None
Data source	DEM, SWI and NDVI

2.7 Reporting and bulletins

This subchapter describes a reporting application which the stakeholders can use to disseminate the data and information presented in chapter 2.6. Dissemination in the form of reports or bulletins is critical in relation to planning as this enables the decision or policy makers to disseminate the actual plans or the background for the decision process to stakeholders.

Not only is it necessary for data to be freely accessible to the stakeholders via the online web portal but supplementing this access to data with a tool to compile reports using templates relevant to the stakeholders will add value to the data and increase its usage and ultimately its applicability.

With this reporting tool, users can view a few default reports set up for demonstration by the DHI team, or develop their own reports based on their specific requirements. The reporting application is based on reporting templates in the form of Word documents containing a number of tags, where the user is able to specify which type of content the reporting application should replace the tags with.

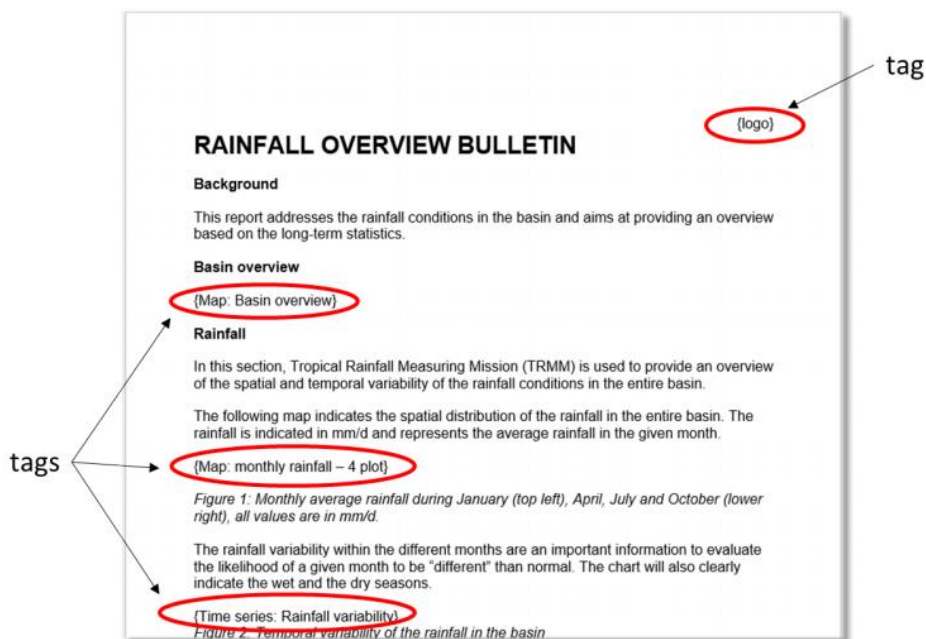


Figure 2.10 Example of a report with tags.

The tool works with template reports containing the overall framework of the report and can insert objects in the form of images, text, charts, or tables at user specified locations and converting the template report into a final report containing for example tables with the latest climate information, drought hazards or other information from the portal.

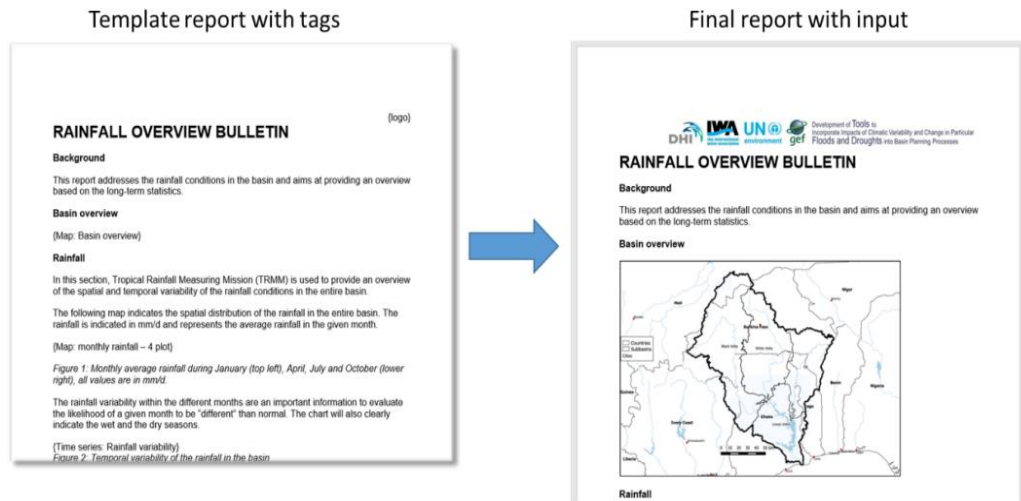


Figure 2.11 Template report with tags and final report with input in the form of images, chart or text replacing the tags.

