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

Deliverable 5 (activity 2.2) Technical training session and Validation report

UNEP

Report

May 2019

The expert in **WATER ENVIRONMENTS**

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

Deliverable 5 (activity 2.2) Technical training session and draft Concept Note guidance

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EXECUTIVE SUMMARY

This report is Deliverable 5 of Activity 2.2 of the Climate Technology Centre and Network (CTCN) technical assistance to Myanmar entitled ‘Strengthened drought and flood management through improved science-based information availability and management’ (reference number 2016000035). It is funded by Green Climate Fund (GCF) Readiness and preparatory support funding. This technical assistance is implemented by DHI in cooperation with the Climate Change Division of the Environmental Conservation Department (ECD), Ministry of Natural Resources and Environmental Conservation (MONREC). The ECD is the National Designated Authority (NDA) of the GCF.

A web portal developed by DHI provides access to state-of-the-art remote sensing data and information, tools and reporting abilities, for flood and drought management, water resources and water related sectors in Myanmar. The portal address is:

www.flooddroughtmonitor.com/myanmar

more can be found in the “Technology specifications and methodology for testing and validation” report (Deliverable 3 of Activity 1.3). DHI will keep the system running for the period of 5 years and is responsible for its maintenance.

This deliverable is documenting the outcomes of a high-level meeting for project upscaling on the 1st of April 2019 at the ECD office in Nay Pyi Taw; the second technical 3-day training that took place from the 2nd to 4th of April 2019 in Nay Pyi Taw; followed by another technical training day on the 5th of April 2019 for stakeholders in Yangon.

The ECD and technical assistance team met with high level technical experts from the Departments of Meteorology and Hydrology (DMH), of Disaster Management (DDM), the Survey Department and the Population Department, to share knowledge of the current situation in Myanmar regarding data portals deliver live demos of their platforms and each institution was asked about whether there are any links between their portals and the Myanmar F&D portal. Additionally, potential roles each institution have in its conceptualization and the upscaling project itself. As next steps, each of the four institutions will refer to their respective Director Generals and return to the Climate Change Division with final conclusions.

The second technical training took place in Nay Pyi Taw from the 2nd to the 4th of April, with a total of 35 people (16 are female and 19 male) in attendance across the three days, and the presence of Deputy Minister Dr Ye Myint Swe who officially opened the event. The training focused on remote sensing data, application of indicators for Myanmar and the newly added Crop Application. The Crop Application provides a crop and region-specific crop calendar based on global datasets and allows the user to calculate crop water requirements and yield estimate for specific crop.

The methodology and validation results for specific locations in Myanmar and portal datasets as selected by stakeholders are also presented herein. The datasets are satellite rainfall from different sources and satellite drought related indices. The methodology is a key deliverable as it is intended to be applied by users and replicated to other datasets and other locations in Myanmar. Validation is a crucial step before application of remote sensing data is done, as it provides a measure of accuracy and reliability at a specific location.

This technical assistance will come to an end with the final deliverable of Activity 3, the *Lessons-learned and Roadmap report*, including recommendations for further development of the portal, and for linkages with national policy development, and informing the design of a *Draft GCF Concept Note* which will be attached to the report. Activity 3 will also include the final workshop, date yet to be established.

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ACCRONYMS & ABBREVIATIONS

CHIRPS	Climate Hazards Group Infrared Precipitation with Station
CTCN	Climate Technology Centre & Network
DDM	Department of Disaster Management
DHI	www.dhigroup.com
DMH	Department of Meteorology and Hydrology
DZGD	Dry Zone Greening Department
ECD	Environmental Conservation Department
GCF	Green Climate Fund
GHG	Green House Gases
GPM	Global Precipitation Measurement
HAII	Hydro and Agro Informatics Institute of Thailand.
HIC	Hydro Informatics Center of Myanmar
IWUD	Irrigation and Water Utilization Department

MAD	Mean Absolute Deviation
MAE	Mean Absolute Error
MIID	Myanmar Institute for Integrated Development
MIMU	Myanmar Information Management Unit
MOALI	Ministry of Agriculture Livestock and Irrigation
MOC	Ministry of Construction
MOEE	Ministry of Electricity and Energy
MONREC	Ministry of Natural Resources and Environmental Conservation
MOTC	Ministry of Transport and Communication
MSWRR	Ministry of Social Welfare, Relief and Resettlement
NDE	National Designated Entity
NDVI	Normalized Difference Vegetation Index
SAP	Simplified Approval Process
SPI	Standardized Precipitation Index
SPI1	Standardized Precipitation Index over 1 month period
SPI3	Standardized Precipitation Index over 3 months period
SPI6	Standardized Precipitation Index over 6 months period
SWI	Soil Water Index
TRMM	Tropical Rainfall Measuring Mission
WCRP	World Climate Research Programme

1 Background

This report is Deliverable 5 of Activity 2.2 of the Climate Technology Centre and Network (CTCN) technical assistance to Myanmar entitled '*Strengthened drought and flood management through improved science-based information availability and management*' (reference number 2016000035). It is funded by Green Climate Fund (GCF) Readiness and preparatory support funding.

This technical assistance is implemented by DHI in cooperation with the Climate Change Division of the Environmental Conservation Department (ECD), Ministry of Natural Resources and Environmental Conservation (MONREC). The ECD is the National Designated Authority (NDA) of the GCF.

A web portal developed by DHI has been set up for Myanmar providing free and easy access to data and information for flood and drought management, water resources and water related sectors (www.flooddroughtmonitor.com). DHI will keep the system running for the period of 5 years and is responsible for its maintenance.

The activities focus on workshops and training, validation of selected datasets of the web-portal, generating a strong user community, and providing guidance to the ECD and other stakeholders for the drafting of a GCF Simplified Approval Process (SAP) Concept Note for upscaling of the outcomes of the technical assistance including installation of the portal in Myanmar.

The purpose of this report is threefold:

- To document the high-level meeting for project upscaling on the 1st of April 2019 at the ECD office in Nay Pyi Taw;
- To document the second technical 3-day training that took place from the 2nd to 4th of April 2019 in Nay Pyi Taw; followed by another technical training day on the 5th of April 2019 for stakeholders in Yangon.
- To present the final methodology for validation and results obtained during this technical assistance.

2 Project upscaling meeting

This technical assistance is funded by GCF readiness funds and support to drafting a concept note of a larger project is being provided. The future project has as key element the scale up of use and ongoing management of the portal throughout the country. On the 20th of February 2019 the first guidance session on how to draft a GCF Concept Note was held at the ECD office with ECD staff. Participants started out by going through a sequence of brainstorming exercises to define:

- the purpose of their projects,
- the outcomes,
- the specific objectives, and finally
- 4 activities/tasks to accomplish each objective

Three draft concept notes were initiated and a plan to merge these into one was set out under the guidance of Director General (DG) U Hla Maung Thein. It was concluded that the project conceptualized met all the GCF SAP Concept Note requirements:

- Ready for scaling up

- Potential for transformation
- Promoting a paradigm shift to low-emission and climate-resilient development
- Up to 10 million USD
- Minimal (to none) social risks and impacts

On the 1st of April 2019 at the ECD's office at MONREC, Nay Pyi Taw, a meeting with high level technical experts from ECD, Department of Meteorology and Hydrology (DMH), the Department of Disaster Management (DDM), the Survey Department and the Population Department was held to discuss the upscaling of the outcomes of this technical assistance. There were 16 participants in the meeting and 8 were female.

These institutions were selected due to the fact that they are key stakeholders in this technical assistance, both producers and consumers of data, and are involved in the Onemap Geoportal https://portal.onemapmyanmar.info/omm/home/, a spatial database used to share data from different institutions amongst institutions. It is developed by the Centre for Development and Environment (CDE), University of Bern, Switzerland.

The topic of discussion was the upscaling of the current portal and finding the overlap and synergies with existing platforms/portals in Myanmar. Specifically, the following points were covered:

- Brief overview of the technical assistance
- Demo of the portal by DHI
- Existing platforms presentation by DMH, DDM, Survey and Population Department
- Overlap and synergies
- Plan for upscaling group discussion
- Next steps

The participants were asked to come prepared by filling out a table with a summary of their platforms. Below is the table filled out for the Myanmar Flood & Drought Portal.

Table 2.1 Description of the web portal delivered during the GCF funded CTCN technical assistance

Overview	The data in the portal is mostly remote sensing data coming from global databases and reputable and widely used sources such as NASA and NOAA. There are two types of datasets: - Raw data originating from different data sources (e.g. rainfall from CHIRPS, rainfall from TRMM, etc.) - Processed data calculated by the portal based on the raw data (e.g. drought indicators, vegetation indicators, etc.)
Data types	There are currently 111 datasets for Myanmar, here is a short list of key items: - Rainfall: historic; near real time; medium range forecast; seasonal forecast - PET - Temperature - NDVI - Climate Change projections: rainfall; PET and temperature - Drought and flood indicators: SPI, SWI, VHI, CDI, ASI, HAND, FFPI - Flood Hazard maps - Night lights maps amongst others.
Functionality	DATA & INFORMATION Visualization, easy and fast download of time series and raster files. REPORTING Automatic update of reporting templates (Word documents) uploaded by users; with a user specified weekly frequency a report is also automatically emailed to the user. ISSUE ANALYSIS

	Tool to assist in the identification, understanding and prioritizing key environmental issues; WRIAM and CCA methodologies. WATER INDICATOR Library of different indicators setting up stakeholders on the building of frameworks to monitor and evaluate the key issues identified. DROUGHT ASSESSMENT Tool to detect when and if a drought hazard might occur and the location and severity of the hazard; and assess risk based on map overlay of hazards and vulnerability. CROP APPLICATION Tool to access all data, information and tools related to crop phenology, crop water requirements and crop yield.
Users	Government institutions and Academic community
Confidentiality	Publicly available
Access	Running for 5 years free for all users

Both the DDM and DMH came prepared with this information and additionally did live demos of their platforms. The next sections summarize the findings and a summary of the findings and agreed next steps.

Department of Meteorology and Hydrology

The DMH use 4 platforms. Their public platform https://www.moezala.gov.mm/nmhss was presented. It has an Early Warning System, daily weather forecasts (e.g. rainfall, temperature, wind speed, wind direction), Weather Research and Forecasting (WRF) model outputs, public advisories, bulletins (flood, navigation, agro-met 10days, monsoon rain, amongst others), MTSAT satellite image, 4 times a day update (Japan); and flood hazard map calculation maps for different cities (free download).

The other two platforms are internal, one of them being the WMO Flash flood guidance system by developed by WMO and HRC http://www.wmo.int/pages/prog/hwrp/flood/ffgs/myanmar/myanmarffgs.php or https://www.hrcwater.org/projects/project-1/. The other one is the Flood warning and advisory system for Myanmar available at www.Flood-mmr.rimes.int (restricted access). This system contains hydrological forecast, rainfall forecast and telemetry data.

The fourth is currently under development, seadrif.cimafoundation.org, supported by the World Bank, that is used to produce flood maps, calculate the population affected and the return periods for flood events.

Department of Disaster Management

The DDM indicated that their department is only an end user for disaster preparedness purposes. They have two portals: Myanmar Disaster Risk Information Portal and the Historical flood analysis tool.

The first one is being built by DDM intended to be their main portal for both planning and also real time national scale systems. It covers river flood hazards, cyclone storm hazards, determining exposure including critical infrastructure, risk assessments and allows creation of their own maps. It is also for data storage and archiving. The web address is not available.

The Historical flood analysis tool, https://hfa.adpc.net/en/, by the SERVIR-Mekong program. It was built using the Joint Research Centre (JRC) Global Surface Water dataset of NASA. The JRC dataset contains maps of the location and temporal distribution of surface water from 1984 to 2015 and provides statistics on the extent and change of those water surfaces.

They utilize the population 2014 census and the tool for planning for preparedness and disaster response, to assess which townships are exposed, how many households are at risk of flood, which areas to prioritize to open township level offices, to name a few tasks.

Population Department

Population department representative did a demonstration of the website http://www.dop.gov.mm/en which has interactive mapping functionality with Onemap support.

The most important database currently is the census carried out in 2014. This is maintained in a platform named REDATAM of free access, located on a local web server containing census data and different selection functionalities, including an online and offline process.

Survey Department

The Survey Department does not have web portal, but there are future plans for this. They have in their archives topographic maps of different scales (1:100,0000 and 1:200,000, Myanmar datum, UTM 46 and 47 projected coordinate system). They receive technical support from Onemap Myanmar. The Survey Department is responsible for the continuous operation of 4 reference stations in Myanmar.

Conclusions

Based on the demo and information collected above, each institution was asked about whether there are any links between their portals and the Myanmar F&D portal. It was considered that a more in-depth analysis would be required from their side to reach a conclusive response. However, it was noted that the portal is very important for the implementation of the 2030 Climate Change National Strategy and considering a potential evolution towards a decision-making portal within a future project.

The existence of a Concept Note from November 2016 was brought up, named *Enhancing Climate Resilience in the Third Pole,* and involving Afghanistan, Bangladesh, Bhutan, Myanmar, Nepal and the World Meteorological Organization (WMO). It was agreed that its status would be enquired about. The proposed project sought to "strengthen the use of weather, water and climate services in the Third Pole region to adapt to climate variability and change and to apply well-informed risk management approaches." Even though it was an international concept note, there are components of interest and there might be the opportunity for using it as a reference for the new concept note. It was confirmed that the WMO is no longer a GCF accredited entity.

Finally, based on the information shared we discussed: what role, if any, would each institution have, how to go about upscaling project conceptualization in a concerted manner, what would be the executing entities, what would be the accredited entity. As next steps, each of the four institutions will refer to their respective DGs and return to the Climate Change Division with final conclusions.

The outcome of the meeting was shared knowledge of the current situation in Myanmar regarding data portals and next steps towards making an informed decision for the upscaling project.

3 Technical training

The second technical training took place in Nay Pyi Taw from the 2nd to the 4th of April, hosted by the Environmental Conservation Department (ECD), Ministry of Natural Resources and Environmental Conservation (MONREC) and the technical assistance team. There was a total of 35 people (16 are female and 19 male), in attendance across the three days (see Appendix C for attendance register) and it was honoured by the presence of Deputy Minister Dr Ye Myint Swe who officially opened the event.

Figure 3.1 Deputy Minister of MONREC Dr. Ye Myint Swe and Senior Water Resources Specialist of DHI Hans Christian Ammentorp during official opening remarks.

The national media was also present namely MRTV and SkyNet broadcasters, covering the first day of the technical training.

Figure 3.2 Media coverage of the event, in the image Daw Thin Thuzar Win giving an interview to MRTV regarding the ECD's efforts in this technical assistance and the portal.

In attendance were the Department of Agriculture (DOA) and the Irrigation and Water Utilization Department from the Ministry of Agriculture Livestock and Irrigation (MOALI); the Department of Meteorology and Hydrology (DMH), Ministry of Transport and Communication (MOTC); the Disaster Management Department, Ministry of Social Welfare Relief and Resettlement (MOSWRR); and Yezin Agricultural University (MOALI) and the Department of Agricultural Research (DAR, MOALI).

More on attendance and participant feedback and evaluation can be found in chapter 3.3 and Appendix C.

The specific objectives of the training session were:

- to inform on the status of the ongoing CTCN technical assistance;

- to continue to train technical specialists in use of the portal, from national institutions in Myanmar, within the flood and drought, water resources and disaster management framework;
- to receive feedback from participants on their use of the portal and application of the data carried out in their own tasks. We will be covering the topics of remote sensing data, indicators and the use of the crop application.

The portal provides access to state-of-the-art remote sensing data and information, tools and reporting abilities, for Myanmar. The portal address is: www.flooddroughtmonitor.com/myanmar, a screenshot of the homepage is in Figure 3.3. More can be found in the Technology specifications and methodology for testing and validation report (Deliverable 3 of Activity 1.3).

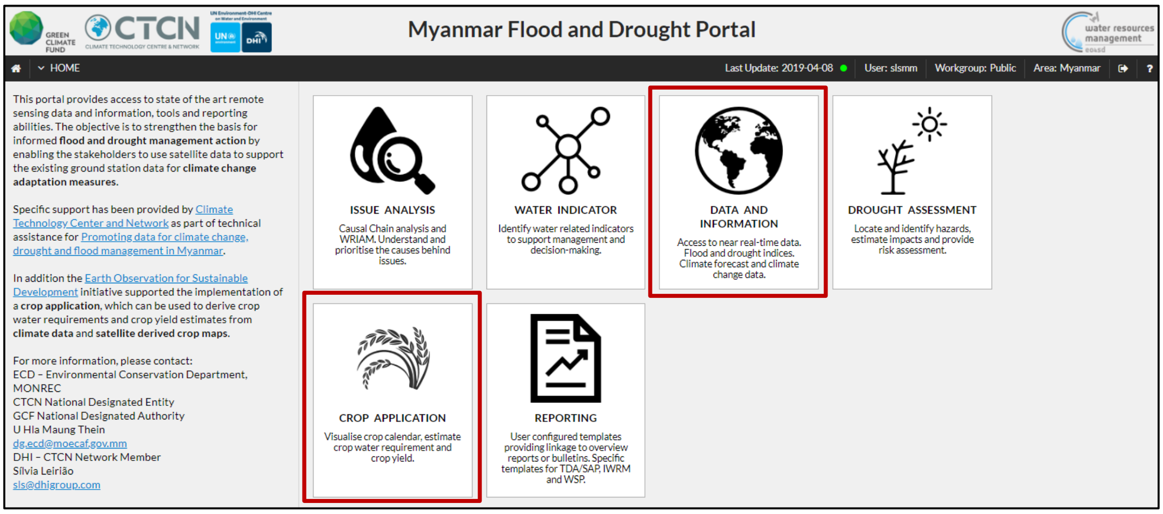


Figure 3.3 Home page of the portal, the data and information and crop applications highlighted in red.

There were participants attending new to the technical assistance, therefore, after the opening ceremony, a brief overview and status was provided.

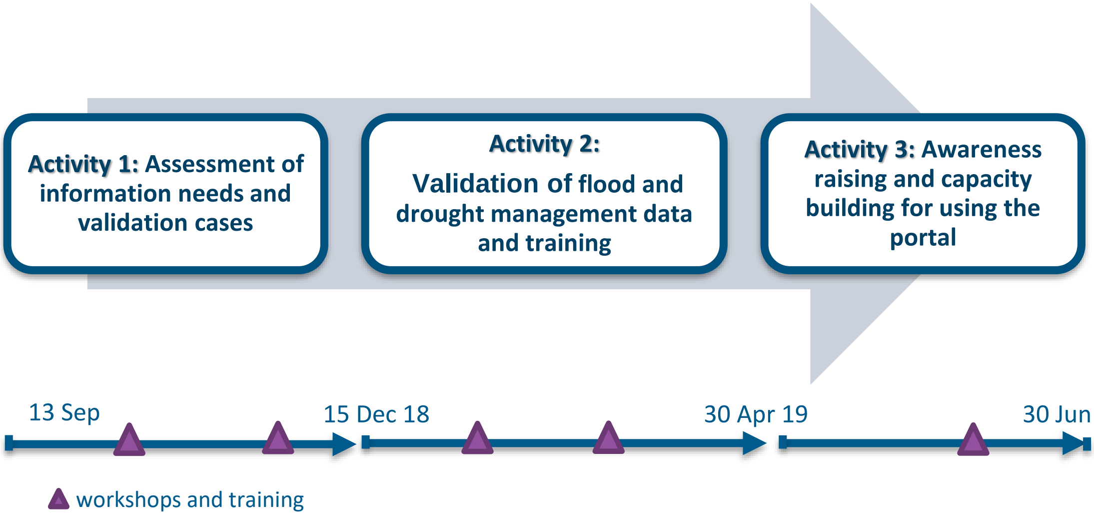


Figure 3.4 Diagram of the Activities of this technical assistance, timeline and key events.

Finally, preliminary results from validation were presented during the workshop. Namely, the result from the analysis of satellite rainfall validation. This analysis was carried out by our regional experts in hydrology the team from Hydro-Informatics Institute from Thailand and is inserted in chapter 4 of this report.

Figure 3.5 Presentation and discussion of validation results with participants (for details see chapter 4).

3.1 Data and Information

The first day and a half of the technical training were spent building on the training of the first national workshop (4-5 December 2018) and first technical training (19-20 February) events. Participants used the Data and Information application of the portal and started by focusing on the identifying and locating climate related hazards of relevance for seasonal planning. They worked with rainfall and temperature but also climate related indices, such as rainfall deviation and Standardised Precipitation Index (SPI).

These indices are indicators which can be used to draw conclusions on current status of climate in Myanmar. Indicators are a way to compile complex values or data into a simple interpretation of a state, e.g. drought or flood status. Therefore, they provide a means by which data can be combined and interpreted to make good decisions (or policies).

Firstly, participants were asked to choose an area of interest whether of hydrological or administrative boundaries and evaluate the rainfall deficit for the last 30 days (see Figure 3.6). They applied the portal tools and assessed how the rainfall is in the current month compared to the long-term average; how the trend is for the last 3 and 6 months (is the period wetter or dryer than expected); and if there are there areas within the country/basin where the rainfall is most below or above what would be expected.

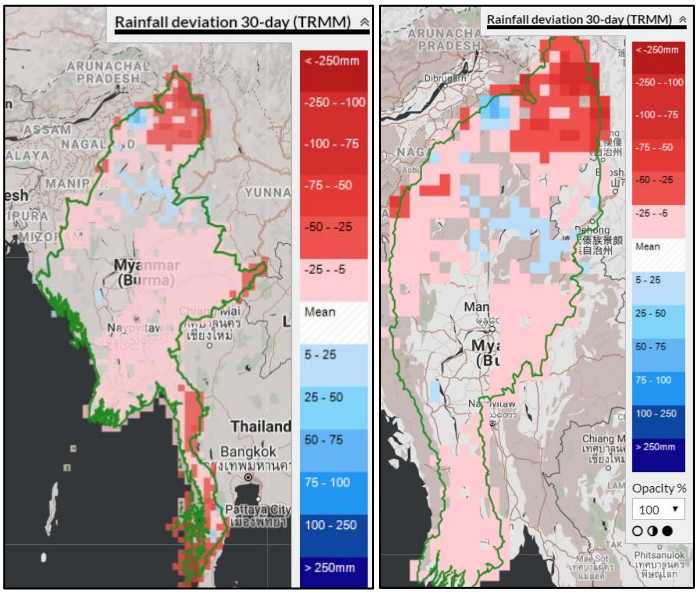


Figure 3.6 Rainfall deviation of the last 30 days (from 02/04/2019) as analyse by participant during identification exercise of climate related hazards, shown both the Myanmar and Ayeyarwady areas of the portal.

Next, participants were asked to evaluate the spatial distribution of the SPI values in search of potential drought related hazard within their areas of interest at the current time. They also analysed the whole period of record identifying historic events with extreme wet or dry conditions. Using several different tools such as the time series and column chart tools.