DHI is currently further developing this application to increase the user-friendliness and efficiency of its usage. Development will be carried out by the DHI team during **Activity 2.1**.

3 Methodology for validation

This chapter presents the methodology for validation of the selected datasets from the ones described in chapter 2.6 Technical Specifications. The validation will take place throughout **Activity 2** of this technical assistance. Based on the feedback from stakeholders during the first national workshop and input from the ECD, the methodology presented next will be used in two locations in Myanmar out of the options reported in **Deliverable 2 Workshop report and cases for validation**.

This process will ensure that the developed technology provides outcomes that can represent the actual conditions in the country, and therefore be used for decisions aiming at increasing the adaptation capacity towards climate change.

Validation of the outcomes will depend on the availability of historical data. DHI will evaluate how the system is able to reproduce events which have already occurred. It will thus depend on the successful collection of information from the stakeholders.

3.1 Remote sensing rainfall

Rainfall is an important component in the water balance and hydrological modelling. As ground data is scarce, remote sensing data sets can be used to give spatially distributed data and fill in data gaps. In this chapter, CHIRPS, GPM, and TRMM rainfall data (three different datasets based on earth observation, combined with models and in the case of CHIRPS combined with ground measurements) will be compared with ground measurements from rainfall gauges. The remote sensing data sets will also be compared with each other.

The ongoing World Bank project supporting the DMH with the development of their ground-based data collection systems and hydro-meteorological service delivery can benefit greatly from the remote sensing rainfall data available and the outcome of its validation. Additionally, while the investment in DMH hydro-meteorological services is being realized, the portal data could be used to supplement their analysis and operations.

The most important aspect to consider when carrying out a validation exercise, is what the data would be used for. In this case it is for activities supporting flood and drought management. This means, catchment rainfall data is validated during this project and rainfall data for a point is not looked at. Then for drought, monthly data is looked at instead of daily data; whereas for floods daily data is of interest.

To carry out the comparison, ground-based measurements are required. These are assumed to best approximate rainfall occurring at a point. However, as catchment rainfall is looked at, the density of the station network within the catchment is crucial to determining how important and useful those ground measurements are. Additionally, station data might be the best measurement available at a point but is very vulnerable to different types of error sources. Finally, station data might not be the most useful information for validating data for occurrence of flood and drought.

There are several parameters that can be investigated ideally for the same time-period. If the different data types have different time-periods, some data must be ignored. As a further investigation, averages and percentages (not accumulated or total values) could be calculated for the entire time series to see if this affects the results.

Considering the portal data and observed data, the first step will be to calculate catchment rainfall for each source. Then the percentage error of the remote sensing data is calculated:

$$\text{percentage error} = \left| \frac{p_{RS} - p_g}{p_g} \right| \cdot 100\%$$

Here p_{RS} is the portal data, while p_g is the observed precipitation. The error is calculated in each time step and averaged over all time steps to find the mean absolute error.

When comparing amongst portal data, one data type is not more trusted than the other. Therefore, it does not make sense to calculate the percentage error, but rather the percentage difference:

$$\text{percentage difference} = \frac{|p_1 - p_2|}{\frac{p_1 + p_2}{2}} \cdot 100\%$$

p_1 and p_2 are precipitation observed by two different remote sensing types.

Note that these calculations make sense for rainfall time series, which are always positive, but not for a time series which contains negative values. For a time-series like temperature, it should be ensured that there are no negative values if percentage error and percentage difference are calculated.

Comparing the data types with each other can also be useful if there are some data types that do not overlap entirely, nor overlap at all. For instance, if GPM and TRMM do not overlap, but both show a good correlation with CHIRPS data, it could be expected that there is also good agreement between CHIRPS and TRMM.

Comparing complete time series records

The full-time series are plotted in mm/month. This shows the agreement of the different data types regarding the timing and magnitude of rainfall events. The mean absolute error/difference should also be calculated, comparing all the data types.

Comparing yearly averages

The average for each year is calculated, and the comparison is as above: by plotting and calculation of the error/difference. This less detailed investigation will show the ability of the different data sources to identify wet and dry years.