Participants evaluated the temperature variability within their areas, finding how the current temperature was and whether it could be classified as being different from normal.

Based on their combined evaluation of the rainfall, rainfall deviation, SPI and the temperature, they were asked to assess the status in their chosen areas and whether there are any signs of an upcoming climate related hazards. To this end, they also learned about the Effective Drought Index (EDI) and applied it to different areas in Myanmar to identify and characterize historical drought events.

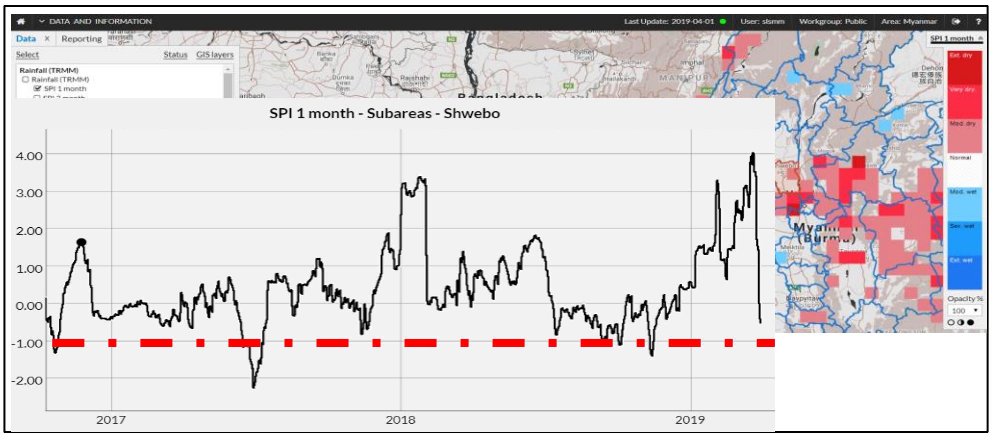


Figure 3.7 Examples of Shwebo district in Myanmar for which SPI values, namely negative occurrence of SPI below -1 indicative of dry conditions, were assessed by participants.

Next, participants evaluated the impact on crops and vegetation in general by looking at the Normalized difference vegetation index (NDVI) dataset and derived indicators. This satellite-based vegetation index is produced on 16-day intervals and at multiple spatial resolutions. It provides consistent spatial and temporal comparisons of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure.

Participants were asked to continue working on their chosen areas of interest and looking at the NDVI, identify different seasonal patterns and assess how the current season compares to the long-term average. They analysed NDVI deviation indicator as well as the Vegetation Condition Index (VCI) indicator and found areas where the vegetation growth is close to historic maximum (corresponding to VCI value close to 100%), or close to the historic minimum (corresponding to VCI value close to 0%).

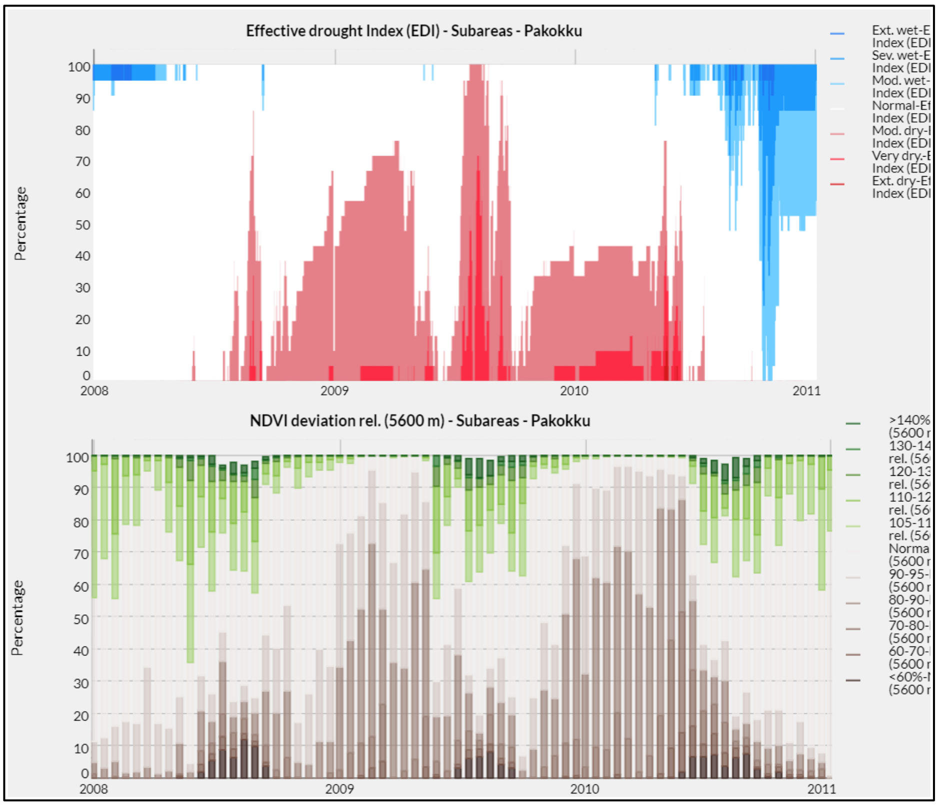


Figure 3.8 Example of column charts applied by participants to use the EDI and NDVI deviation indicators to their areas.

Finally, participants focused on the Soil Water Index (SWI), an indicator of daily information about moisture conditions in different soil depths. They identified years where the soil moisture appeared to be significantly lower than the average and combined this assessment with the results from the NDVI data to be able to draw holistic conclusion on occurrence of vegetation related hazards.

Figure 3.9 Participants at work during the data and information hands-on exercises.

3.2 Crop Application

The second part of the training focused on the Crop application. Since all the participants were new to this application, a presentation of the application was done at the beginning.

The Crop application is divided into three main sections:

- **Data**: provides a quick access to all datasets relevant for crop and related to the agriculture sector. The functionalities are similar to the Data and information application.
- **Crop calendar**: provides a crop and region-specific crop calendar based on global datasets
- **Yield estimates**: provides access to a tool that allows the user to calculate crop water requirements and yield estimate for specific crop based on the data available in the portal.

The participants started the hands-on exercises on the crop application by analysing the data available to better the crop phenology in the different regions or districts of the country. Crop phenology is the study of periodic events in the life cycle of living species. In the case of crops, understanding the timing of periodic events in the life cycle of a crop (start and end growing season) is relevant for various activities, such as irrigation scheduling, evaluating crop productivity impact of climate change, etc. The following datasets were used: historical ensemble from CHIRPS and NDVI long term average.

It was noted that most of the regions in Myanmar have one rainy season which is distinct from the rest of the year. However, it was noted that one region has a bi-modal rainy season, which means that two rainy seasons are occurring during the same hydrological year.

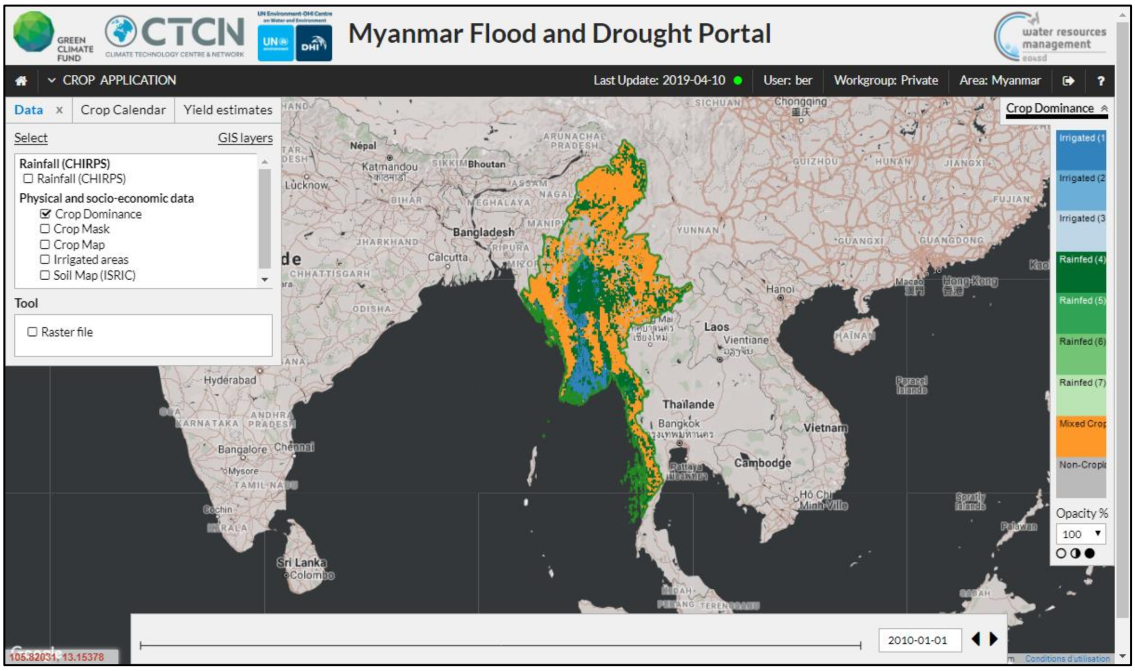


Figure 3.10 View of the data tab in the crop application

Afterwards the participants were asked to explore the crop calendar for the area they had selected. The crop calendar allows for display of typical planting, growing and harvesting periods for different crops. The data for the crop calendar is coming from the Center for

Sustainability and the Global Environment (SAGE), University of Wisconsin-Madison (https://nelson.wisc.edu/sage/data-and-models/crop-calendar-dataset/)

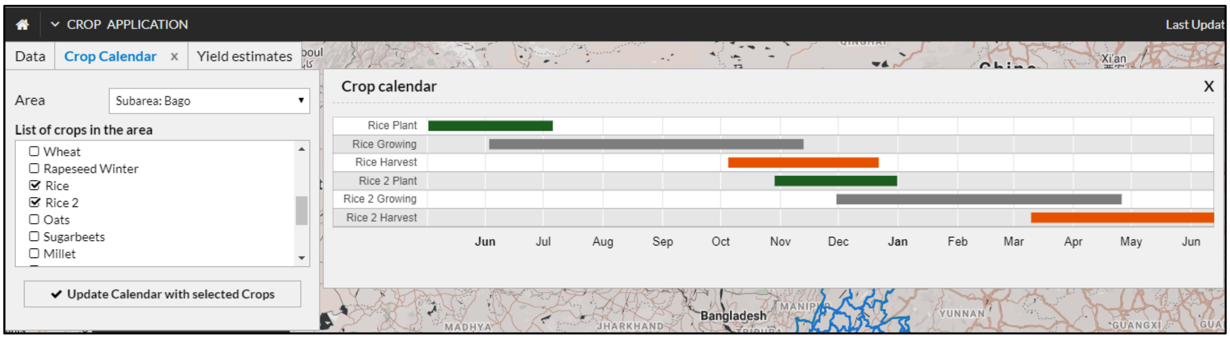


Figure 3.11 Crop calendar view showing dry and wet season rice in the Bago district.

Many of the participants questioned the accuracy of the data provided by University of Wisconsin-Madison. Two aspects were mentioned:

- spatial accuracy: many subareas were found to have the same crop calendar while it is known that they are differences between them

- Temporal accuracy: the suggested time for sowing seems to be slightly different from the one observed on the ground.

The participants recommended the integration of local crop calendars to complement this information. This has been recorded as an action to take place during Activity 3 of this technical assistance.

The last part of the hands-on exercises focused on the Yield estimates section of the crop application. The yield estimates tool is based on the AquaCrop tool for calculation of crop water requirements and yield estimates using underlying remote sensing data as forcing. AquaCrop is a crop water productivity model developed by the Land and Water Division of FAO (http://www.fao.org/land-water/databases-and-software/aquacrop/en/).

The AquaCrop model estimates the crop yield or the crop water demand under given conditions. The environmental conditions are specified by the user as input:

- weather conditions (rainfall, air temperature, and the evaporative demand of the atmosphere)
- soil characteristics
- crop characteristics
- field management practices (fertilizer management, irrigation, etc.)

By altering the input, the expected crop water demand or crop production and yield can be simulated for different environmental conditions. By entering forecasted climate conditions, the impact on yield and crop water demand under various climate change scenarios can be studied as well with the model.

Figure 3.12 Participants engaged in discussions during the crop application exercise, providing feedback on the crop information available in the tool.

In the “user defined” mode, the user can define different combinations of input parameters, which are displayed in the form of a table (see Figure 3.13).

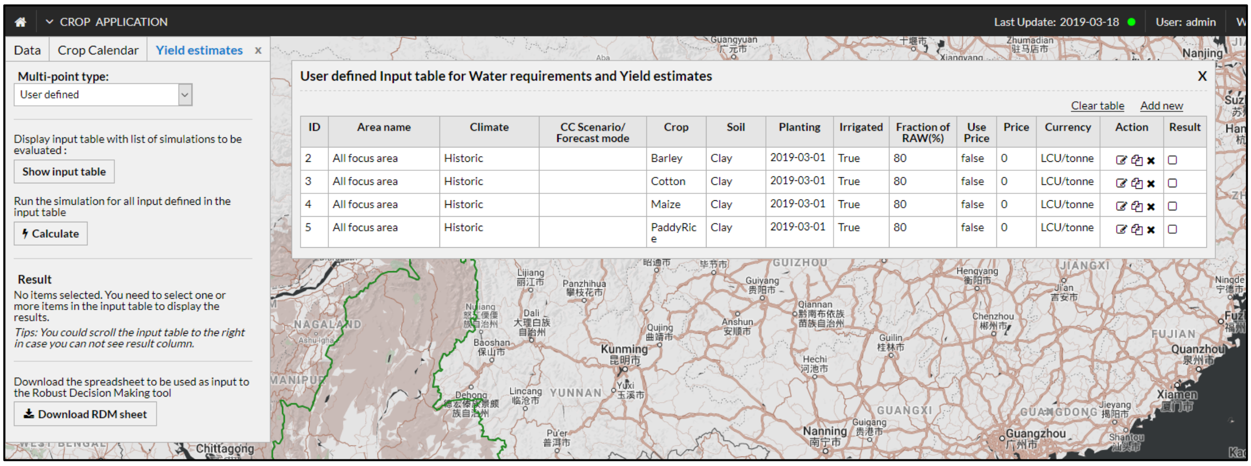


Figure 3.13 Table with input data in the Yield estimate tool in the crop application.

The participants were asked to calculate the irrigation demand for growing paddy rice in their district of interest during the dry season.

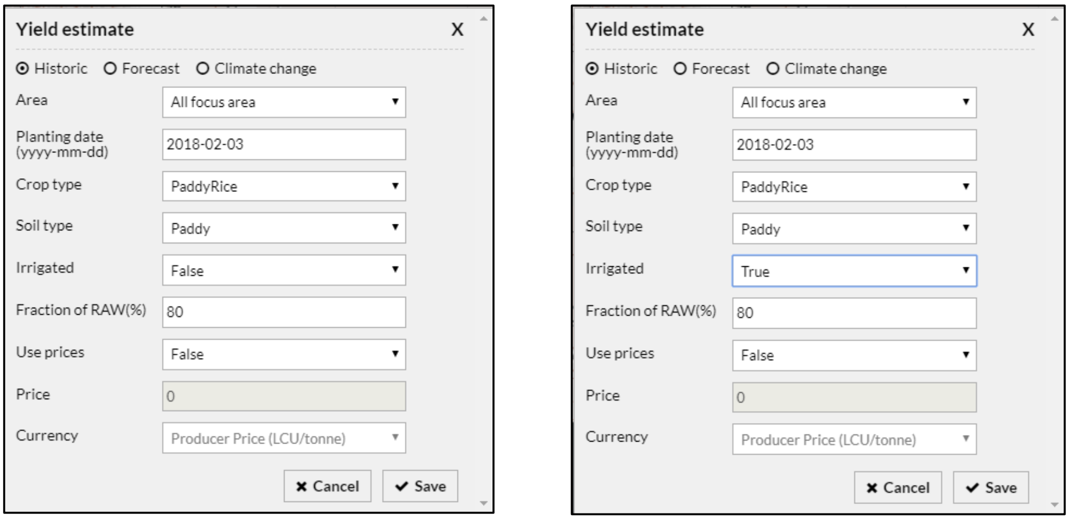


Figure 3.14 Dialog where the user can input the parameters for the yield estimates. These dialogs would lead to the same simulations but one with irrigation (right) and the other one without irrigation (left).

Many participants asked for clarifications about the parameter named “Fraction of RAW”. This parameter is used when the irrigation option activated and is the value for allowed depletion of the Readily available water (RAW), where RAW is the maximum amount of water that a crop can extract from its root zone without inducing stomatal closure and reduction in crop transpiration. The value is in percent and a default value is 80 %. Small values (0%) will lead to higher irrigation demand than large values (100%).

When selecting irrigation, AquaCrop will calculate during simulation the amount of water required to avoid crop water stress. When the root zone depletion exceeds a given threshold, a small amount of irrigation water will be applied to keep the root zone depletion just above the threshold. The threshold could be adjusted.

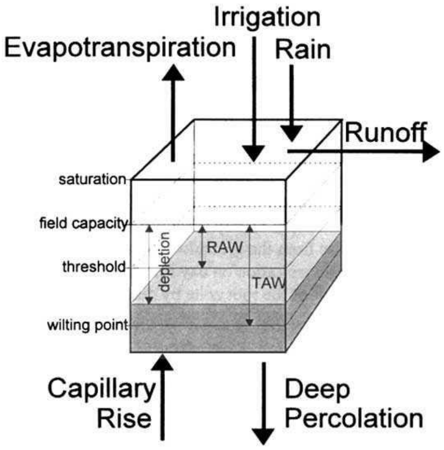


Figure 3.15 Concept image for the AquaCrop model (from FAO 56) explaining the relationship between RAW and TAW.

The total amount of irrigation water required to keep the water content in the soil profile above the threshold is the net irrigation requirement for the period

Once these concepts had been clarified, the participants were asked to use historical ensemble as well as climate change as input to the crop simulation model. This illustrated the strength of the Yield estimates tool, which can directly link to all the data available in the Data and information application to drive the model.

Finally, the participants were introduced to a new feature of the crop application, which allows to run yield estimates simulations directly based on spatial input. Instead of selecting all the parameters such as crop type, soil type etc some input data are directly derived from removed sensing images

The participants were specifically asked to compare the yield for paddy rice during the wet and the dry season.

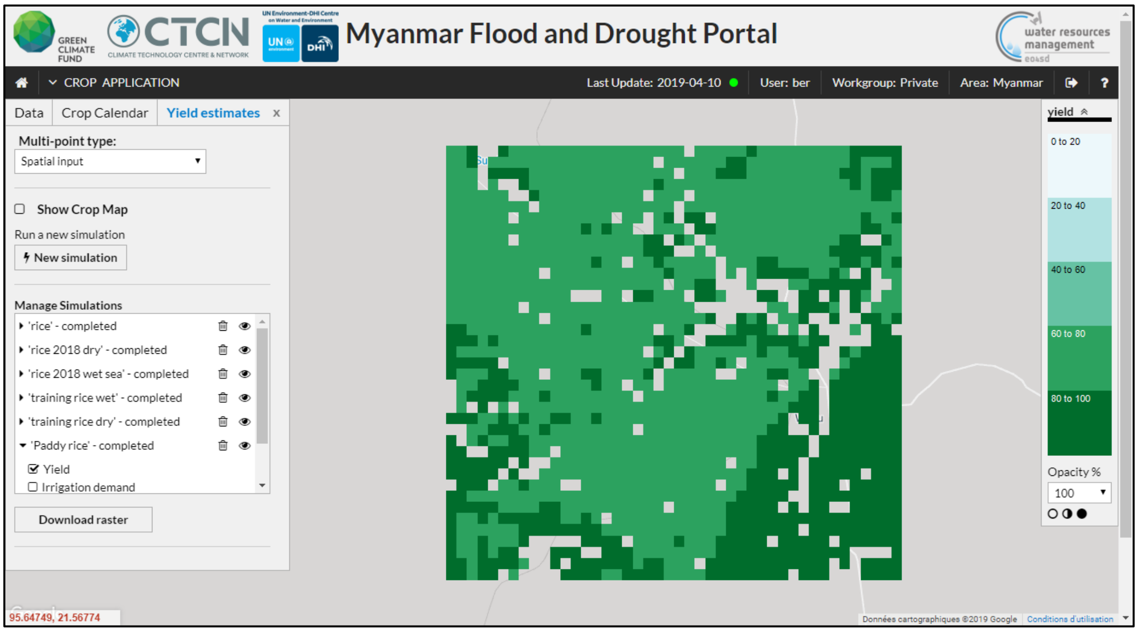


Figure 3.16 Results of the spatial input mode of the yield estimates tool in the crop application.

It was found that irrigated rice in the rice season yield to lower yield than non-irrigated rice during the wet season. These results were surprising for some participants since dry season rice is known to normally perform better than wet season rice.

Figure 3.17 Work and discussions during the exercises, where participants were asked to run simulations for different climate change scenarios using the crop application.

It was agreed that further investigation should be carry out to validate the results of the tool. Result from several years and for several locations should be taken into for a proper assessment.

In addition, the area being limited to 10,000 ha was found too restricting to fully take advantage of the tool. This limitation was enabled only due to computation limitation during the training when 30 users are using the tool at the same time. It was agreed that the limitation will be removed after the training.

3.3 Feedback from participants

The workshop was held over three days in Nay Pyi Taw followed by a complementing day for stakeholders in Yangon. The responses to these two workshops are treated separately. The feedback comes from the official CTCN evaluation form. The questionnaire is divided in two parts, where the first part regards satisfaction with the course and the second part is about previous knowledge and knowledge increase on several topics.

The questions in part 1 are:

- Relevance of the training course in relation to your work
- Quality of the presentations
- Time available for questions and discussions
- Format of the training course
- Overall satisfaction with the training course
- Contribution of the training course to your understanding of the topic

The topics in part 2 are:

- Knowing about this technical assistance
- Knowledge about remote sensing in Myanmar
- Viewing and downloading data from the portal
- How the use the data in flood and drought, WR studies

It is important to note all participants found this form hard to understand and to fill out. We have also found in our analysis of participant's answers to the form's quantitative questions, are many times contradictory and non sensical, which is an indication that the evaluation form should be improved.

3.3.1 Three-day technical training, Nay Pyi Taw

In Nay Pyi Taw there were 35 participants, of which 19 were male and 16 female. Of these, 23 responded in the evaluation.

Part 1

The overall satisfaction is high, with 78% being satisfied or significantly satisfied. However, 22%, corresponding to 5 people, are only moderately satisfied.

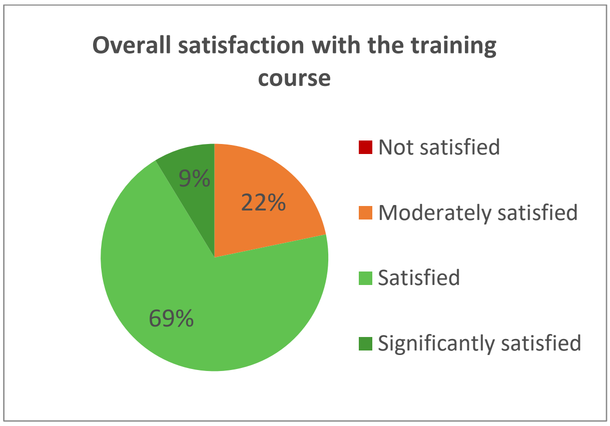


Figure 3.18 The overall satisfaction with the training course in Nay Pyi Taw.

69% of participants are satisfied or significantly satisfied with the relevance of the training course to their work. The remaining 31% are moderately satisfied.

Part 2

The knowledge increase is generally not so high, with 35-57% saying that their knowledge was only moderately increased for all four topics in this part of the questionnaire. For three of the topics, only one person feels that their knowledge has significantly increased, while no one feels so in the last case. For two of the four topics, one person feels that their knowledge has not increased at all. The highest knowledge increase is for knowing about this technical assistance where 61% find that their knowledge has increased or significantly increased and no participants state that their knowledge has not increased.

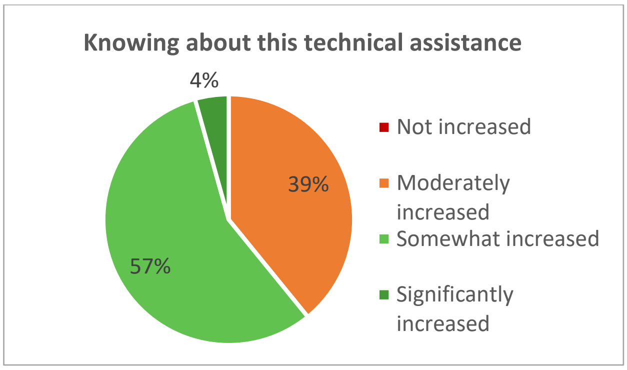


Figure 3.19 Knowledge increase regarding the technical assistance for participants in Nay Pyi Taw.

The smallest knowledge increase is for knowledge about remote sensing data for Myanmar, 57% feel that their knowledge has only moderately increased, 4% (one person) feels that their knowledge has not increased at all, and no one feels that their knowledge has significantly increased.

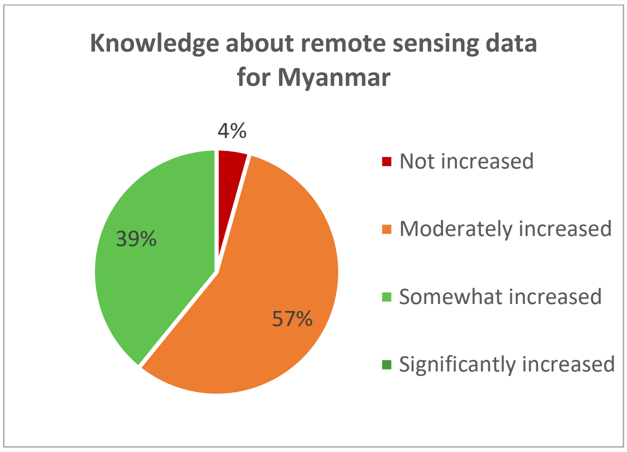


Figure 3.20 Knowledge increase for remote sensing data in Myanmar for the participants in Nay Pyi Taw.

It makes sense that there is a large knowledge increase for knowing about this technical assistance as 68% have only some prior knowledge on this topic and 23% had no prior knowledge.

For the topic remote sensing for Myanmar, 33% had no prior knowledge and 48% had only some prior understanding. 14% had very good prior understanding.

Comments

One comment calls for more crops to be added and for the crop calendar to be updated. Another specifically wants to be able to specify varieties of pulses.

Quite a few comments question the reliability and coverage of the data. One comment states that the remote sensing data should be validated that the data should be modified to be reliable data for Myanmar. Three other comments say that the data should be updated or that data should be correct, collected from the right places, and applied correctly. One participant has found data gaps and would like some additional data, such as sea level rise.

Regarding the training, one comment would like more technical training. Another asks for the validation processes to be covered while one participant would like some examples of application areas using the available data. One person wants to learn more about remote sensing, while another calls for knowledge on RCP's and model parameters.

In response to the above comments, it falls outside of the technical assistance scope to validate all data in the portal. It is a characteristic of this technical assistance that the pool of stakeholders is increased with time as the user community grows. It is expected as this happens there is a tendency to lose sight of the whole context. In addition, it is possible that some training participants could not be present during the first session of the first day, which is when the introduction and status of the technical assistance is customarily presented. The next chapter presents the data validation carried out within the scope of work.

Finally, it has been agreed that is crop calendar data is successfully collected from the Department of Agriculture, it will be added to the portal during Activity 3.

3.3.2 One-day training, Yangon

There were 11 participants for the workshop in Yangon. The participants were all female and came from the Hydro-Informatics Centre (HIC) and ICEM.

Part 1

Overall, participants are very satisfied with the training course, with 55% being significantly satisfied and only 18% being moderately satisfied. No participants state that they are not satisfied. The least satisfaction is with the time available for questions and discussions, with 36% being only moderately satisfied or not satisfied and only 9% being significantly satisfied. Considering there were 11 participants this amounts to 1 person who replied not satisfied and one person significantly satisfied.

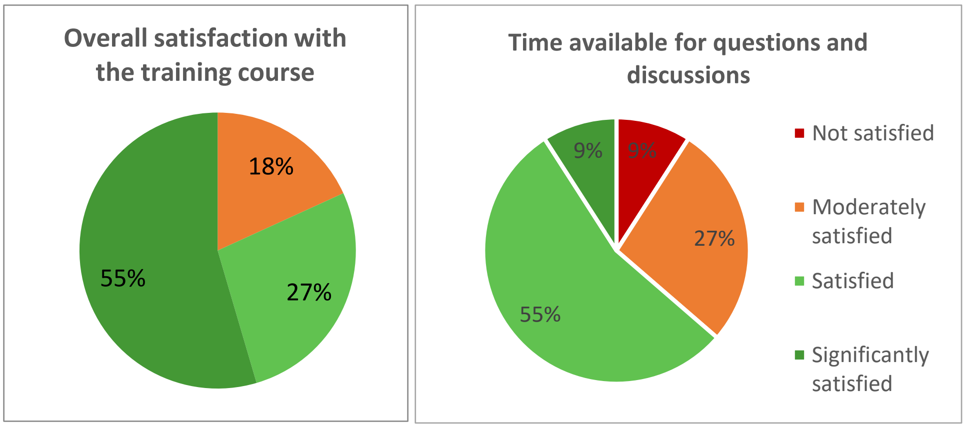


Figure 3.21 Charts showing the overall satisfaction with the training course (left) and the satisfaction with the time available for question and discussions (right) for the training course in Yangon.

Most participants find the course relevant, with 27% being moderately satisfied and no participants who are not satisfied. Regarding the format of the training course, opinions differ. 27% are moderately satisfied or not satisfied, but there are also 27% who are significantly satisfied.

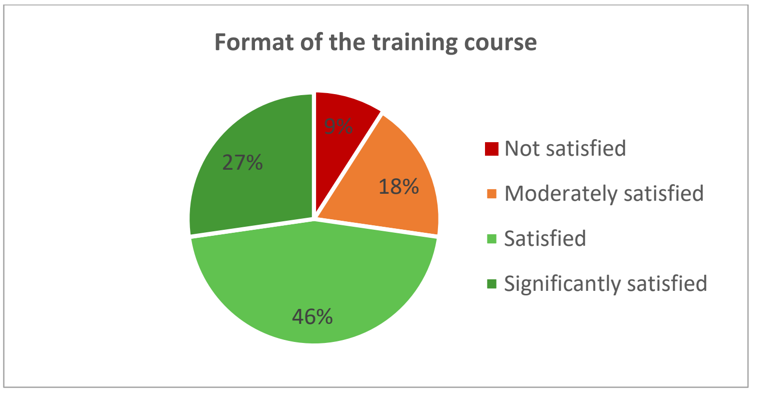


Figure 3.22 Figure showing the satisfaction with the format of the training course for the workshop in Yangon.

Part 2

Regarding knowledge increase, 46-64% of participants state that their knowledge was somewhat increased for all four topics. The largest knowledge increase was regarding viewing and downloading data from the portal, where the knowledge for 5 persons was somewhat increased and for 5 persons was significantly increased. One person did not answer.

The smallest knowledge increase is for knowledge about remote sensing data for Myanmar where the knowledge for 18% was only moderately increased and only another 18% found that their knowledge was significantly increased.

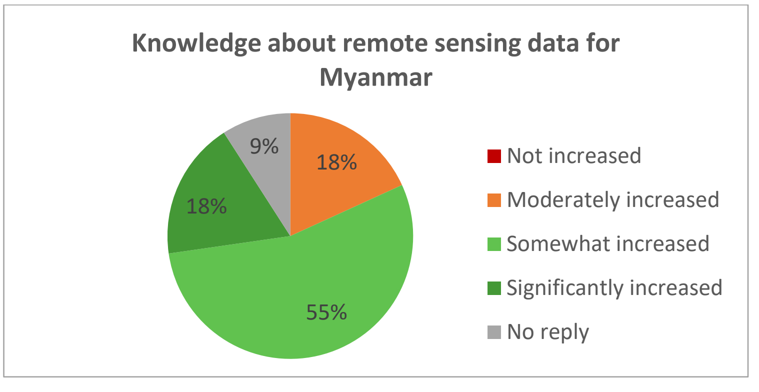


Figure 3.23 Knowledge increase for remote sensing data for Myanmar for the participants in Yangon.

Large and small knowledge increases do not seem to be related to prior knowledge, as 46% stated that they had good prior understanding about remote sensing data for Myanmar, while 18% had good prior understanding and 27% had very good prior understanding of viewing and downloading data from the portal. The same number of participants, 18%, had no prior knowledge for both topics.

Comments

There are four comments from participants. One finds the time too limited and another specifies that they would like more time to analyse the differences between results and outputs. The same person also calls for more detailed explanations of some factors.

One person finds the portal useful but thinks that is too complicated for “normal users”. Contrarily, another thinks that it is very useful as a planning tool and that it is easy to download data.

4 Validation

This chapter presents the final methodology for validation of datasets and locations selected by stakeholders in accordance with **Deliverable 3 (activity 1.3) Technology specifications and methodology for validation** report. The validation process took place during Activity 2 based on the feedback from stakeholders during the first national workshop and input from the ECD, and the selection process for the locations in Myanmar is reported in **Deliverable 2 (activity 1.2) Workshop report and cases for validation**.

The aim of validation is to 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 depended on the availability of historical data and on the successful collection of information from the stakeholders. The ECD and the efforts of the Climate Change Division were the most important factor in ensuring observed data was collected from the DMH, the DDM and the Department of Agriculture.

This chapter describes the location, climate and other geomorphological features of study area, the available data and methodology used in the validation process, and finally, the results are presented and discussed.

4.1 Flood and drought affected areas

The study areas were selected based on two categories; flood and drought. According to the information from stakeholders and historical record, the lower part of Myanmar especially in Bago, Kayin and Mon state for flooded areas and central dry zone of Myanmar for drought-affected area.

Bago is located between 16°45'N and 19°20'N and 94°35'E and 97°10'E. Total area of Bago region is 39,402.3 km^2, total length of Bago River is 352 km, average yearly maximum discharge is 1080 m^3/s and population density at the year 2014 is 120 pers./km^2. Bago River normally floods every year. The severe flood in Bago city occurred in 2013, 2015 and 2018 by seeing flood hazard maps from MIMU. Kayin State is located between latitudes 15° 45' north and 19° 25' north and longitudes 96° 10' east and 98° 28' east. It is bordered by Mon State and Bago Region to the west and south. Hpa-An is the capital of Kayin state and flood was happened in it. The total area of Kayin State is 30,382.8 km^2 and population density is 52 pers./km^2 contributing to 2014 Census data. Also, the neighbouring state; Mon is also chosen for validation because Mawlamyine; the capital of Mon state had flood in 2018. The population was 2,054,393 according to 2014 Census and total area is 12,296.6 km^2.

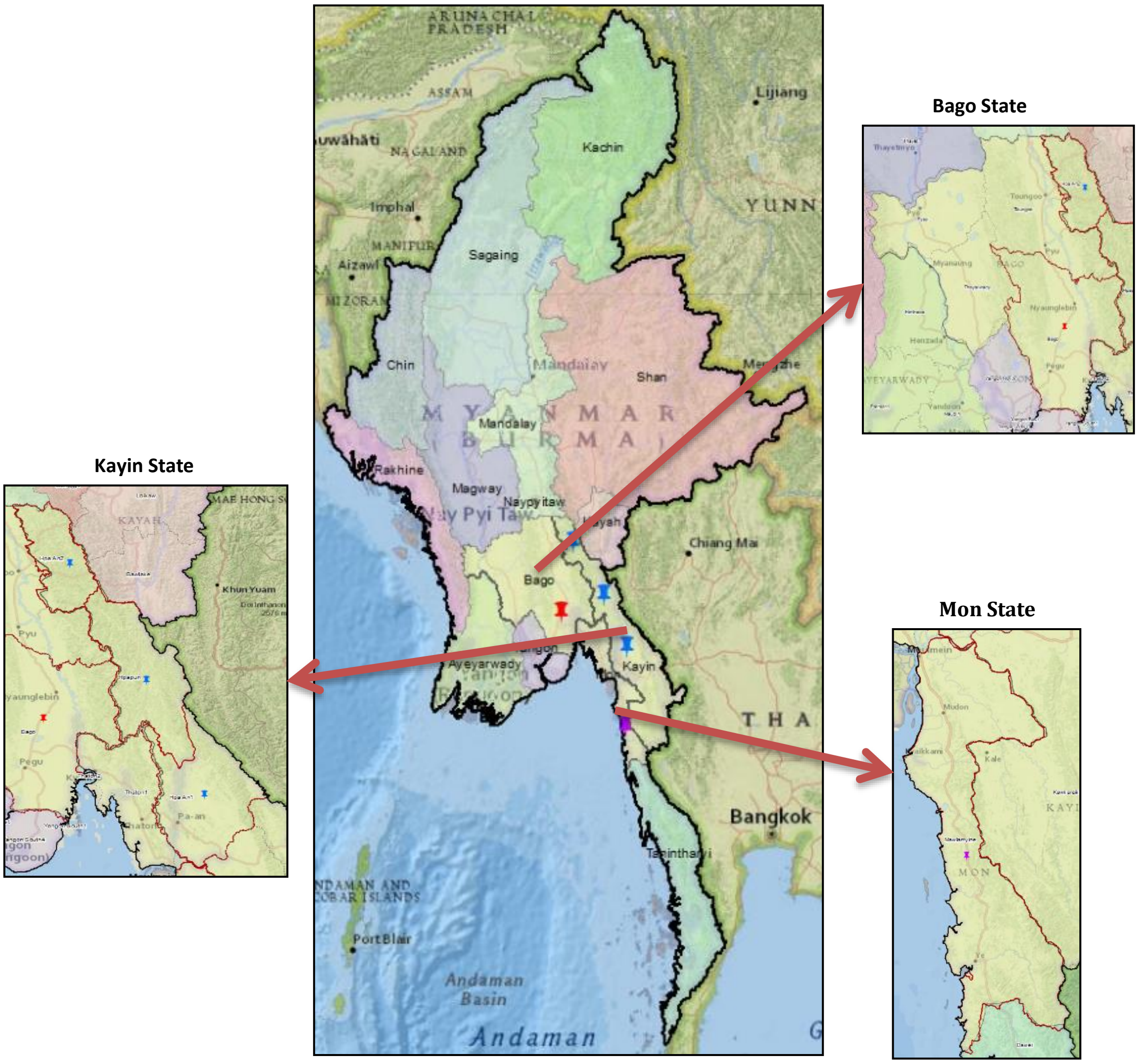


Figure 4.1 Location of flooded regions; Bago, Kayin and Mon State.

The Dry Zone is part of the central plain of Myanmar, sandwiched by the mountainous zone on the west, and the highlands on the east. It is mostly flat, with the Ayeyarwaddy flowing through it from north to south.

The Chindwin and the Ayeyarwaddy are major rivers and pass through the Dry Zone area from North to South towards the Delta region of the South part and then flow into Bay of Bangal. The position of this area is between latitudes 19°20'N and 22°50'N and longitudes 93°40'E and 96°30'E covering Sagaing, Mandalay and Magway Regions.

This region is approximately 10% of the country's total area and is about 870,000 km^2 according to record from Dry Zone Greening Department (DZGD). For validation, Magway, Mandalay and Myingyan are selected because there have been notable droughts in those areas.

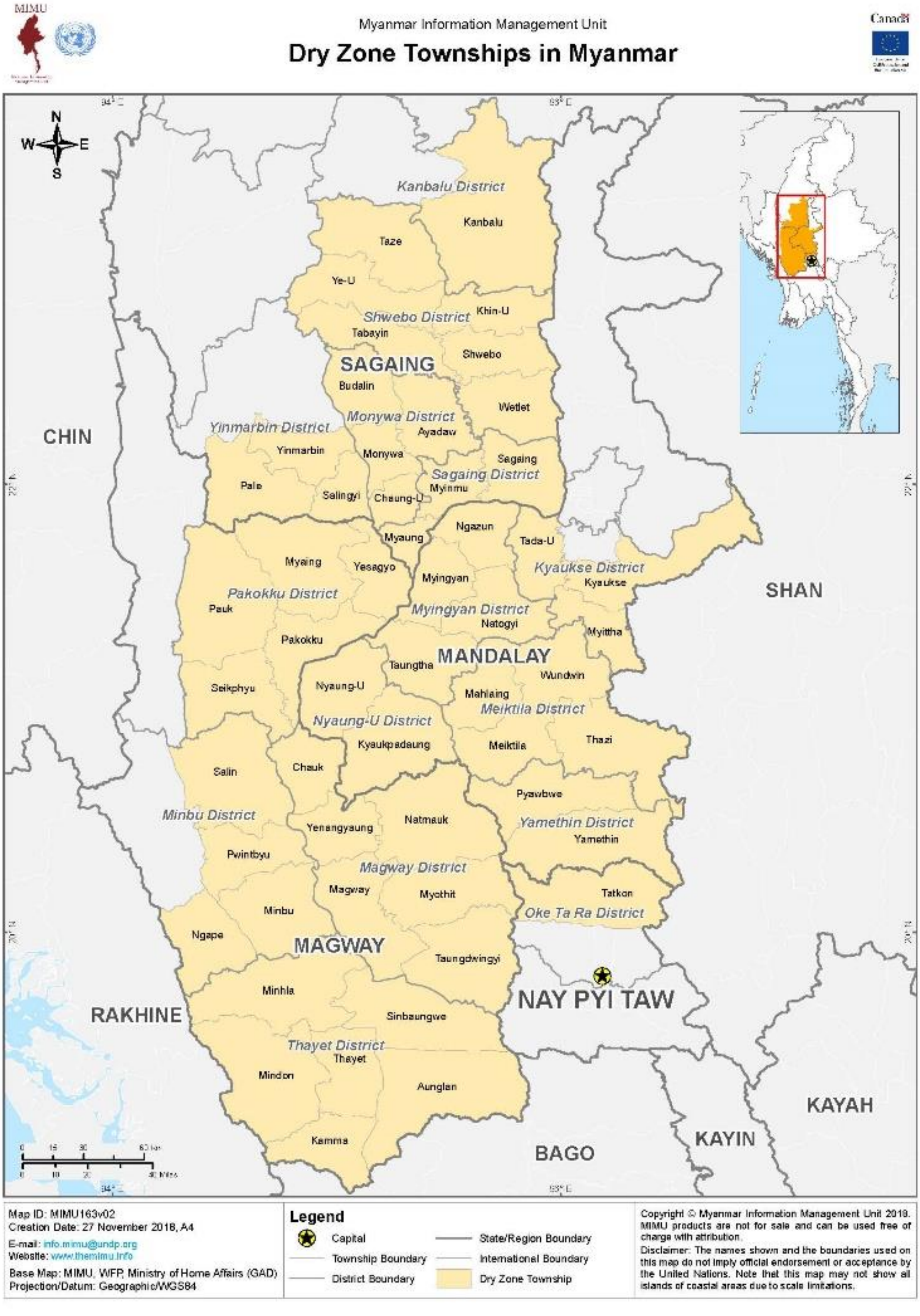


Figure 4.2 Location of central dry zone in Myanmar (source: MIMU).

4.2 Available data

For satellite rainfall validation, three satellite-based datasets: CHIRPS, TRMM and GPM are used to compare with observed rainfall. The characteristics of the types of data are presented in Table 4.1 and are briefly described as follows:

- Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a 30+ year quasi-global rainfall dataset. Spanning 50°S-50°N (and all longitudes), starting in 1981 to near-present, CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring. As of February 12th, 2015, version 2.0 of CHIRPS is complete and available to the public.

- The Tropical Rainfall Measuring Mission (TRMM) is the first Earth Science mission dedicated to studying tropical and subtropical rainfall. It measures precipitation that falls within 35 degrees north and 35 degrees south of the equator.

- The Global Precipitation Measurement (GPM) mission is an international network of satellites that provide the next-generation global observations of rain and snow. Building upon the success of the Tropical Rainfall Measuring Mission (TRMM), the GPM concept centers on the deployment of a 'Core' satellite carrying an advanced radar / radiometer system to measure precipitation from space and serve as a reference standard to unify precipitation measurements from a constellation of research and operational satellites. Through improved measurements of precipitation globally, the GPM mission is helping to advance our understanding of Earth's water and energy cycle, improve forecasting of extreme events that cause natural hazards and disasters, and extend current capabilities in using accurate and timely information of precipitation to directly benefit society. GPM, initiated by NASA and the Japan Aerospace Exploration Agency (JAXA) as a global successor to TRMM, comprises a consortium of international space agencies, including the Centre National d'Etudes Spatiales (CNES), the Indian Space Research Organization (ISRO), the National Oceanic and Atmospheric Administration (NOAA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and others.

Table 4.1 Climate data for satellite rainfall validation.