Finding number of days with rainfall

For each data source the number of days with rainfall (defined as days with rainfall above 2 mm) should be identified. Calculating the percentage of days with rainfall shows whether there is agreement between the data sources or whether one data type overestimates or underestimates the number of wet days.

Average monthly rainfall

Calculating the average rainfall for each month based on the full-time series (that is, the averages of all Januaries, all Februaries, etc.) gives a way to identify seasonality. This will show if the same seasonality is reflected in all data types and whether there is agreement in the magnitude of rainfall in different seasons or the difference between the seasons. For instance, although all data types may show a rainy season, they may not agree on the amount of rainfall in this season or the difference between dry and rainy seasons.

Correlation between data

This can be calculated for both daily and monthly values. The R^2 -value should be calculated. This will indicate how good the agreement between the data types is – for instance, how often a high value in one data set corresponds to a high value in the other data set.

Duration curves

The duration curve is calculated by ordering the data based on the magnitude of the rainfall event with the largest event first. Each event is then given a rank, with the largest event getting rank one. Finally, the probability P that the event is exceeded is calculated as

$$P = \frac{M}{n + 1} \cdot 100\%$$

Here, M is the rank and n is the number of events. P shows how often a given event is exceeded. For instance, $P = 60\%$ means that rainfall rate is equal to or exceeding the given rate 60% of the time.

The shape of the duration curves gives information about the behaviour of the catchment, so if the shapes for the different data types are similar, it shows that all data types show the same overall behaviour.

In addition to plotting the duration curves, some percentiles – for instance, 25th, median, and 75th – can be selected and compared for the different data types.

Accumulated volumes

The accumulated volume gives a clear picture of the difference between data types, as the deviations in each time step are accumulated. This can be analysed visually by plotting, and the error/difference in the total accumulated volume can be calculated. The accumulated volume is calculated by adding the rainfall at the given time step to the accumulated value of all previous time steps. It follows that it is very important to use the same time-period for all data types.

3.2 Flash Flood Potential Index

During Activity 1.2, stakeholders identified flash floods as a key issue in Myanmar with impacts prioritized highly by their institutions. Therefore, an attempt will be made by the team to validate the Flash Flood Potential Index.

The methodology for validation of this dataset will be carried out in GIS environment by running overlay routines and visual inspection, we anticipate the following steps:

1. Identify extent and duration of flash flood events
2. Collect data on the event, rainfall, water level, damage to property and any other record of impacts from national institutions such as the Department of Meteorology and Hydrology (DMH) and the Department of Disaster Management (DDM). Regarding the former, efforts will be made to coordinate with the World Bank ongoing project to develop DMH hydro-meteorological services, in the specific case of rainfall data collection.
3. Confirm the Index dataset registers on that period of time and coordinates potential for flash floods
4. Compare amongst confirmed events if the degree of potential correlates with the magnitude of the historical event
5. Potentially updating the weights used in the FFPI formula (view chapter 2.6.9); this step is optional and will depend on the quality of the data collected to support validation.

It will only be possible to carry out the above exercise, given the degree of documentation of the flash flood historical events is appropriate. Particularly the duration and magnitude.

The latter can be analysed via flood volumes, but also damage recorded and magnitude of the event's related impacts.

3.3 Drought indicators

Along with floods, there are drought-stricken areas in Myanmar, which have devastating impacts on agriculture, quality of life of farmers and national economy. The drought related indicators which are the most interesting to attempt validation are:

- Standardised Precipitation index (SPI)
- Effective Drought Index (EDI)
- Soil Water Index (SWI)
- Normalized Difference Vegetation Index (NDVI) based such as NDVI deviation.

The methodology for validation of these datasets will also be carried out in GIS environment. The objective is to evaluate the ability to anticipate the historical drought event based on the raw datasets used to calculate the indicators, and the composite indicators themselves. The following steps are needed:

1. Identify extent and duration of drought.
2. Collect data on the event, rainfall, temperature, damage to property and any other record of impacts from national institutions such as the Department of Agriculture (DOA), the Department of Meteorology and Hydrology (DMH) and the Department of Disaster Management (DDM); also, the news media can be a source of information of the severity of the drought events.
3. Analyse the observed rainfall, SPI and EDI for the given events.
4. Based on the previous step find alignment between drought detection using SPI and EDI, and the state of SWI and one of the NDVI based indicators for the locations and events.
5. Compare amongst confirmed events if the magnitude found in the portal indicators correlate with the magnitude of the historical events.