No	Data	Source	Record	Frequency	Spatial Resolution	Coverage
1	Rainfall	CHIRPS, Climate Hazard Group	1981 - 2018 (present)	Daily	0.05 deg	All
2	Rainfall	TRMM; NASA, JAXA	2000 - 2018 (present)	Daily	0.25 deg	All
3	Rainfall	GPM, NASA	2014 - 2018 (present)	Daily	0.1 deg	All
4	Temperature	Level 3 MODIS global Land Surface Temperature (LST)	2000-2018 (present)	8- daily	1km deg	All

No	Data	Source	Record	Frequency	Spatial Resolution	Coverage
5	Rainfall	DMH	2010-2018	Monthly	Station data	Hpa-An
6	Rainfall	DMH	2010-2018	Monthly	Station data	Shwegyin
7	Rainfall	DMH	2010-2018	Monthly	Station data	Magway
8	Rainfall	DOA	2010-2018	Monthly	Station data	Mawlamyine
9	Rainfall	DOA	2010-2018	Monthly	Station data	Myingyan
10	Max, Min Temperature	DMH	2010-2018	Monthly	Station data	Hpa-An
11	Max, Min Temperature	DMH	2010-2018	Monthly	Station data	Shwegyin

Flooded years can be seen obviously due to the flood impact data from Department of Disaster Management. According to the record, flood affected households and population were higher in 2018 than others in Mawlamyine. In Hpa-An, 2018 had the highest affected population and household, with 11,699 and 2,346 respectively. Therefore, it can be assumed that 2018 was a flooded year for Mawlamyine and Hpa-An cities. Flood events periods are collected from MIMU flood hazard maps.

Table 4.2 Historical flood events record.

Dates of flood events (MIMU)		
Bago (Bago State)	**Mawlamyine (Mon State)**	**Hpa-An (Kayin State)**
29-Jul-18	25-Jul-18	2-Aug-18
28-Jul-15	2-Aug-18	6-Aug-18
17-Aug-15	6-Aug-18	18-Aug-18
11-Aug-15	14-Aug-18	19-Aug-18
9-Aug-15	19-Aug-18	22-Aug-18
31-Oct-13	22-Aug-18	-
2-Nov-13	-	-

Along with floods, there are drought-stricken areas in Myanmar, which have devastating impacts on agriculture, quality of life of farmers and national economy. Stakeholders during the first national workshop selected drought as a key issue in Myanmar. 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.

Table 4.3 Types of drought related indicators for drought index validation.

No	Data	Source	Record	Frequency	Spatial Resolution	Coverage
1	SPI1 (Standardised Precipitation Index) comparison of precipitation over a specific 1 month period	TRMM	2000-2018 (present)	Daily	0.25 degree	All
2	SPI3 (Standardised Precipitation Index) comparison of precipitation over a specific 3 month period	TRMM	2000-2018 (present)	Daily	0.25 degree	All
3	SPI6 (Standardised Precipitation Index) comparison of precipitation over a specific 6 month period	TRMM	2000-2018 (present)	Daily	0.25 degree	All
4	NDVI (Normalized Difference Vegetation Index)	Terra-MOD13C1 (5600m)	2000-2018 (present)	16-Daily	5600m to 250m	All
5	NDVI deviation	NDVI data	2000-2018 (present)	16- Daily	5600 m to 250m	All
6	SWI (Soil Water Index)	METOP-ASCAT satellite	2007-2018 (present)	10-day	0.1 degree	All
7	SWI percentile	SWI data	2007-2018 (present)	10- day	0.1 degree	All

In addition, Annual Damage of Crops and Annual Irrigated Agriculture of Summer Crops in selected townships are collected from Department of Agriculture. These records are useful for validation of drought indices and they can be found in Appendix A.

4.3 Methodology for validation

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. Therefore two methodologies are presented. 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.

The objective of the portal is also to provide a better understanding of the climate at regional and national scale. Rainfall estimates from remote sensing at a large catchment scale might actually be more accurate than from single stations, since there is not a sufficient coverage of stations in the entire country.

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.

Firstly, three satellite datasets such as CHIRPS, TRMM and GPM are chosen and observed rainfall data are collected from DMH. Before comparing with observed data, satellite data are compared to see the correlation and deviation between them. After that, observed rainfall and satellite data are compared at each station. The comparisons are made in flooded years which are collected from MIMU flood hazard maps.

Secondly, performance indicators are used to check the validation and the results discussed. The methodology for validating of satellite rainfall is schematized in Figure 4.3.

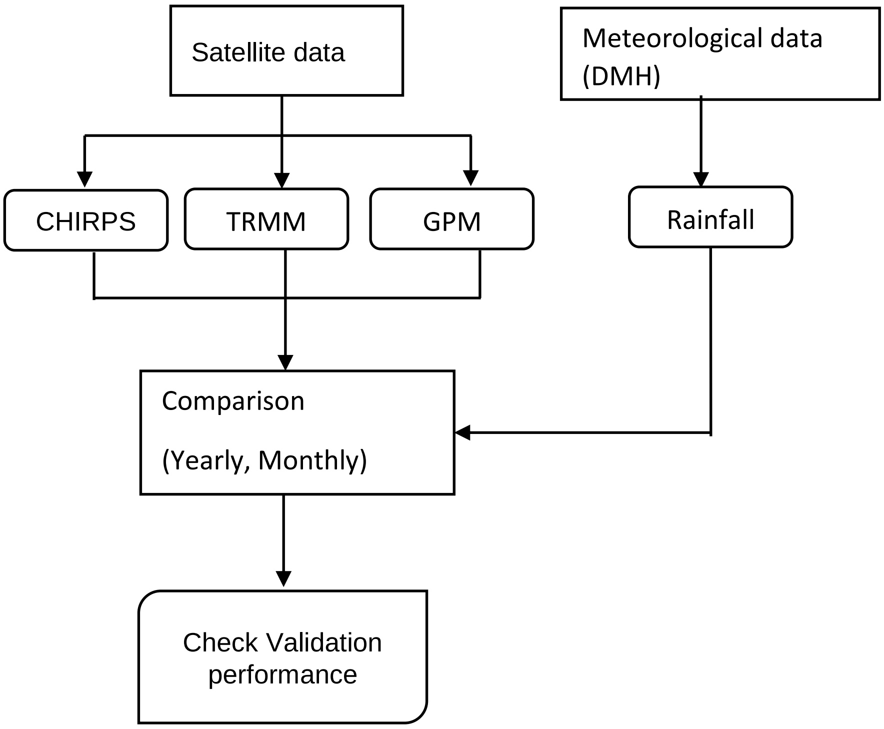


Figure 4.3 Flow chart for satellite rainfall validation.

According to drought facts (FAO, 2013), drought can be defined according to meteorological, agricultural, hydrological, and socio-economic criteria.

- Meteorological, when precipitation departs from the long-term normal;
- Agricultural, when there is insufficient soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought is typically evident after meteorological drought but before a hydrological drought;
- Hydrological, when deficiencies occur in surface and subsurface water supplies;
- Socio-economic, when human activities are affected by reduced precipitation and related water availability. This form of drought associates human activities with elements of meteorological, agricultural, and hydrological drought.

Datasets required to assess each type of drought are listed in the following table.

Table 4.4 Required datasets for Drought Indicator and types of drought.

Drought Parameter/ Drought Index	Drought Indicator			Types of Drought		
	Short-term	Seasonal	Annual	Meteorological Drought	Agricultural Drought	Hydrological Drought
Rainfall	✓	✓	✓	✓		
Temperature	✓	✓	✓	✓	✓	✓
SPI	✓	✓	✓	✓		
NDVI	✓	✓	✓		✓	
SWI	✓				✓	

First, yearly satellite and observed rainfall are analysed to choose the drought year by seeing the lowest rainfall period. Comparisons are made between SPI 1, 3, 6, NDVI, NDVI deviation, SWI and SWI percentile. Detailed procedure can be found in the following Figure 4.4.

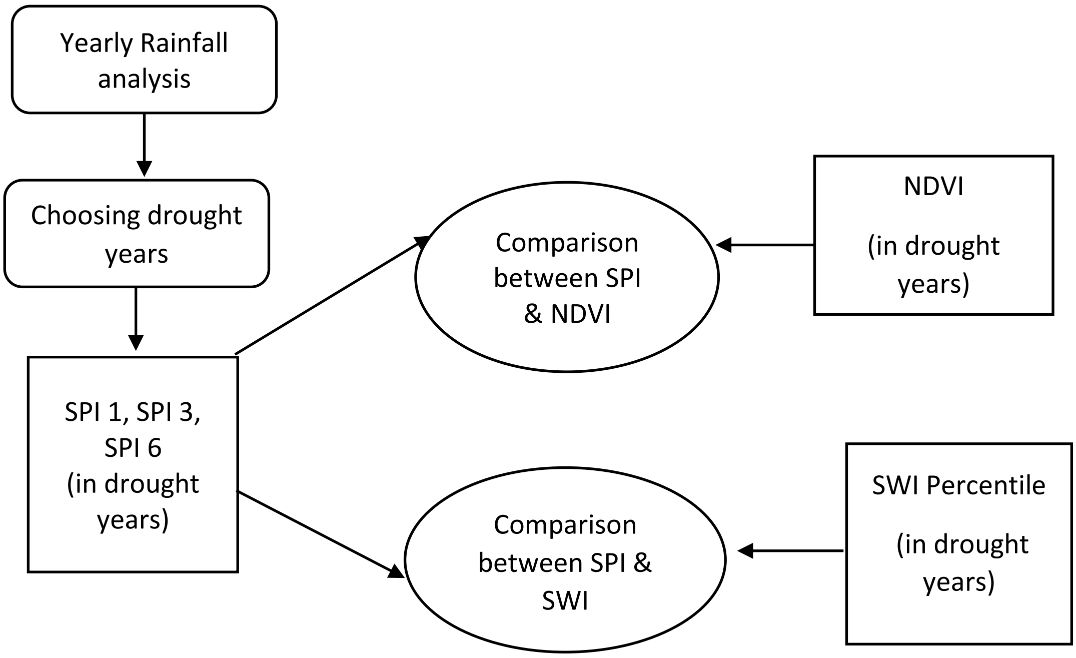


Figure 4.4 Flow chart for drought index validation.

4.4 Analysis of validation performance

To check the performance of validation, error parameters are calculated. Mean Absolute Error (MAE), Mean Absolute Deviation (MAD), Coefficient of determination (R2) and Percentage Difference are calculated to see the correlation and deviation. The formulations of these error estimations are as follows;

(a) Mean Absolute Error (MAE)

$$\mathrm{MAE} = \frac{\sum_{i=1}^{n}|y_i - x_i|}{n}$$

Where y_i is observed value and x_i is satellite value.

(b) Mean Absolute Deviation (MAD)

$$MAD = \frac{\sum_{i=1}^{n}|x_i - x^{-}|}{n}$$

Where x_i is observed or satellite value and x^{-} is average of that values.

(c) Coefficient of determination (R2)

$$R^2 = \frac{\sum_{i=1}^{n}[(x_i - x^{-})(y_i - y^{-})]^2}{\sum_{i=1}^{n}(x_i - x^{-})^2 \sum_{i=1}^{n}(y_i - y^{-})^2}$$

Where, x_i and y_i are observed and satellite data and $x^{-}$and y^{-} are average data of these two datasets.

(d) Percentage difference

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

Where p_1 and p_2 are precipitation by collected satellite and observed station.

4.5 Results

4.5.1 Analysis of Satellite Rainfall data

First of all, satellite data sets are compared for three states; Bago, Kayin and Mon and for five cities; Bago, Hpa-An1, Hpa-An2, Hpapaun and Mawlawmying. Yearly and monthly graphs are prepared to see the trend and correlation between each dataset. According to the graphs of Bago state, TRMM has the highest yearly averaged rainfall followed by GPM and CHIRPS. However, for Bago City, TRMM has averaged yearly rainfall (3012 mm) which is quite close to the observed average rainfall (2993 mm). A year of 2015 was picked up as flooded year for Bago and the trend looked similar for all datasets in comparison charts. For the peaks, TRMM was the highest, followed by CHIRPS and GPM.

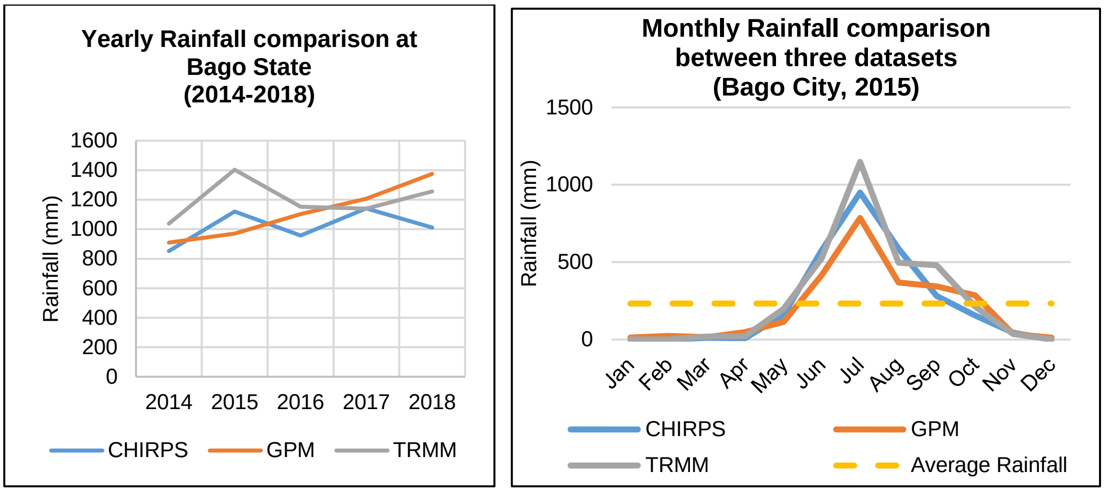


Figure 4.5 Yearly rainfall at Bago State; Satellite Monthly Rainfall comparison for Bago city in 2015.

Hpa-An is located in Kayin State and there is a validation with observed data for it in the following section. For yearly average rainfall, CHIRPS had the highest followed by TRMM and GPM. It is obvious that CHIRPS and TRMM were going to increase rainfall in 2018 which was recorded as flooded year. As 14 August 2018 was recorded as the date for flood, it can be said true by seeing the obvious peaks in this period. All datasets showed a similar trend and GPM has the highest peak followed by TRMM and CHIRPS. In Mon State, CHIRPS has the highest average yearly rainfall whereas GPM and TRMM values are closed enough with 2682.5mm and 2563.6mm. Same with Kayin state, 2018 is chosen as flooded year and three satellite data are compared for that year. In this case, GPM and CHIRPS coincide in rainfall peaks whereas TRMM had a slight gap with them. In addition, it can be stated that July and August are flooded months because the significant peaks occurred in that period.

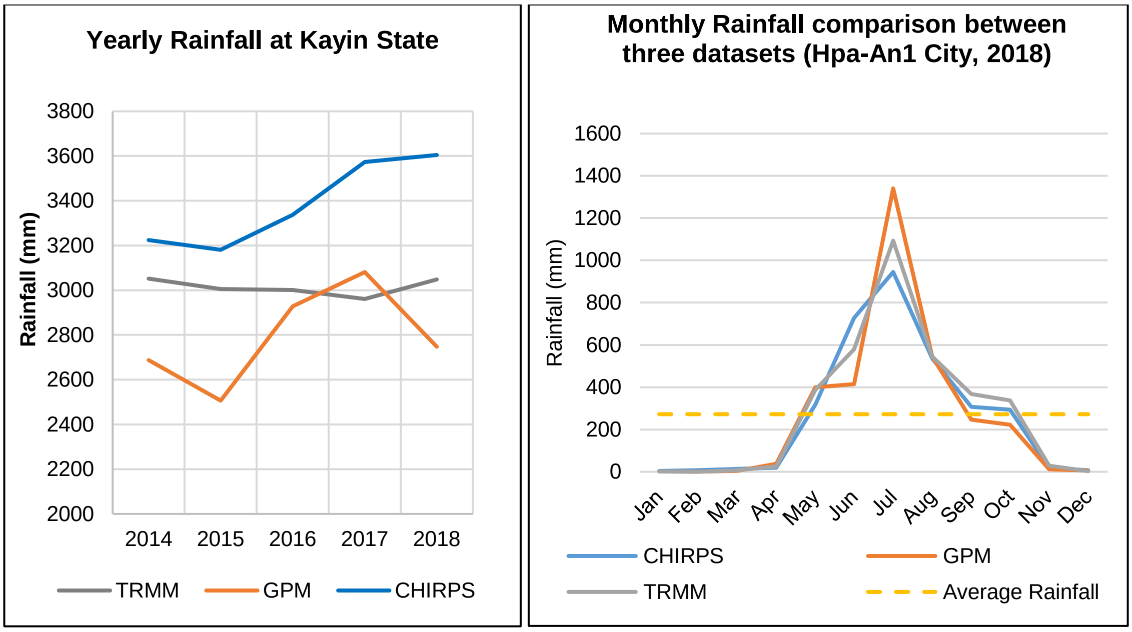


Figure 4.6 Yearly Rainfall at Kayin state; Satellite monthly rainfall comparison for Hpa-An1 city (2018).

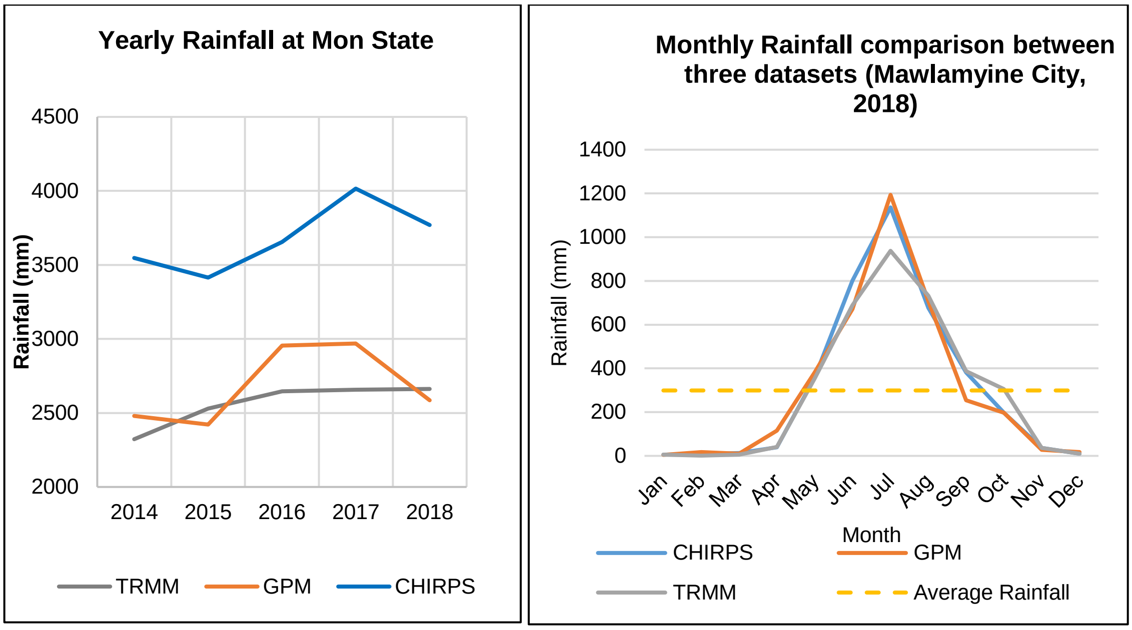


Figure 4.7 Yearly Rainfall at Mon State; Satellite monthly rainfall comparison for Mawlamyine city (2018).

4.5.2 Validation performance with satellite rainfall data

Satellite rainfall data for all cities and states are collected in the period of (2014-2018). Overall, all data has good correlation .TRMM and GPM has a lower difference than the others. It might be possible because GPM is a new version of TRMM and it uses a similar detector with the new function. The difference between CHIRPS and TRMM is similar to CHIRPS and GPM. The value of difference is higher than 70 percent in all states, while they provide lower value in the cities. Because the area of city is smaller than the state, which means that, the rainfall variation will be less in cities rather than states.

Table 4.5 Coefficient of determination (R2) between satellite rainfall for cities and states.

State/ City	CHIRPS & TRMM	CHIRPS & GPM	TRMM & GPM
Bago State	0.84	0.69	0.79
Kayin State	0.92	0.85	0.91
Mon State	0.88	0.84	0.89
Bago City	0.91	0.88	0.96
Hpa-An1City	0.90	0.81	0.94
Hpa-An 2 City	0.88	0.84	0.91
Hpapun City	0.82	0.77	0.94
Mawlamyaing City	0.93	0.89	0.94

Table 4.6 Percentage difference between satellite rainfall for cities and states.

State/ City	CHIRPS & TRMM	CHIRPS & GPM	TRMM & GPM
Bago State	70.34	77.55	50.94
Kayin State	75.57	79.44	58.48
Mon State	75.52	77.77	61.12
Bago City	45.09	64.18	59.44
Hpa-An1City	56.20	58.17	51.46
Hpa-An 2 City	48.61	70.88	58.70
Hpapun City	47.60	59.46	61.3
Mawlamyaing City	48.30	50.54	40.67

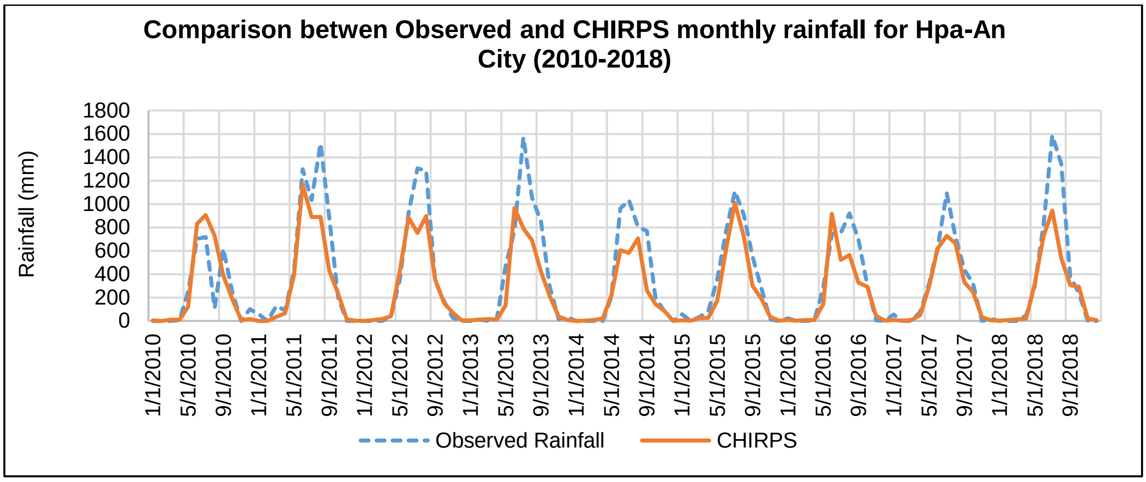
To calculate the mean absolute error (MAE), satellite rainfall in the period of (2014-2018) are used. MAE represents the difference between two dataset. MAE of CHIRPS and GPM is higher than others which is same with percentage difference. The MAE values between GPM and TRMM, and CHIRPS and TRMM are very low, except for Kayin and Mon state. Therefore, it can be decided that rainfall data from TRMM and GPM is slightly different in both city and state. CHIRPS and TRMM, CHIRPS and GPM have more differences but it was not much. MAD is the average distance between each data point and the mean. It represents the variability in a dataset. The result represents the variable of three-satellite rainfall is very high in both city and state. For example, Bago city, the MAD value is higher than average (above 170 mm). TRMM, CHIRPS, and GPM are slightly different with each other but they have more variation. Therefore, they should be improved carefully before use.

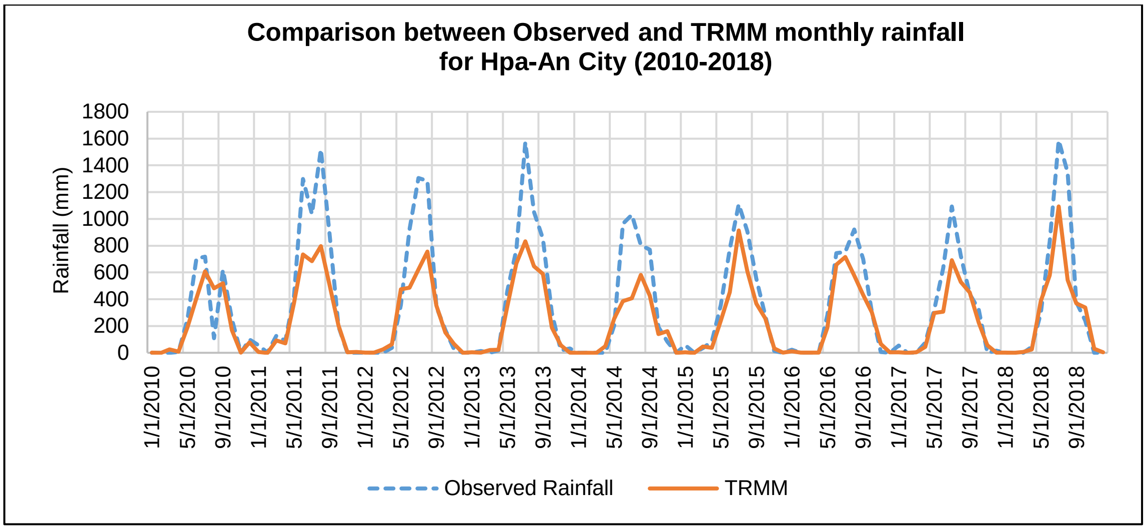
Table 4.7 Mean Absolute Error (MAE) and Mean Absolute Deviation (MAD) of satellite rainfall for cities and states.

City/ State	Comparison between two satellite datasets	Mean Absolute Error (MAE)	Mean Absolute Deviation (MAD)	Satellite datasets
Bago City	GPM-TRMM	77.33	172.93	GPM
	CHIRPS-TRMM	51.66	248.61	CHIRPS
	CHIRPS-GPM	81.51	247.41	TRMM
Hpa-An1 City	GPM-TRMM	49.98	191.83	GPM
	CHIRPS-TRMM	57.14	244.32	CHIRPS
	CHIRPS-GPM	79.64	224.49	TRMM
Hpa-An 2 City	GPM-TRMM	38.10	67.13	GPM
	CHIRPS-TRMM	26.80	106.20	CHIRPS
	CHIRPS-GPM	45.67	99.97	TRMM
Hpapaun City	GPM-TRMM	55.33	94.23	GPM
	CHIRPS-TRMM	43.52	135.60	CHIRPS
	CHIRPS-GPM	55.58	143.21	TRMM
Mawlamyaing City	GPM-TRMM	43.19	213.10	GPM
	CHIRPS-TRMM	68.41	299.32	CHIRPS
	CHIRPS-GPM	85.73	234.76	TRMM
Bago State	GPM-TRMM	31.31	84.50	GPM
	CHIRPS-TRMM	29.11	76.17	CHIRPS
	CHIRPS-GPM	36.24	89.03	TRMM
Kayin State	GPM-TRMM	57.12	205.35	GPM
	CHIRPS-TRMM	80.31	301.26	CHIRPS
	CHIRPS-GPM	115.81	240.61	TRMM
Mon State	GPM-TRMM	48.24	198.78	GPM
	CHIRPS-TRMM	119.54	326.51	CHIRPS
	CHIRPS-GPM	135.39	203.68	TRMM

4.5.3 Analysis of Satellite and Observed rainfall data

There are monthly rainfall and temperature for five observed stations so that satellite data and observed rainfall are compared to check the correlation between them. Hpa-An ,Shwegyin and Mawlamyine stations are located in flooded regions and Magway and Myingyan stations are located in drought affected area. Overall, all observed and satellite rainfall are in good correlation with acceptable coefficient of determination. For Hpa-An station, CHIRPS and TRMM data show a similar trend which are underestimated only in the period of rainfall peaks. As 2018 was observed flooded period according to flood records, the gap between GPM and Observed rainfall peaks was small which can be assumed that GPM can estimate close to observed data.





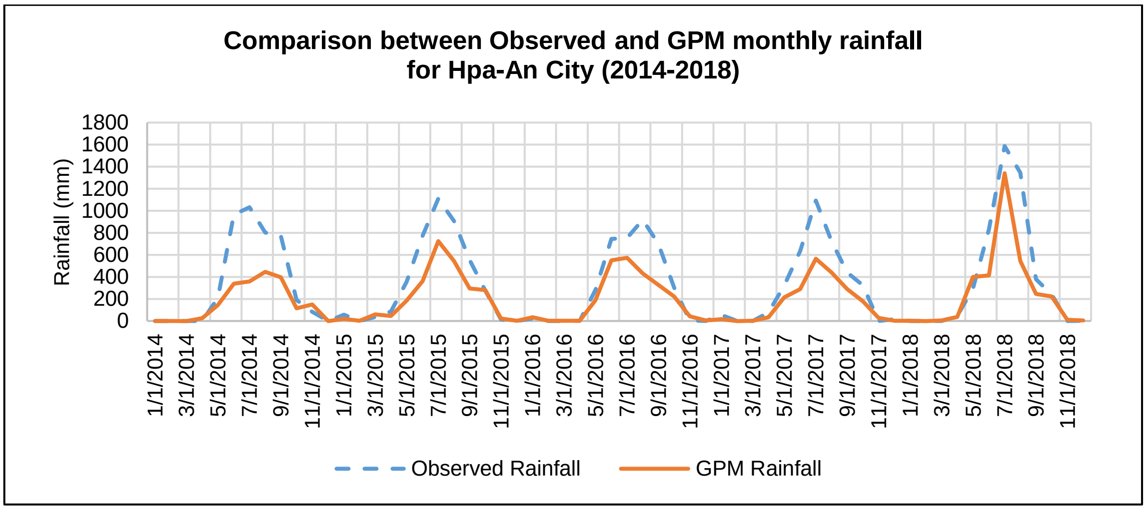
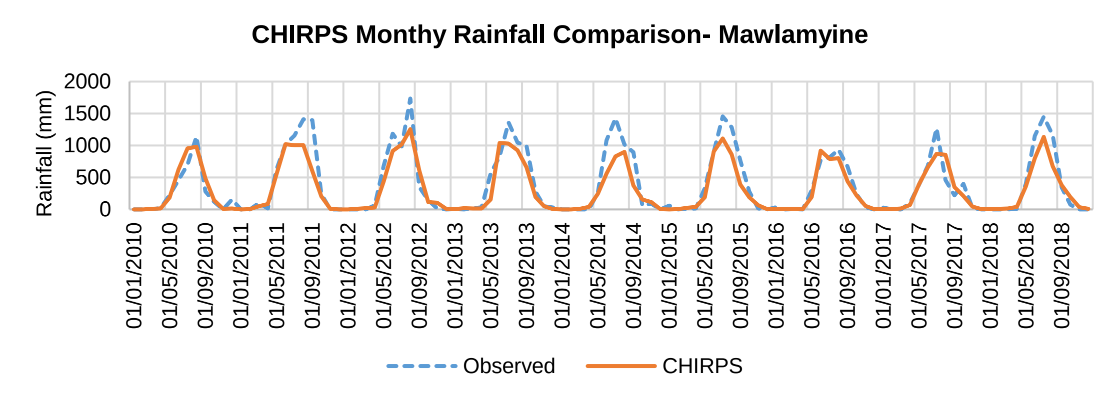
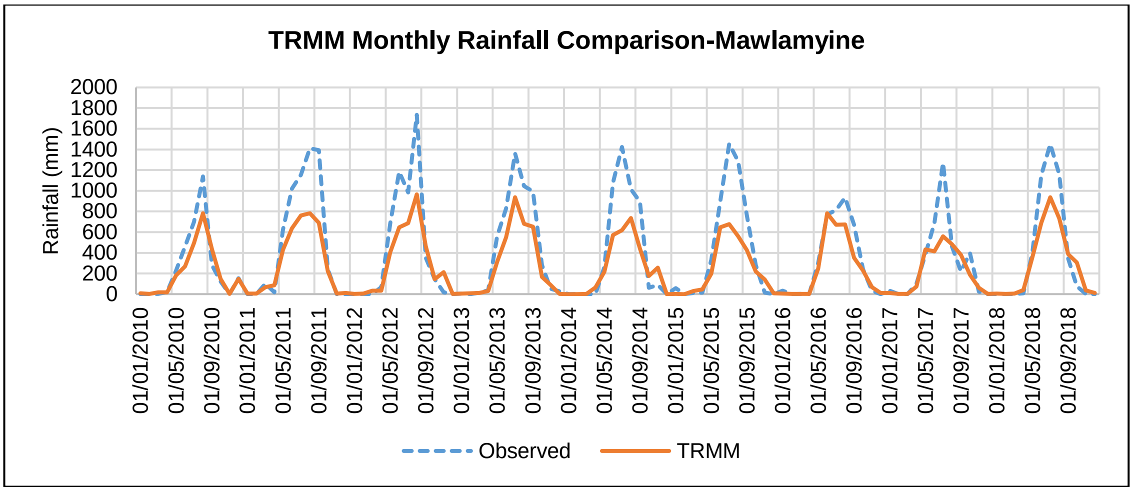


Figure 4.8 Comparison between CHIRPS and Observed rainfall for Hpa-An Station; Comparison between TRMM and Observed rainfall for Hpa-An Station; Comparison between GPM and Observed rainfall for Hpa-An Station.

According to the observed rainfall data collected form Department of Agriculture, they have good correlation between satellite data. Although rainfall peaks did not match, they were in similar trend. In 2018, the gap of rainfall peaks between them was smaller so that it can say that there was a flood. Therefore, the assumption of flooded year that chosen before is true. For Shwegyin station, the trend was similar when comparing with observed and satellite data. It is the same pattern with Hpa-An and Mawlamyine case, where satellite rainfall was underestimated only in the period of rainfall peaks occurred.





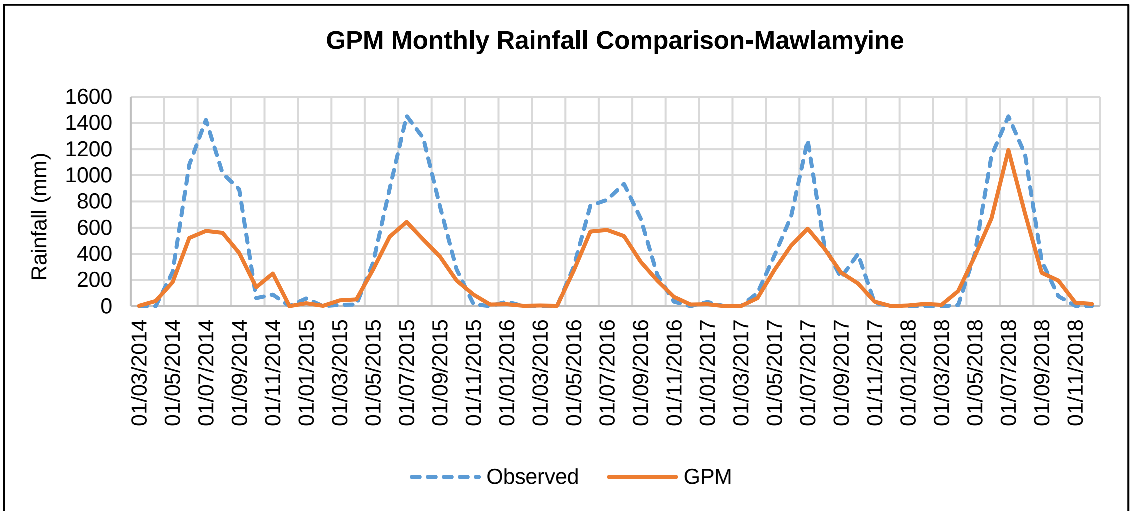
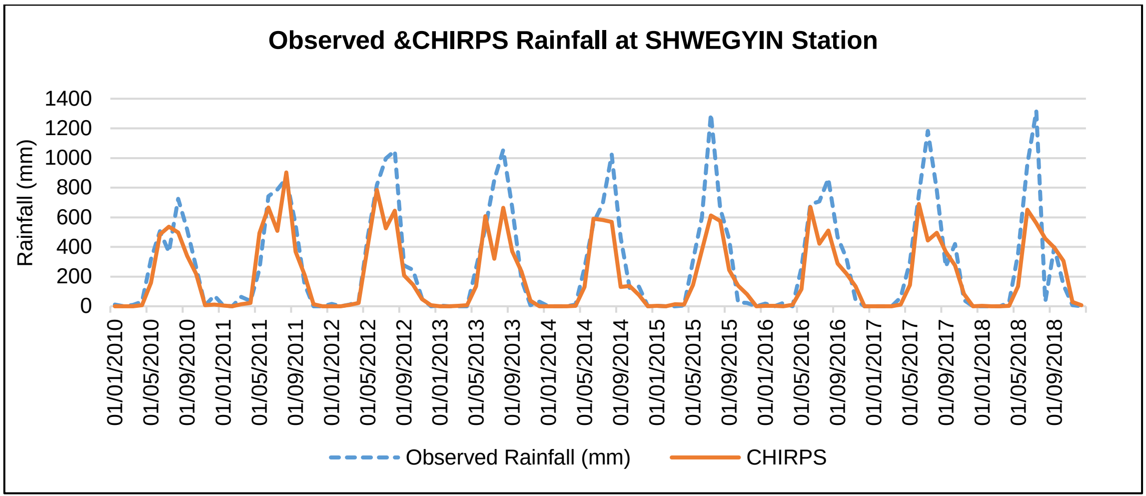
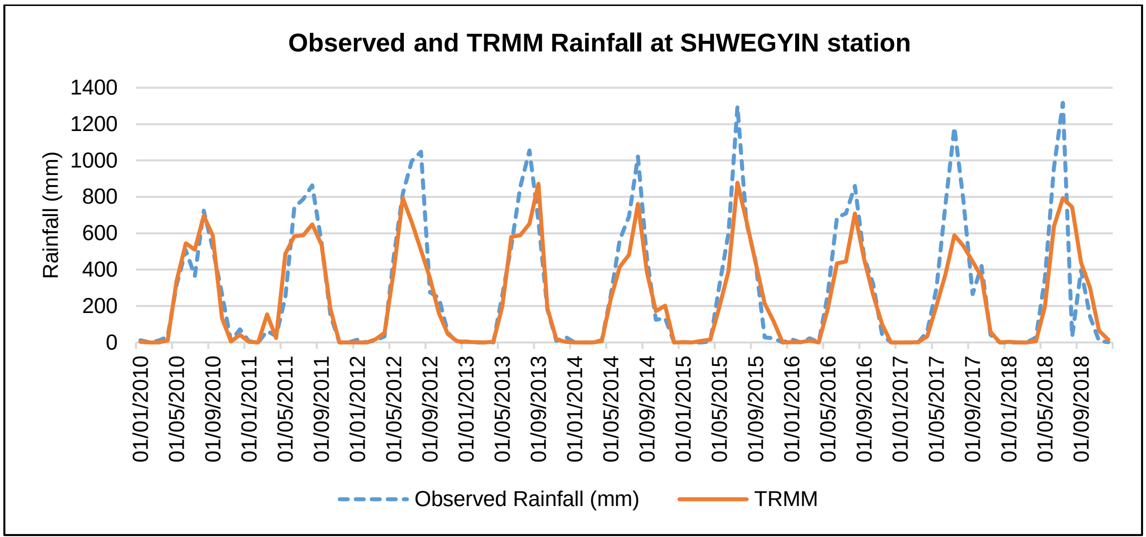


Figure 4.9 Comparison between CHIRPS and Observed rainfall for Mawlamyine Station; Comparison between TRMM and Observed rainfall for Mawlamyine Station; Comparison between GPM and Observed rainfall for Mawlamyine Station.





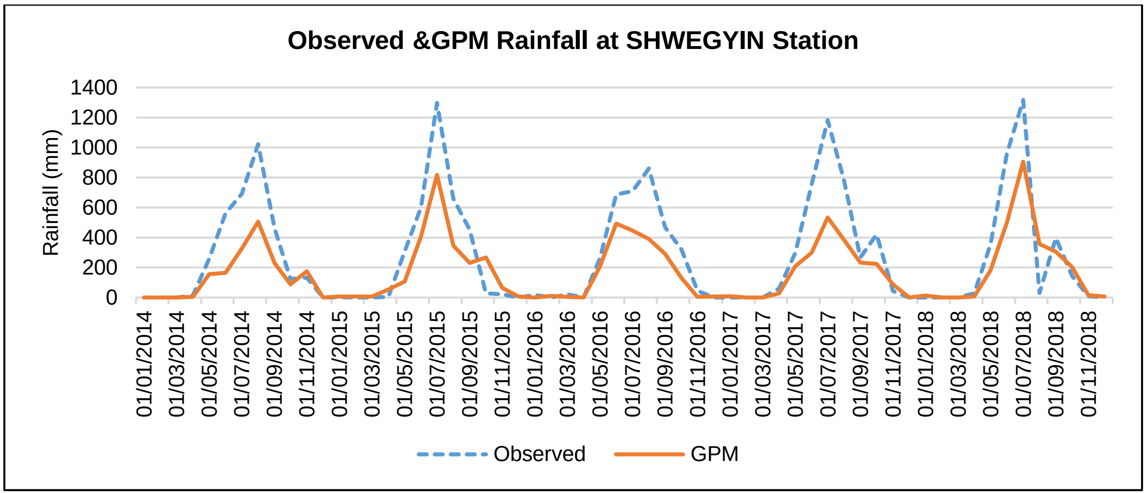
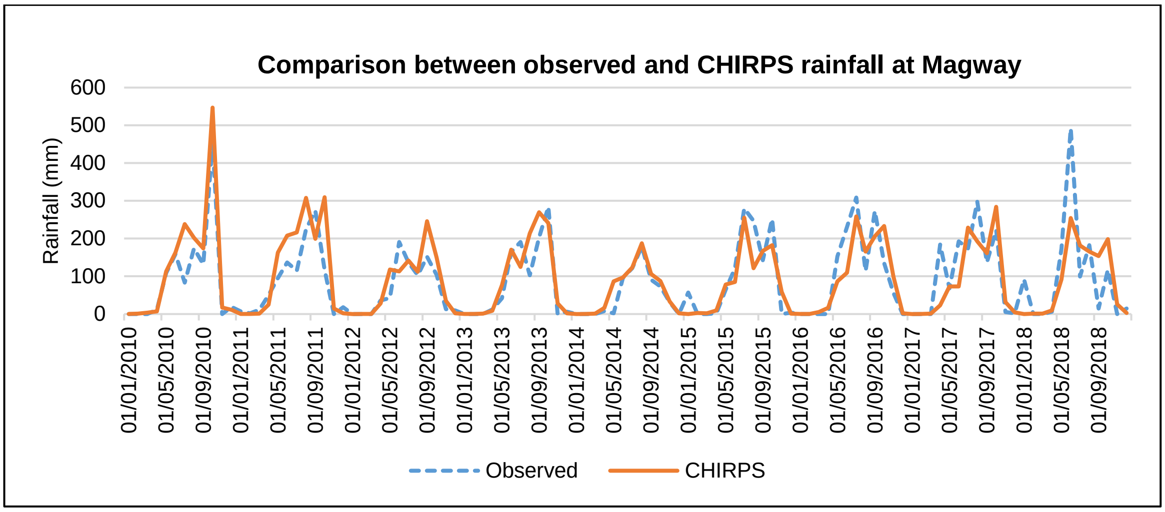
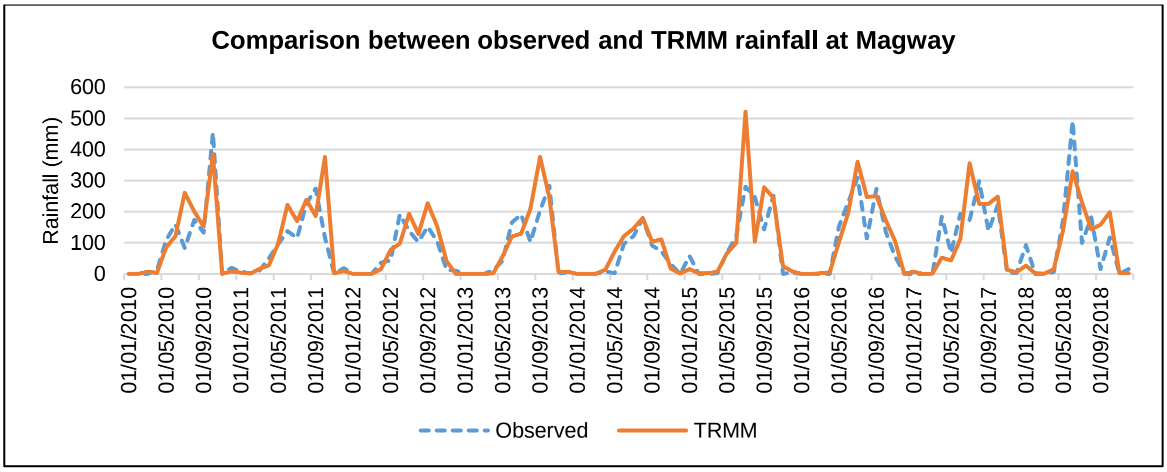


Figure 4.10 Comparison between CHIRPS and observed rainfall for Shwegyin; Comparison between TRMM and observed rainfall for Shwegyin; Comparison between GPM and observed rainfall for Shwegyin.

As there are monthly rainfall data from Department of Agriculture, it has been compared to check the correlation between satellite and observed data. For Magway station, which is located in drought-affected area, the comparison showed that the trend was in a similar shape and satellite data still underestimated in the period of rainfall peaks occurred. There is also a similar result for Myingyan station.