This validation exercise would be very useful to demonstrate the combined use of drought indicators, as it links rainfall, to soil moisture, to vegetation conditions.

Similarly to the flash flood dataset validation, it will only be possible if historical drought events are well documented, notably with regards to duration, magnitude and extent.

3.4 Infosheets

From Activity 1.2 and the first national workshop, a series of information sheets are sent off weekly, about the data provided under this technical assistance and presented in the previous chapter. The Monday emails are sent with descriptions of data, tools and How-to information regarding the portal.

The infosheets will be used as a tool for demonstration on usage of data, water indicator, issue analysis and reporting tools delivered by the technical assistance. They will be translated to Burmese language whenever possible. However, as the mailing list is an interactive tool, with stakeholders potentially placing requests and suggestions for topics the week before, translation might not be feasible.

An infosheet is a two-page note shared weekly on different aspects such as:

- access to the time series and spatially distributed data for Myanmar and the Ayeyarwady Basin area, in near real time;
- climate data, seasonal forecasts and a variety of indicators;
- applications such as the water indicator and reporting tool;
- or the innerworkings of the web portal.

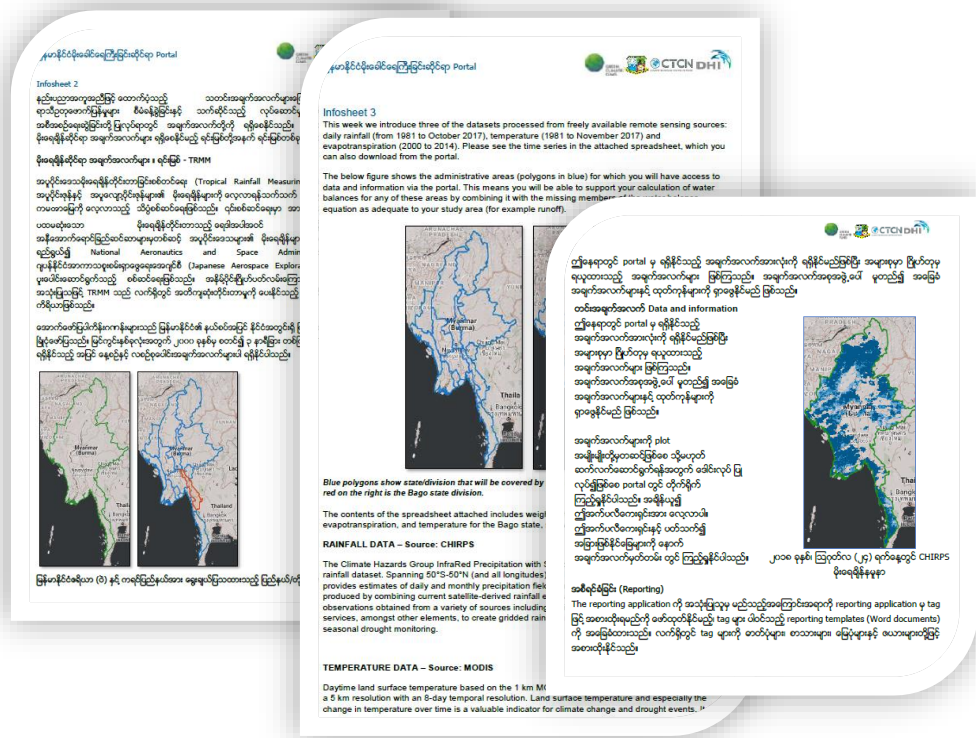


Figure 3.1 Examples of infosheets in both Burmese and English languages.

4 Work plan for Activities 2 and 3

During Activity 2 the project team will improve the portal data selection and configuration following feedback from users, running from January to the end of April 2019.

The portal has a reporting tool allowing the user to disseminate the available data and information to relevant stakeholders in the form of tables and charts in pdf and html format. The specific dissemination formats are to be decided by the stakeholders, but emphasis will be on supporting activities related to climate change, flood and drought management. During Activity 2, this feature of the portal will be further enhanced to meet the objectives.

Additionally, within Activity 2, the data validation process will be carried out and a report prepared describing the technical validation and testing of the drought and flood management portal.