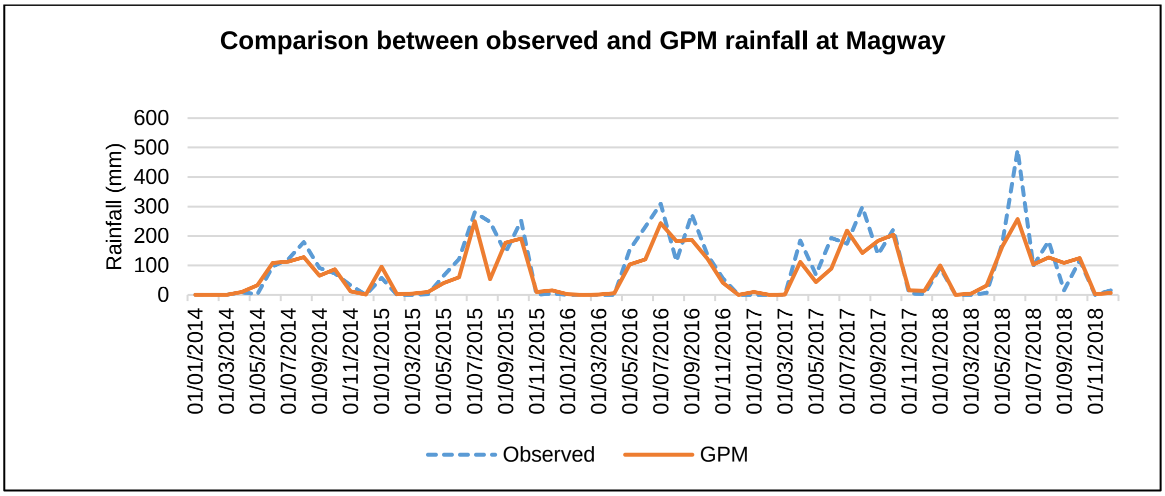
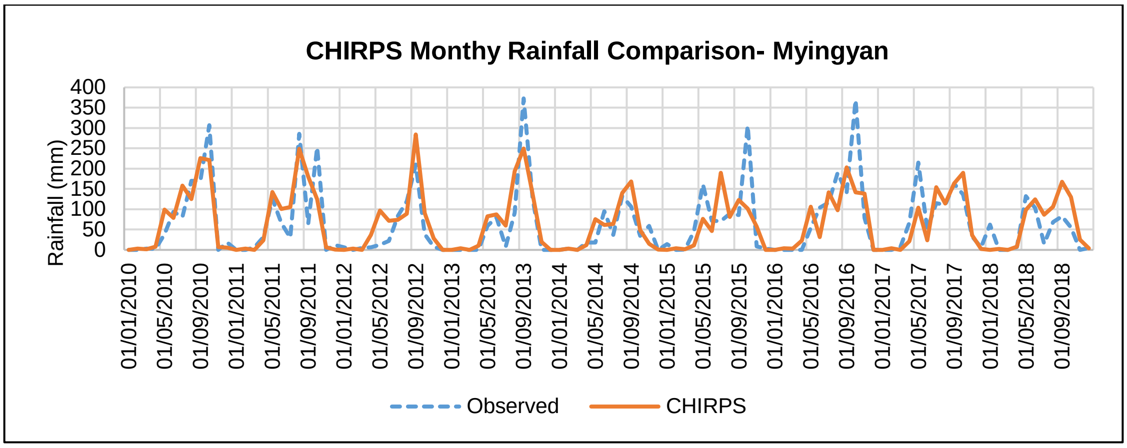
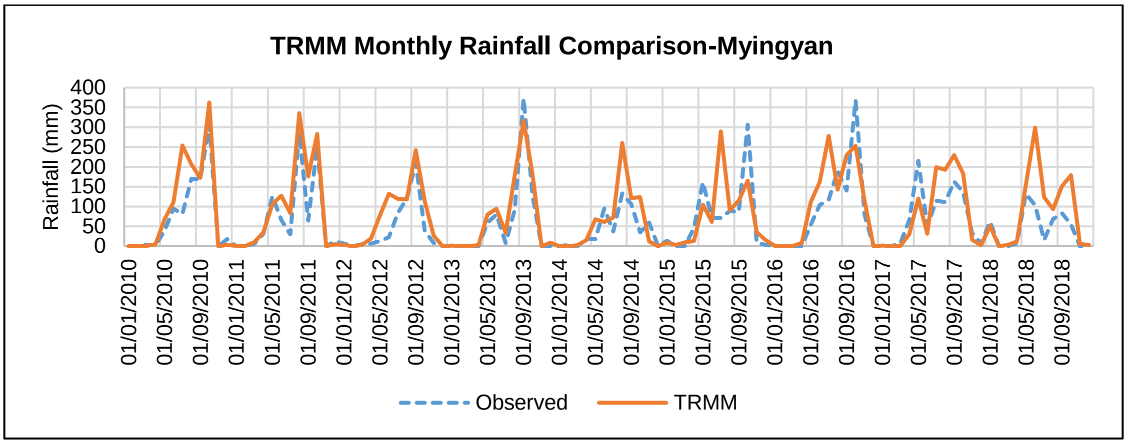


Figure 4.11 Comparison between CHIRPS and Observed rainfall for Magway; Comparison between TRMM and observed rainfall for Magway; Comparison between GPM and observed rainfall for Magway.





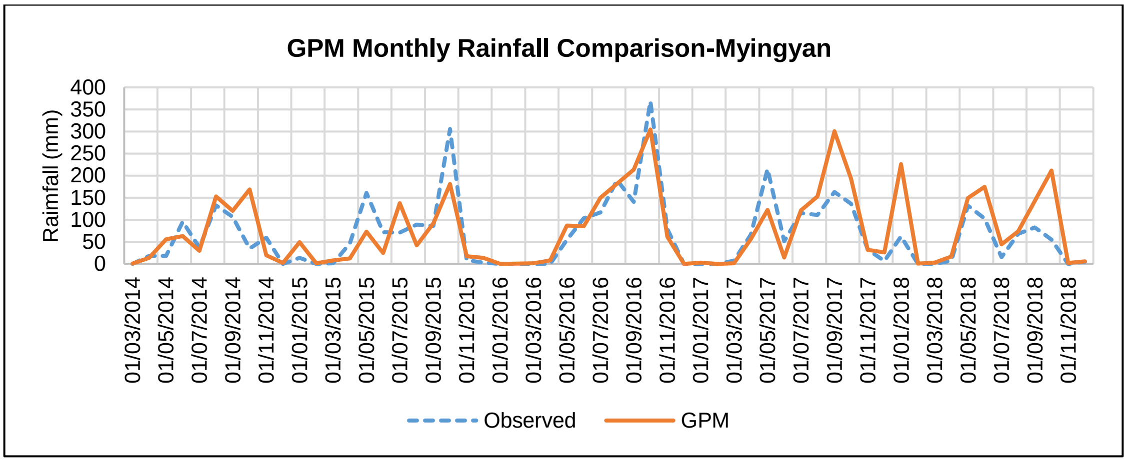


Figure 4.12 Comparison between CHIRPS and Observed rainfall for Myingyan; Comparison between TRMM and observed rainfall for Myingyan; Comparison between GPM and observed rainfall for Myingyan.

4.5.4 Validation performance between satellite and observed rainfall

In case of correlation, TRMM and GPM has the highest R2 value among others in all three observed stations. Therefore, overall correlation of three datasets and observed data is quite good. Mean Absolute Error (MAE) is used to determine the prediction quality of the satellite data based on the prediction errors and it can tell us how big of an error we can expect from the forecast on average. According to the result, MAE values are acceptable because Singh et al. (2004) state that RMSE and MAE values less than half the standard deviation of the measured data are considered low and that either is appropriate for model evaluation. MAE values of Magway station are less than other stations because rainfall is very less in Magway where drought occurred according to the record.

Table 4.8 Performance Indicators for the validation of satellite rainfall with observed data.

Stations	Performance Indicators	Observed and CHIRPS	Observed and TRMM	Observed and GPM
Hpa-An	R^2	0.82	0.88	0.88
	MAE	124	152.94	112.07
Mawlamyine	R^2	0.87	0.90	0.87
	MAE	118.89	158.10	166.51
Shwegyin	R^2	0.78	0.81	0.86
	MAE	127.85	110.49	144.63
Magway	R^2	0.68	0.68	0.76
	MAE	41.73	43.33	34.60
Myingyan	R^2	0.59	0.68	0.61
	MAE	37.48	44.2	33.71

4.5.5 Rainfall analysis for choosing drought years

Since there is no detailed drought information available from our data collection effort, satellite and rainfall data are analysed to check the lowest rainfall occurred periods and assumed as drought years. In case of Magway, yearly observed and satellite rainfall were analysed. Since 2014 had the lowest rainfall and is assumed to be drought year for Magway. Moreover, temperature plays an important role in exacerbating water scarcity during drought. Warm temperatures have an equally important impact on how much water is lost to the atmosphere by transpiration of plants and evaporation from soils.

In data scare regions, satellite temperature can be used so that the accuracy of satellite temperature is important before using it. Therefore, validation with satellite and station temperature is required. As Magway station has observed temperature, it has been analysed with satellite MODIS temperature data. The correlation between MODIS and station temperature is quite good and has similar trend that can be acceptable.

In case of Mandalay, only satellite data are compared to choose drought years. CHIRPS and TRMM datasets showed that 2012 and 2014 had the lowest yearly rainfall whereas GPM also showed that there was a low yearly rainfall in 2014. Therefore, 2012 and 2014 were assumed to be drought years from (2010-2018) yearly rainfall analysis. According to the graphs of Myingyan, 2014 has lowest rainfall so that it was assumed as drought year. The graphs are presented in the Appendix.

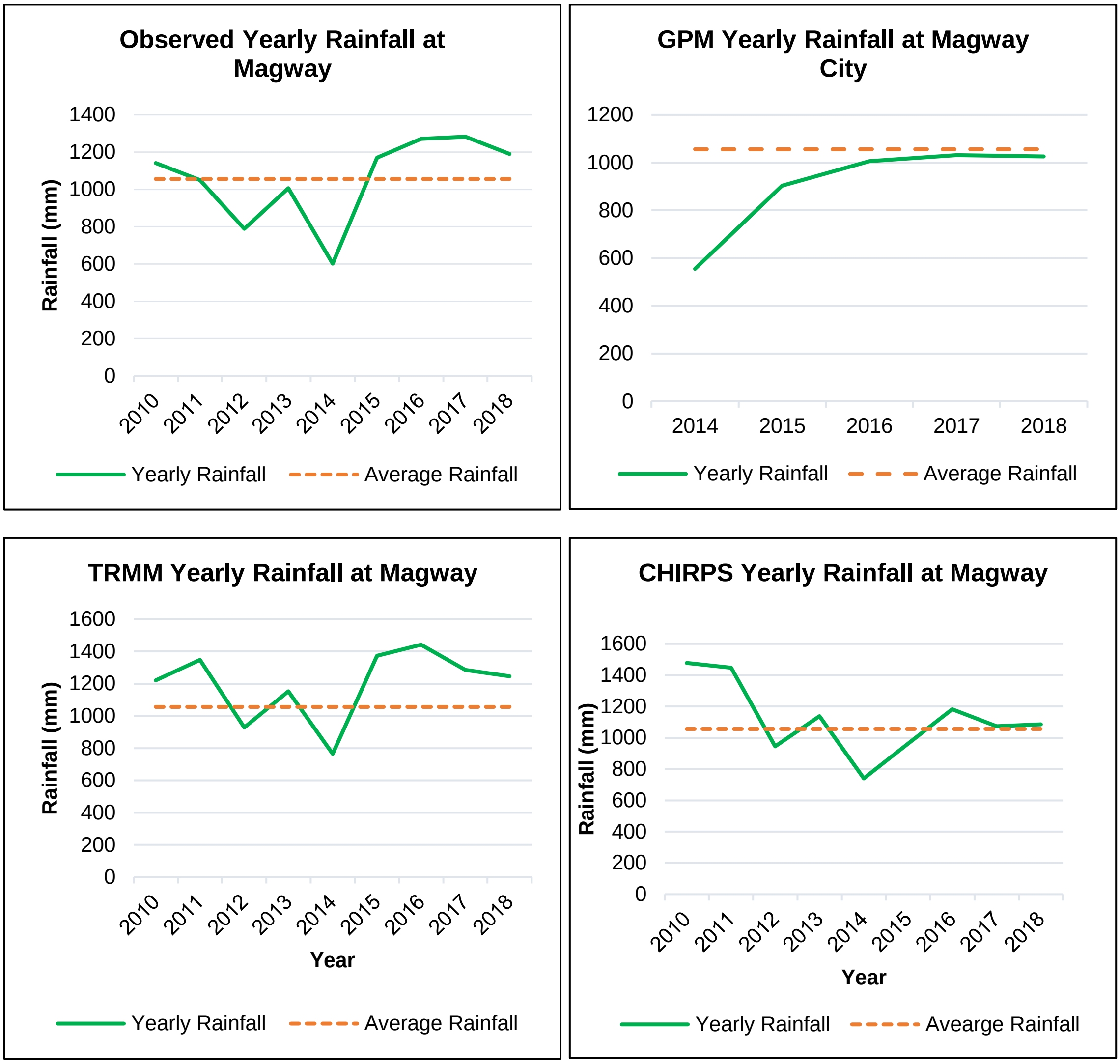


Figure 4.13 Observed yearly rainfall for Magway; GPM yearly rainfall for Magway; TRMM yearly rainfall for Magway, (d) CHIRPS yearly rainfall for Magway.

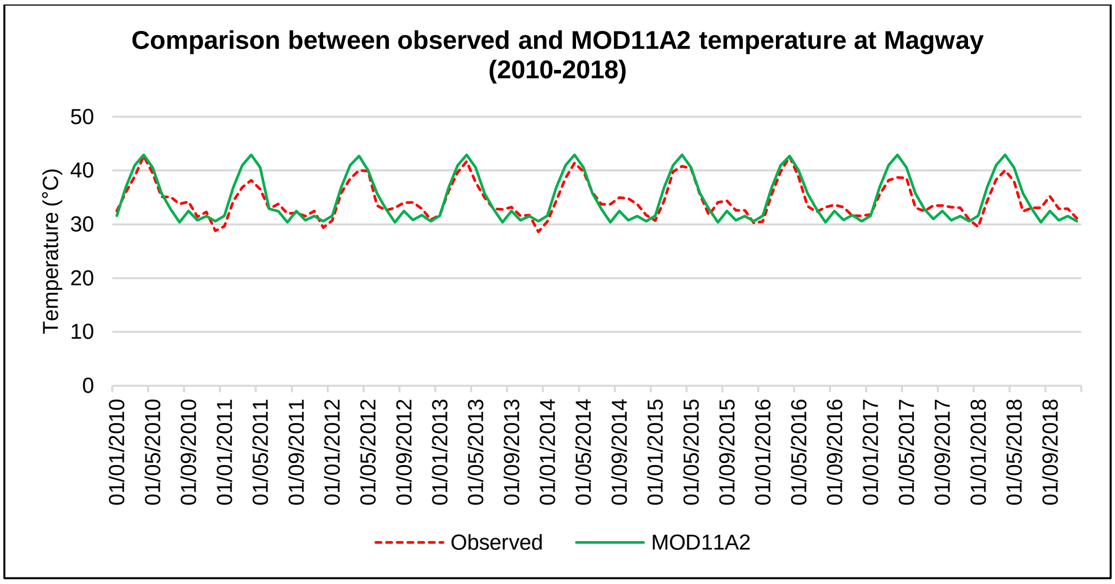


Figure 4.14 Comparison between observed and satellite temperature for Magway (2010-2018).

4.5.6 Analysis of Standard precipitation index (SPI)

According to the 8 years period SPI1 trend (2010-2018) in Magway, (April to Oct) are dry periods mostly in 2014 because it was considered as drought year from rainfall analysis. SPI3 graph can show that 2014 has severe drought (-2 index value) which is assumed to be severe drought according to the SPI classification. Temperature is also around 30 °C during the drought periods. Also for SPI6 graph (2010-2018), it can be seen clearly that end of 2014 and start of 2015 had severe drought with the value of nearly -2 index value. Therefore, the assumption of drought year 2014 is correct. In addition, SPI has been analyzed in Mandalay and Myingyan. The results are quite similar to Magway and the graphs are shown in Appendix A. The SPI values in the charts are calculated as average values for the entire month.

Table 4.9 SPI Index classification.

SPI Index value	Classification
>2.0	Very Wet
1.5 to 2.0	Moderately Wet
1.0 to 1.5	Nearly Normal
-1.0 to 1.0	Moderately dry
-2 to -1.5	Severely dry
<-2	Extremely dry

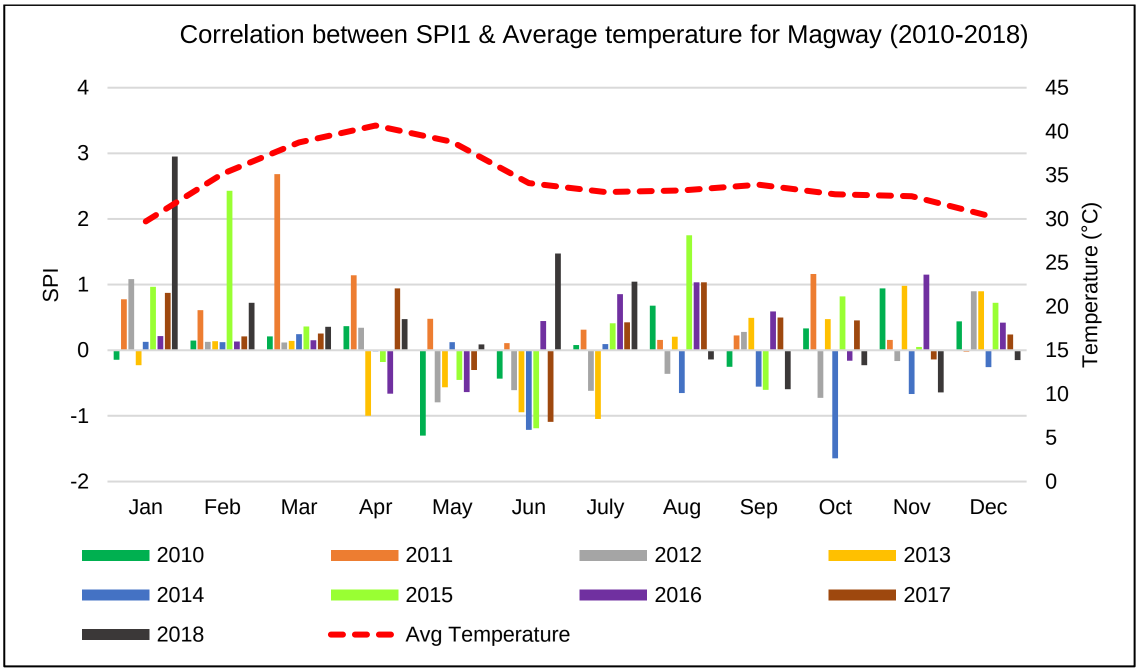


Figure 4.15 Correlation between SPI 1 and averaged temperature for Magway (2010-2018).

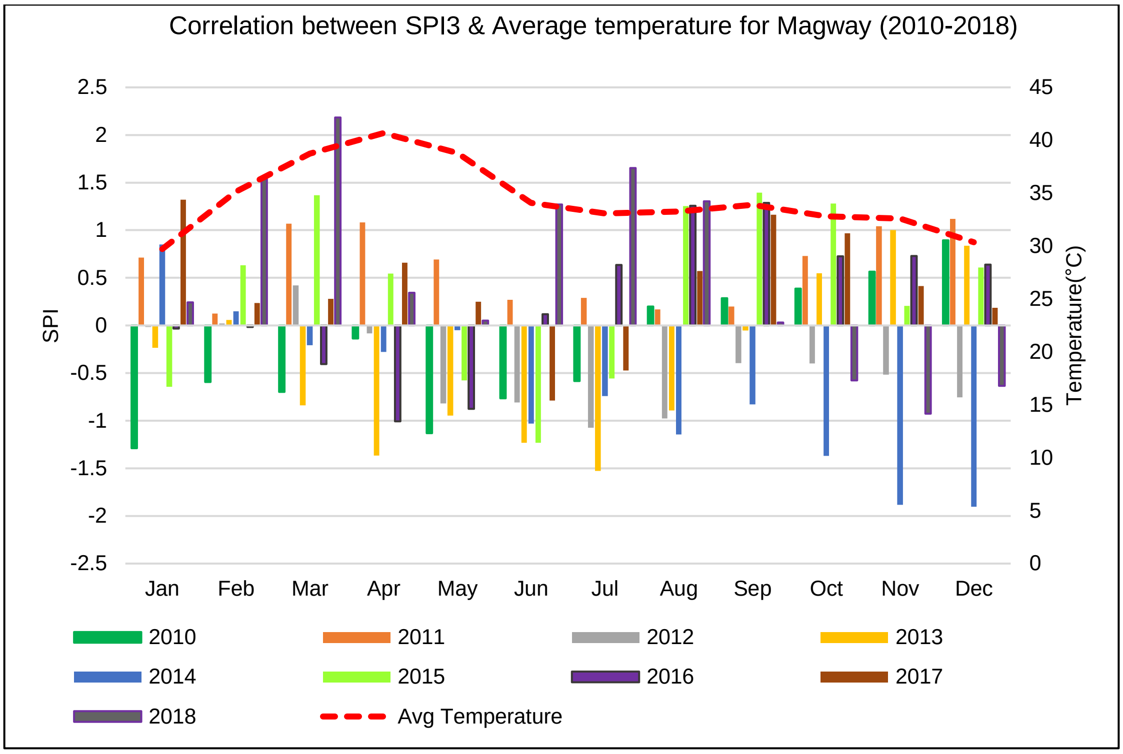


Figure 4.16 Correlation between SPI3 and averaged temperature for Magway (2010-2018).

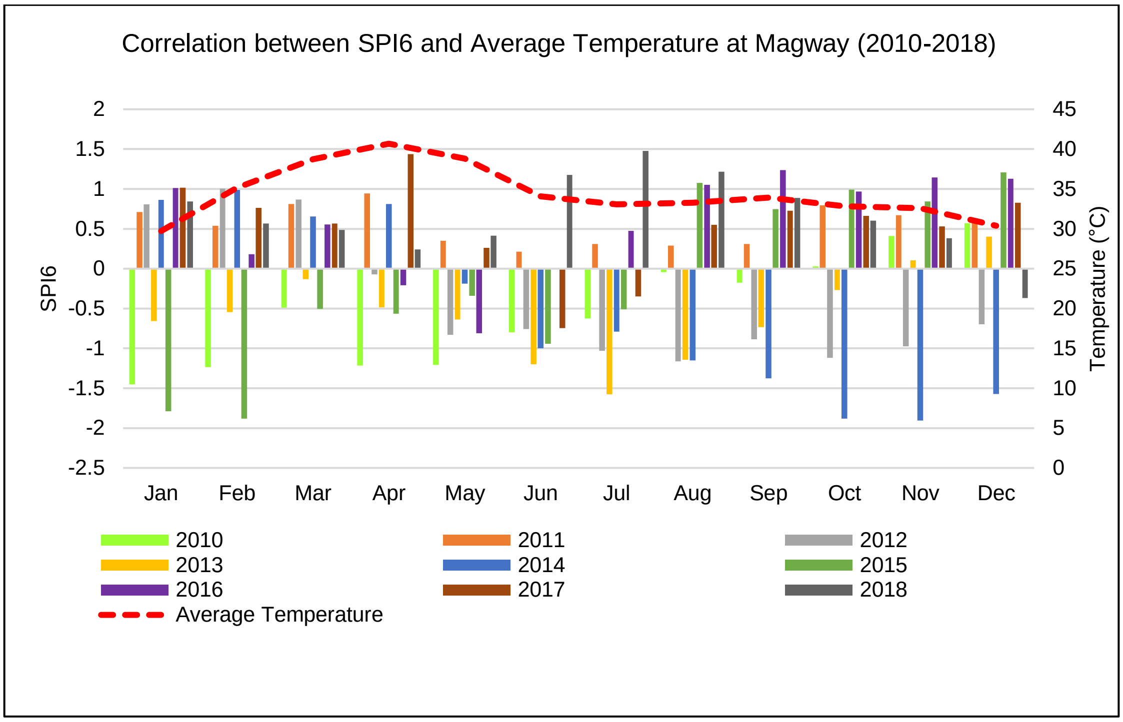


Figure 4.17 Correlation between SPI6 and Averaged temperature for Magway.