Activity 3 will cover May and June 2019, the final two months of technical assistance. Within this time, the final training and second national workshop will be organized. According of the response plan, 15 individuals are to be trained in use of the project outcomes. The outputs are a lessons-learned report from the use case and the initial use of the data portal in Myanmar; and a roadmap describing recommendations for further development, linkages with national policy development, and potential for engagement of the private sector. It will also include an evaluation and recommendations of funding options to scale up, which will directly inform design of a project proposal to the GCF.

Below the proposed implementation schedule, along with important dates.

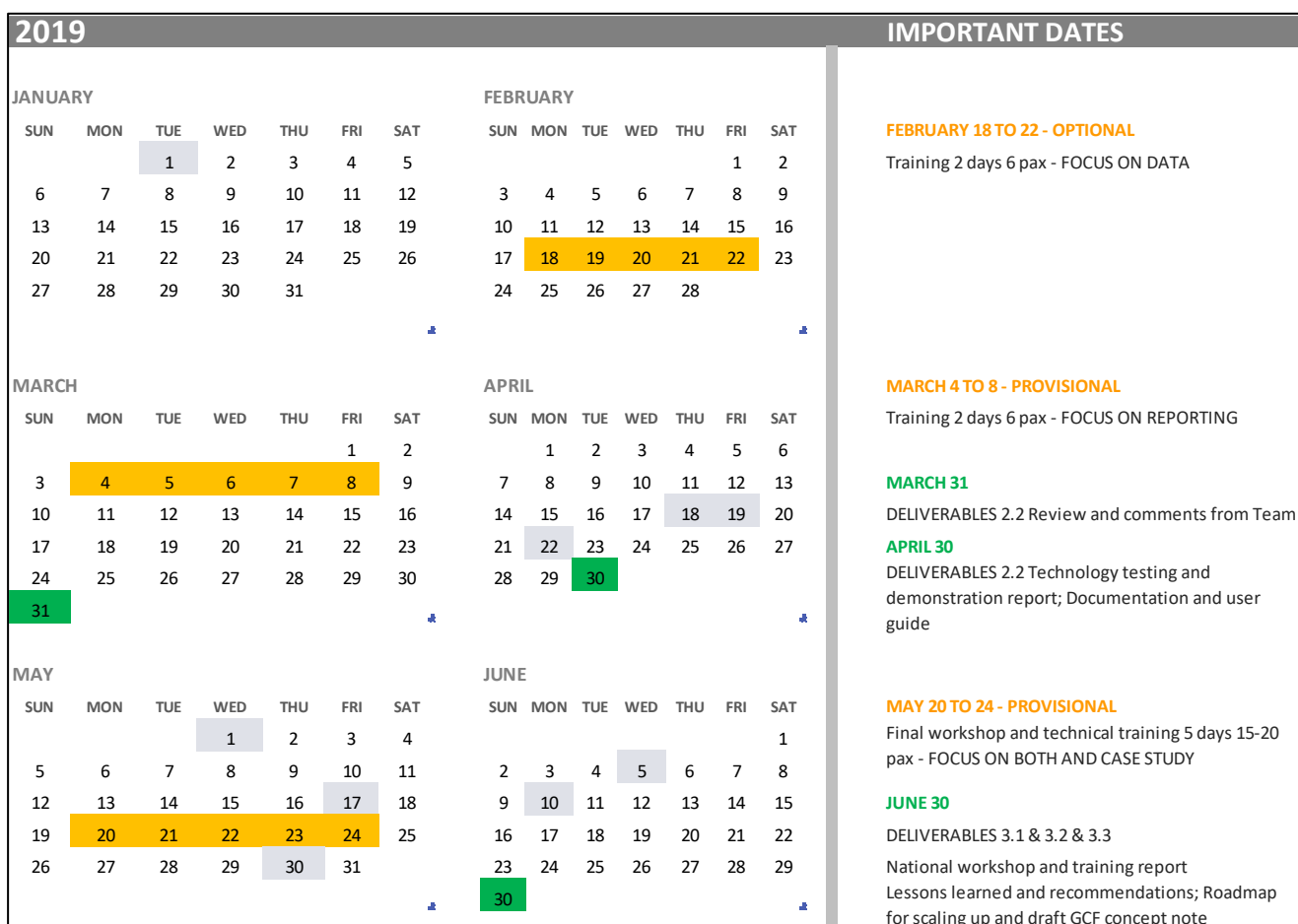


Figure 4.1 Proposed work plan schedule

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