4.5.7 Comparison between SPI and NDVI

In Magway, SPI and NDVI were negatively correlated in the selected drought year. Rainfall in 2014 was higher than average yearly rainfall so that SPI took positive values even though there was low rainfall. Note positive SPI values indicate greater than median precipitation (i.e. wet conditions), and negative values indicate less than median precipitation (i.e. dry conditions).

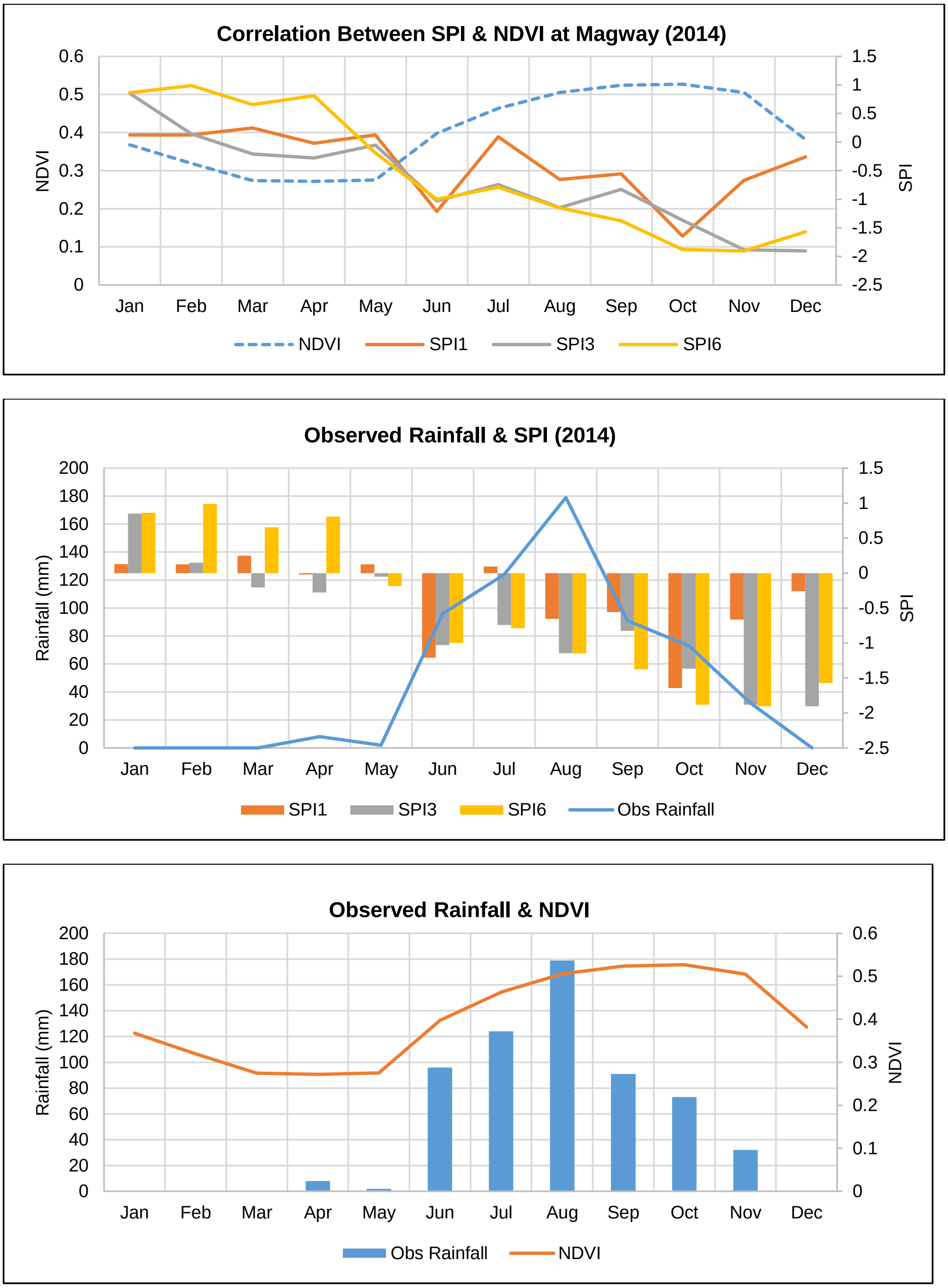


Figure 4.18 Comparison between SPI and NDVI for Magway (2014); Correlation between rainfall and SPI for Magway (2014); Correlation between rainfall and NDVI for Magway (2014).

Because SPI are calculated based on historical records, rainfall and NDVI appear to be acceptable when compared. Also for Mandalay and Myingyan, there was negative correlation between SPI and NDVI. The graphs are presented in Appendix A.

The correlation coefficients are determined based on the seasons to see the significance of vegetation growth seasonally. The summer season starts from March to June, the rainy season starts from July to October and the winter season starts from November to February.

Table 10. Pearson's Correlation Coefficient, r of SPI and NDVI comparison for Magway (2014).

Pearson's Correlation Coefficient, r	SPI1	SPI3	SPI6
Summer	-0.98	-0.97	-0.86
Rainy	-0.81	-0.61	-0.88
Winter	-0.93	-0.66	-0.79

Considering the NDVI data cannot stand alone in checking a drought condition, we used the Crop Application of the portal and sought the crop calendar.

Since there are rice plantation areas in central dry zone, NDVI starts to decrease from the end of rice harvesting and entering the dry season. This can be seen from the crop calendar, which is downloaded from the portal. Once this data is improved depending on stakeholder input, it may be that the results are affected.

The following is the crop calendar for Magway. As for Mandalay and Myingyan, the crop calendar is same with Magway because they all are located in central dry region.

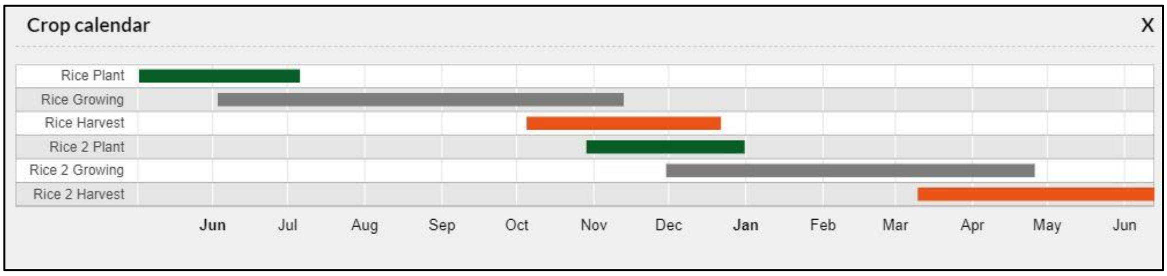


Figure 4.19 Crop Calendar for Magway region.

Table 4.10 Crop planting, growing and harvesting period in Magway region.

Types of crop	Period
Rice plant	May- Jul (2 months, 4 days)
Rice growing	Jun-Nov (5 months, 10 days)
Rice harvest	Oct-Dec (2 months, 17 days)
Rice2 plant	Oct-Jan (2 months, 3 days)
Rice2 growing	Nov-Apr (4 months, 27 days)
Rice2 harvest	Mar-Jun (3 months, 3 days)

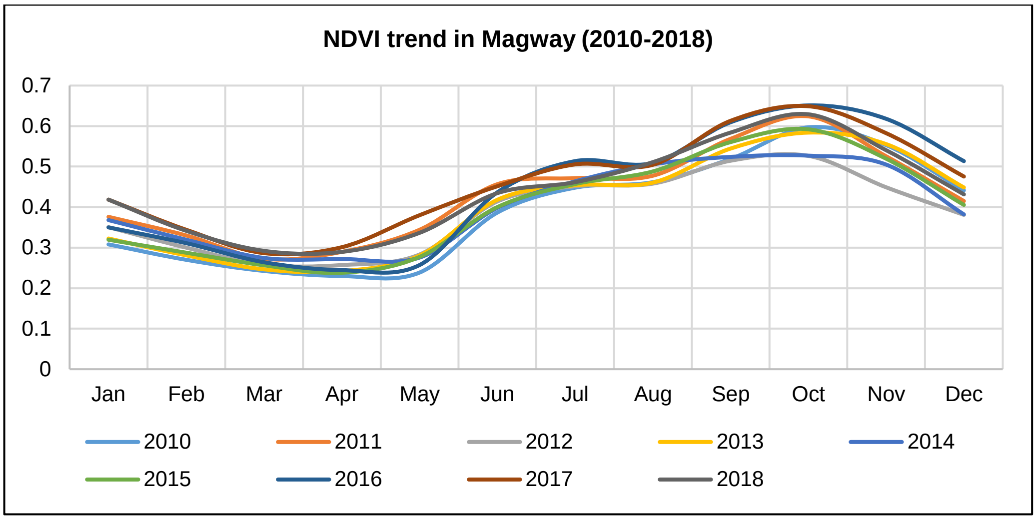


Figure 4.20 NDVI trend in Magway (2010-2018).

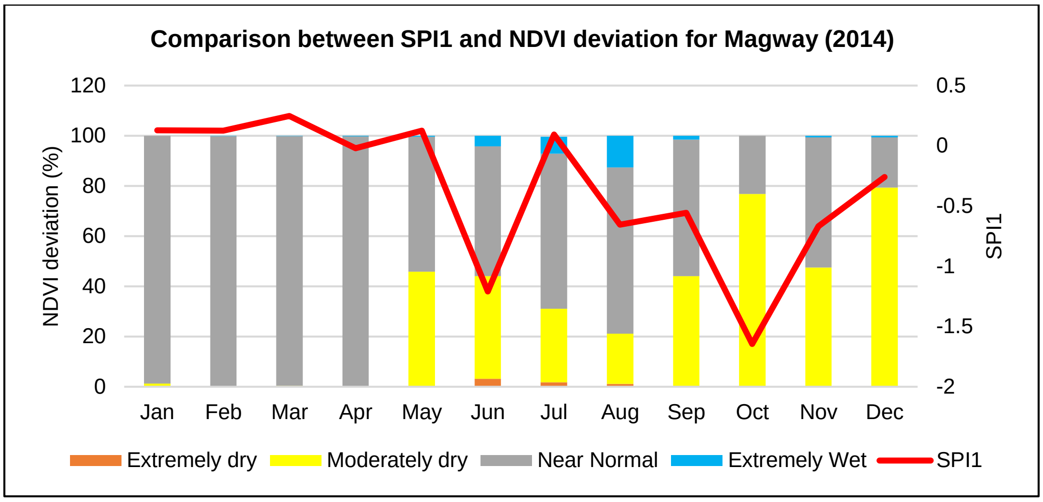
4.5.8 Comparison between SPI and NDVI deviation

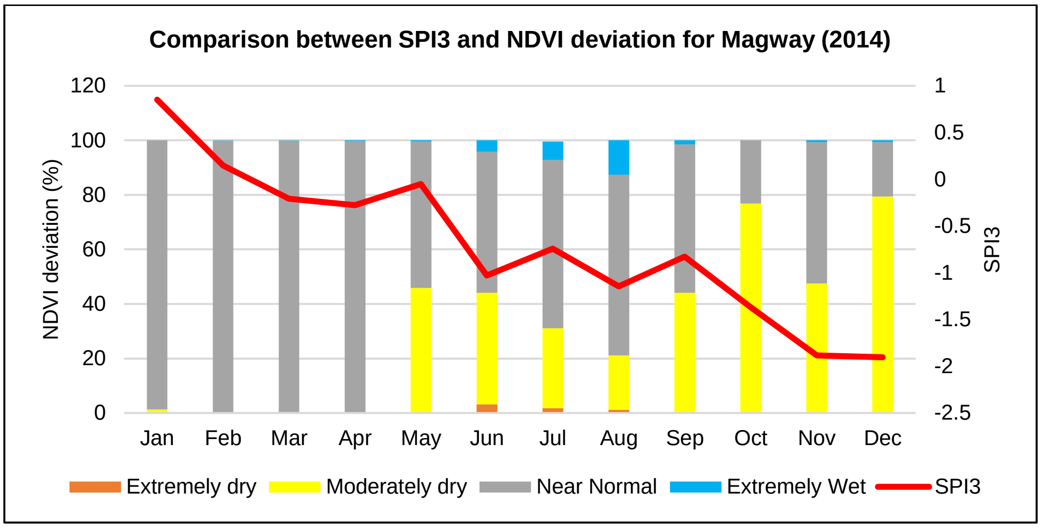
NDVI deviation is calculated as the deviation from the long-term mean. It expresses the current vegetation growth compared to the long -term mean for the same period. It can be used to define a drought as it is defined as the difference between NDVI for the current time step and long term NDVI for the same month. When NDVI deviation is negative, it indicates below normal vegetation condition and suggests a prevailing drought situation. The greater the negative departure, the greater the magnitude of a drought.

When comparing with SPI values and NDVI deviation, the SPI trend matches the NDVI deviation. The NDVI deviation classification table and comparison charts are below. In case of Mandalay and Myingyan regions, there is a correlation between SPI and NDVI deviation. SPI negative values meet in the moderately dry range of NDVI deviation. The comparison charts between SPI and NDVI deviation for Magway and Mandalay Regions are attached in Appendix A.

Table 4.11 NDVI deviation classification.

NDVI deviation	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 optima; (extremely wet)





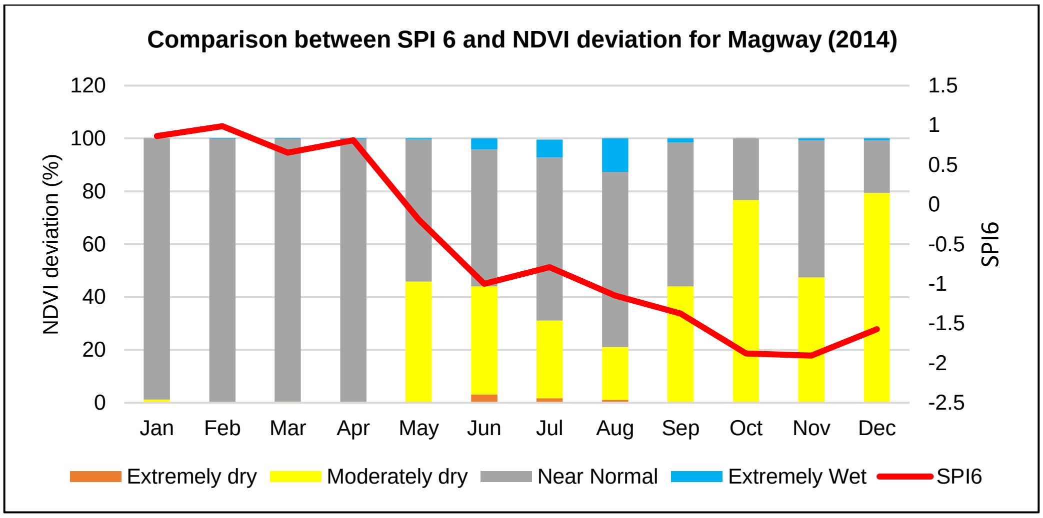
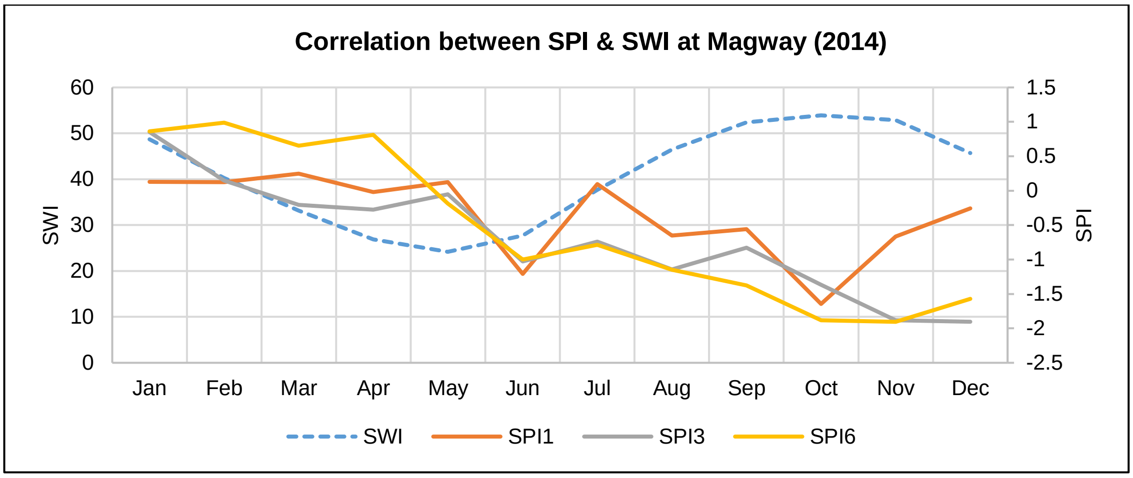


Figure 4.21 Comparison between SPI1 and NDVI deviation for Magway (2014); Comparison between SPI3 and NDVI deviation for Magway (2014); Comparison between SPI6 and NDVI deviation for Magway (2014).

4.5.9 Comparison between SPI and SWI

In Magway, the correlation analysis between indices showed that the correlation coefficient is different on the various time scales, and correlation amount is weak in winter season and strong in rainy season. SWI seems to have direct correlation with observed rainfall. Similar results came out for Mandalay and Myingyan. The comparison graphs are presented in Appendix A.



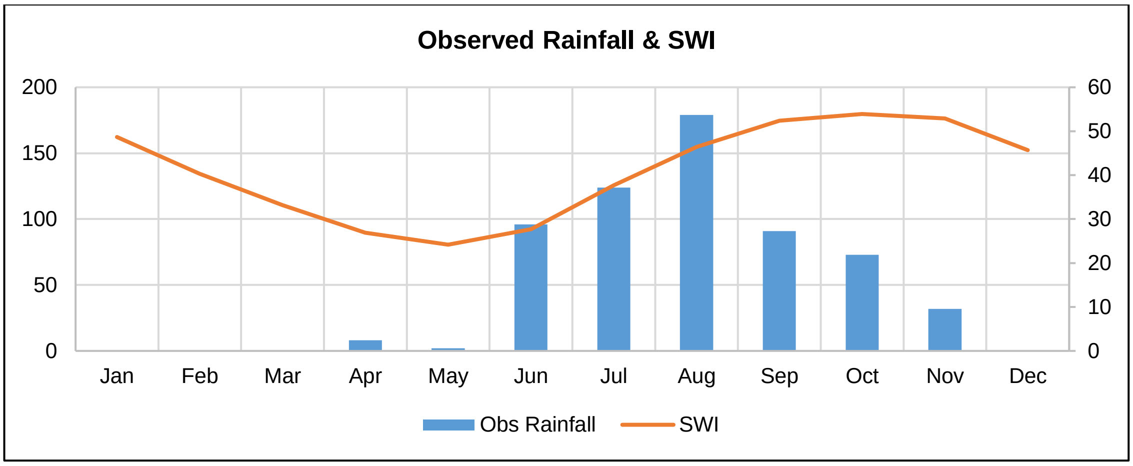


Figure 4.22 Correlation between SPI & SWI at Magway (2014); Correlation between observed rainfall and SWI for Magway (2014).

Table 4.12 Pearson's Correlation Coefficient, r of SPI and SWI comparison for Magway (2014).

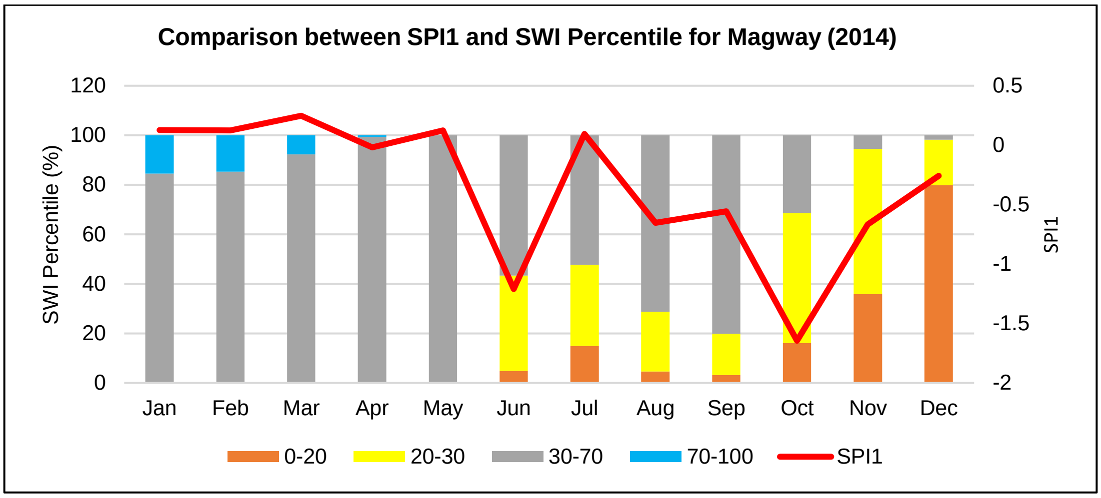
Pearson's Correlation Coefficient, r	SPI1	SPI3	SPI6
Summer	0.15	-0.06	0.37
Rainy	-0.83	-0.61	-0.92
Winter	-0.71	-0.38	-0.59

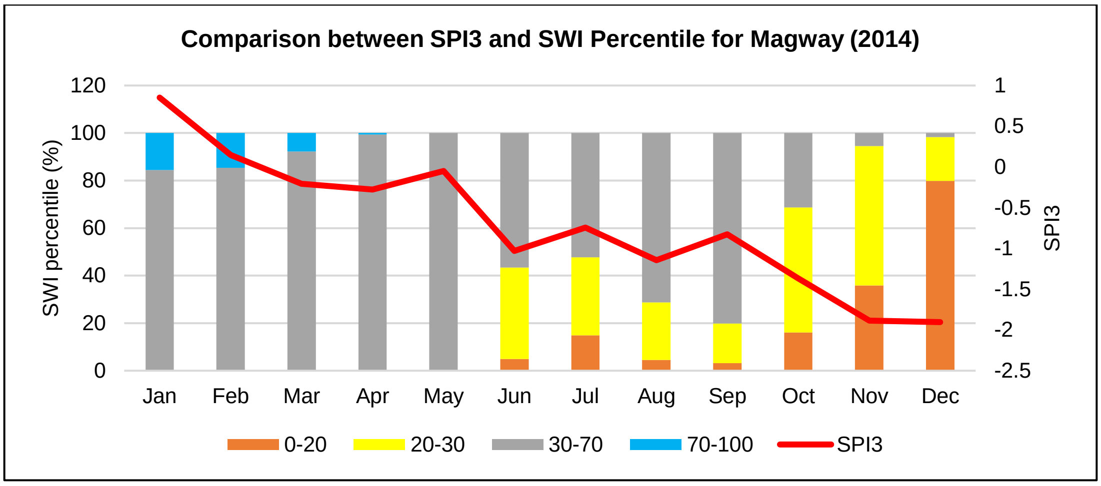
4.5.10 Comparison between SPI and SWI percentile

The SWI percentile expresses the percentage of soil moisture that is equal to or below a certain amount of each year in the entire record. A drought or water scarcity condition is often defined when the soil moisture percentile drops below 30 or 20%. Therefore, SPI and SWI percentile are compared.

As a result, the SPI trend match with the lower SWI percentile, which is regarded as drought. Comparison charts are drawn as follows.

When comparing SPI and SWI percentile for Mandalay and Myingyan, the result is similar to Magway. The drop of SWI percentile coincide with negative values of SPI so that this comparison can be the indicator of a drought happening in the central dry zone. The charts of comparing SPI and SWI in the selected drought year for Mandalay and Myingyan are attached in Appendix A.





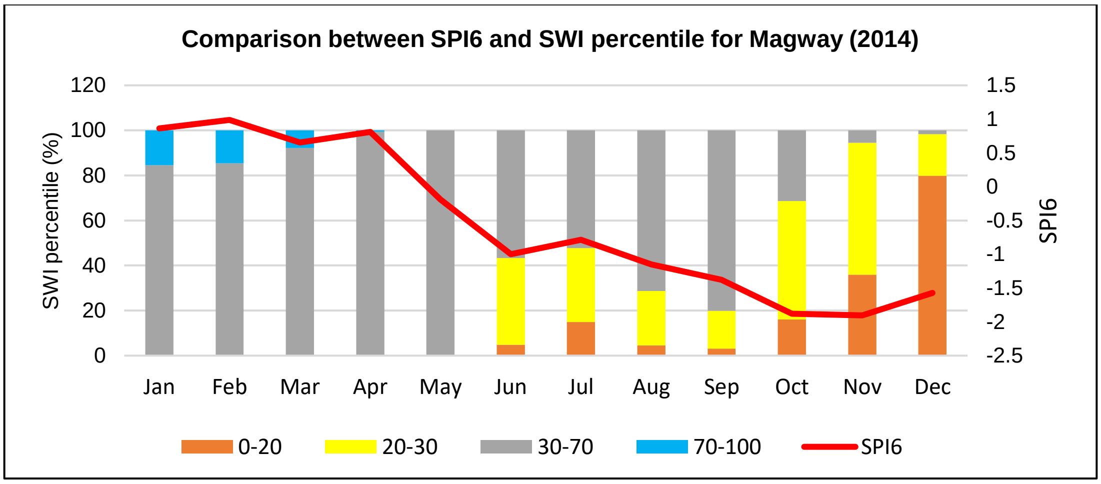


Figure 4.23 Comparison between SPI1 & SWI percentile for Magway (2014); Comparison between SPI3 & SWI percentile for Magway (2014); Comparison between SPI6 & SWI percentile for Magway (2014).

4.6 Conclusions

This report describes the validation of satellite datasets with observed historical data in selected locations in Myanmar. It includes two main parts; satellite rainfall validation and satellite drought index validation. According to the result of validation, the following conclusions are drawn.

1. In statistical validation of satellite data, percentage difference and R- square values represent ‘all dataset are in good correlation’. While, MAE and MAD represent the deviation of each dataset. Although compared dataset provide a high correlation, each dataset still has high uncertainty.

2. For comparing with observed rainfall data in five stations, satellite data have a same pattern with monthly-observed rainfall. However; they did not capture a peak of rainfall in which satellite data was lower than observed data.

3. CHIRPS has smallest resolution, long period dataset, but high uncertainty whereas TRMM has largest resolution and high uncertainty. GPM is an improved product from TRMM. It has smaller resolution, but very high uncertainty.

4. From the comparison of SPI and SWI, they had a good correlation in rainy season in Mandalay and Myingyan. Also for NDVI, SPI values are positively correlated with it in rainy season. Therefore, this can show that there are rain fed rice plantation areas where rainfall has much influence on it.

5. As vegetation activity is highest in July and August (Rainy Season) and lowest in March and April (summer) in Myanmar, NDVI trend can prove with increasing in rainy season and decreasing in summer.

6. The drought years are selected based on rainfall analysis whereas lowest rainfall periods are assumed drought. It was checked with the analysis of SPI index whereas the assumed drought year has negative SPI value, which is moderately, and severely drought. This can also be proved by checking with an increasing number of damaged planted area, which was collected form Department of Agriculture.

7. SPI alone cannot correlate with the vegetation deficit as it shows only the deviation from the long term mean (wetter or dryer than normal) and NDVI seems to have follow the crop calendar pattern. The available data is very limited to make a direct comparison between rainfall and vegetation to see the influence of the drought. So here we applied the crop calendar, NDVI deficit and SWI percentile and tried to find the correlation with SPI. The correlations with the drought condition are more pronounced.

8. Data has been validated using a methodology that assumed that observed data at the station is “correct”. The objective of the portal is also to provide a better understanding of the climate at regional and national scale. Using remote sensing data can be relevant – even with poor performance at specific locations/stations - since there is not a sufficient coverage of stations in the entire country. In addition, rainfall estimates from remote sensing at a large catchment scale might actually be more accurate than from single stations. Finally, continuous bias in rainfall data will not be considered if indices such as SPI are used since only relative state is assessed.

5 Next steps

This report marks the end of Activity 2 and the start of Activity 3 consisting of the following sub-activities:

- Activity 3.1: Final national workshop to continue with awareness generation on the portal
- Activity 3.2: More technical training in the use of the portal
- Activity 3.3: Outreach, dissemination and possible next steps
- Activity 3.4: CTCN reporting requirements namely a monitoring and evaluation plan, a closure report and an impact description.

The main written deliverable of Activity 3 is the *Lessons-learned and Roadmap report*, the latter describing recommendations for further development of the portal, and for linkages with national policy development, and potential for engagement of the private sector. These recommendations will directly inform the design of a *Draft GCF Concept Note* which will be attached to the report.

Due to the stakeholder feedback received during the second technical training from 2nd to 4th of April, we will continue to refine where possible the content of the portal well into Activity 3, as documented in chapter 3.1 and 3.2. It will depend as well on final data collection efforts from the DOA regarding crop information for Myanmar.

Continued and close coordination with the Climate Change Division of the ECD will determine the dates of the final training and the date for the final guidance session on drafting the concept note.

APPENDIX A

Validation Extended Results

Table A1. Mon State, Mawlamyine Flood Impact (2010 – 2018)

Source: Department of Disaster Management (DDM)

No.	Year	House	House hold	Population	Death	Injuries	Loss	Remark
1	2010	_	_	_	_	_	_	
2	2011	_	_	_	_	_	_	
3	2012	208	208	908	_	_	_	
4	2013	_	_	_	_	_	_	
5	2014	_	_	_	_	_	_	
6	2015	_	_	_	_	_	_	
7	2016	_	_	_	_	_	_	
8	2017	_	_	_	_	_	_	
9	2018	_	2015	5607	1	_	_	
Total		**208**	**2223**	**6515**	**1**	_	_	

Table A2. Kayin State, Hpa-an Township Flood Impact (2010-2018)

Source: Department of Disaster Management (DDM)

No.	Year	House	House hold	Population	Death	Injuries	Loss	Remark
1	2010	_	_	_	_	_	_	
2	2011	_	838	4312	_	_	_	
3	2012	_	1045	5497	_	_	_	
4	2013	_	1597	8268	_	_	_	
5	2014	_	_	_	_	_	_	
6	2015	_	1222	6444	_	_	_	
7	2016	_	_	_	_	_	_	
8	2017	_	_	_	_	_	_	
9	2018	_	2346	11699	_	_	_	
Total		_	**7048**	**36220**	_	_	_	

Table A3. Pearson's correlation coefficient (r) in SPI, NDVI and SWI comparison for Mandalay and Myingyan

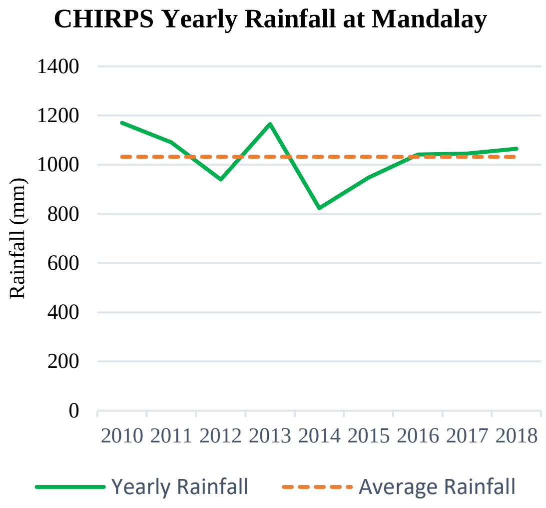
Area	Year	Index	Pearson's Correlation Coefficient (r)		
			Summer	Rainy	Winter
Mandalay	2012	SPI1 & NDVI	-0.71	0.99	-0.87
		SPI3 & NDVI	-0.88	0.95	-0.14
		SPI6 & NDVI	-0.90	0.77	-0.84
		SPI1 & SWI	0.10	0.87	-0.75
		SPI 3 & SWI	-0.41	0.98	-0.38
		SPI 6 & SWI	-0.29	0.91	-0.88
	2014	SPI1 & NDVI	-0.84	0.95	-0.93
		SPI3 & NDVI	-0.95	0.97	-0.14
		SPI6 & NDVI	-0.97	0.87	-0.93
		SPI1 & SWI	0.10	0.87	-0.75
		SPI 3 & SWI	-0.41	0.98	-0.38
		SPI 6 & SWI	-0.29	0.91	-0.88
Myingyan	2014	SPI1 & NDVI	-0.87	0.02	-0.92
		SPI3 & NDVI	-0.95	0.93	-0.43
		SPI6 & NDVI	-0.71	0.78	-0.95
		SPI1 & SWI	0.17	-0.18	-0.78
		SPI 3 & SWI	-0.02	0.85	-0.48
		SPI 6 & SWI	0.38	0.65	-0.90

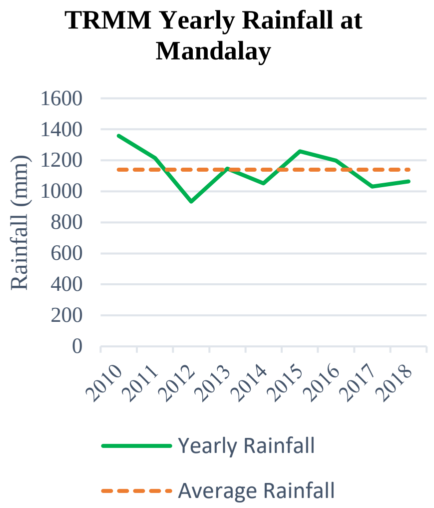
Table A4. Annual damage of crops in Mawlamyine Township (2010-2018)

Crop Name	Year	Planted area	Risk Area	Damage Area
Monsoon rice	2010	14943	~	~
	2011	13896	~	~
	2012	13868	~	~
	2013	13772	~	~
	2014	13667	~	~
	2015	14589	~	~
	2016	14582	~	~
	2017	14534	~	~
	2018	14434	2051	1638

Table A5. Annual damage of crops in Myingyan

No	Crop Name	2013-2014			2014-2015			2015-2016			2016-2017			2017-2018			2018-2019		
		plantedAcre	Risk Acre	Damage Acre	plantedAcre	Risk Acre	Damage Acre	plantedAcre	Risk Acre	Damage Acre	plantedAcre	Risk Acre	Damage Acre	plantedAcre	Risk Acre	Damage Acre	plantedAcre	Risk Acre	Damage Acre
1	Summer sesame							1562	99	99	1958	61	61						
2	Summer rice							1426	18	18	1780	104	66						
3	Monsoon rice							3621	334	200	3429	25		3625	539	311			
4	Monsoon rice								12	12		19			336	176			
5	Monsoon sesame	24182	18093	18093										15921	105	105			
6	Monsoon groundnut													19566	68	68			
7	Bean													20150	16				
8	Sorghum													12753	4				
9	Cotton													8253	19	1			
10	Onion (monsoon)													1878	13	2			
11	Onion (summer)													12545	39				
12	Onion (winter)																4653	1.39	1.39
13	Chick-pea													12355	97	97			
14	Corn							2368	3	3									
15	Barley							322	7	7									





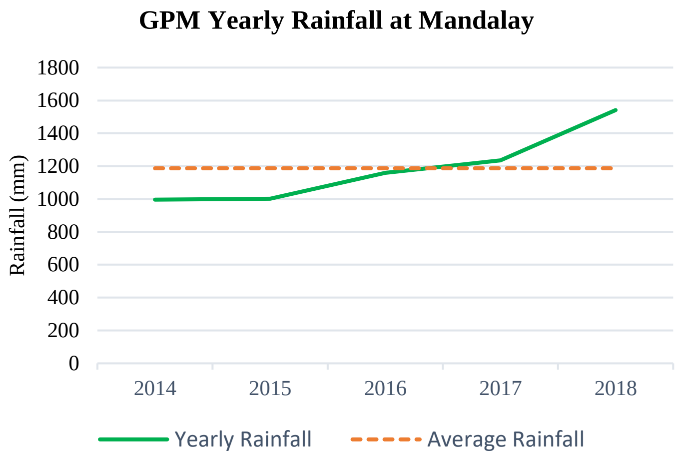


Figure A1.(a) CHIRPS yearly rainfall at Mandalay, (b) TRMM yearly rainfall at Mandalay, (c) GPM yearly rainfall at Mandalay

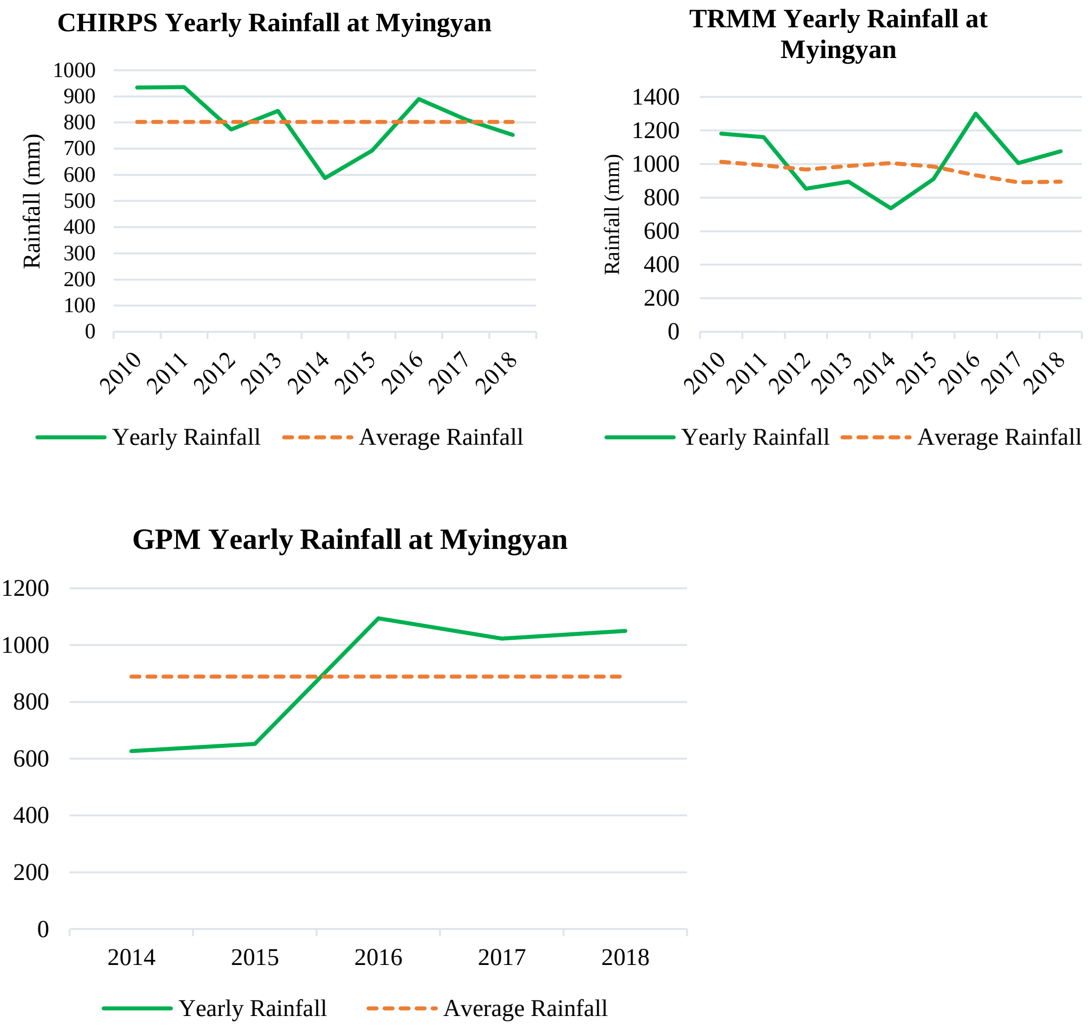
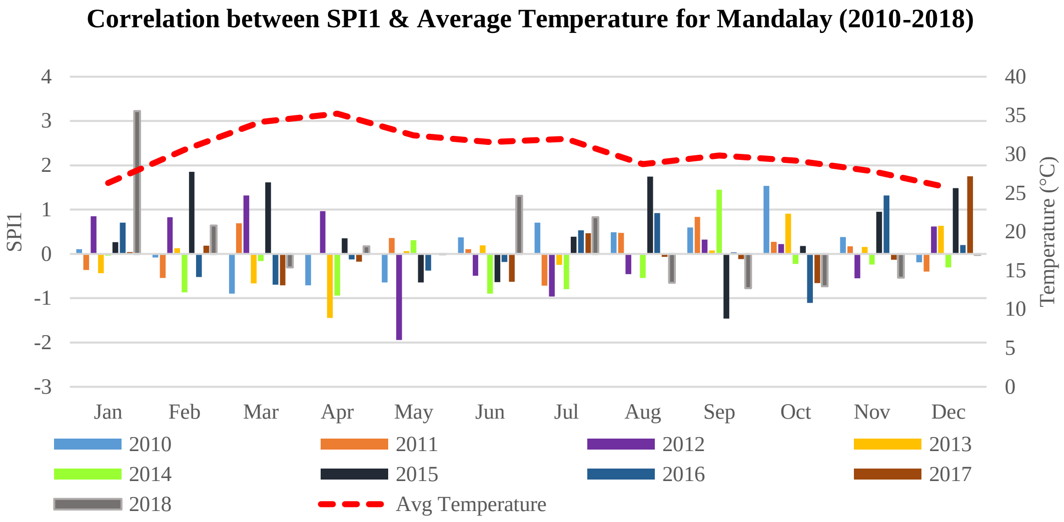
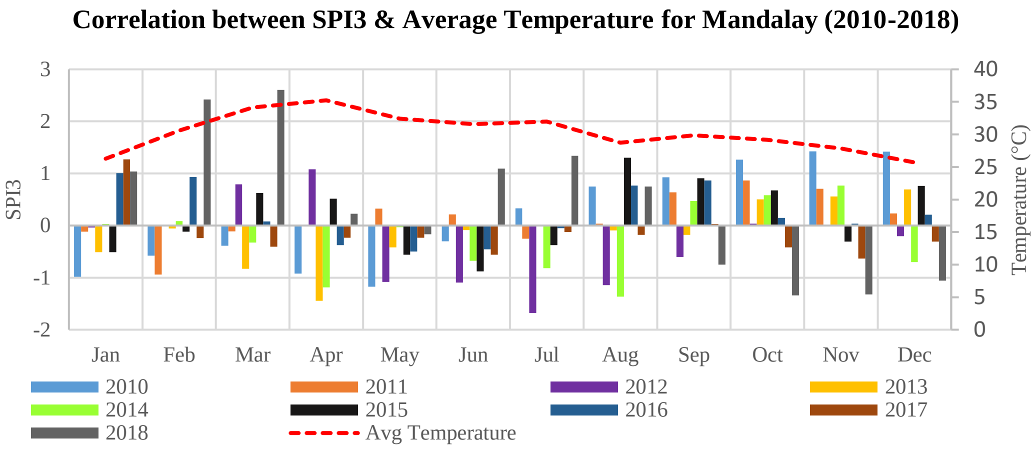


Figure A2. (a) CHIRPS yearly rainfall at Myingyan, (b) TRMM yearly rainfall at Myingyan, (c) GPM yearly rainfall at Myingyan.





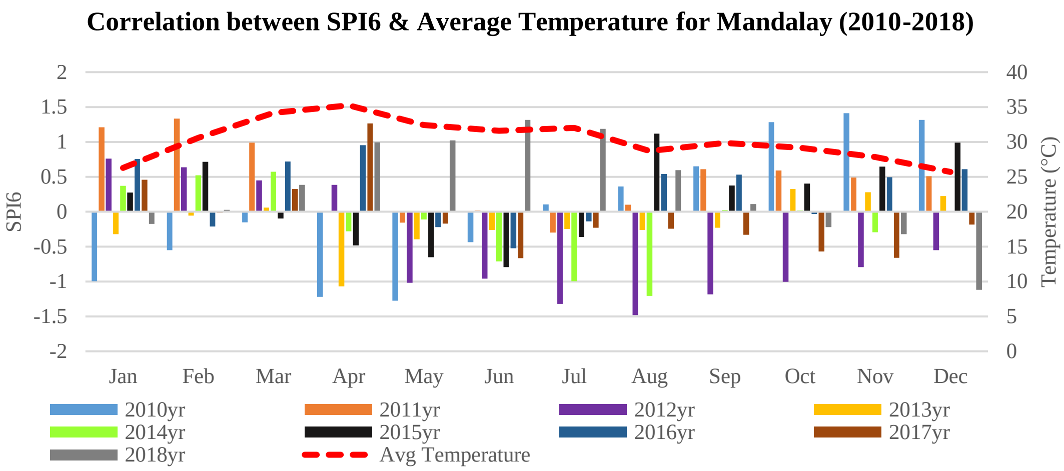
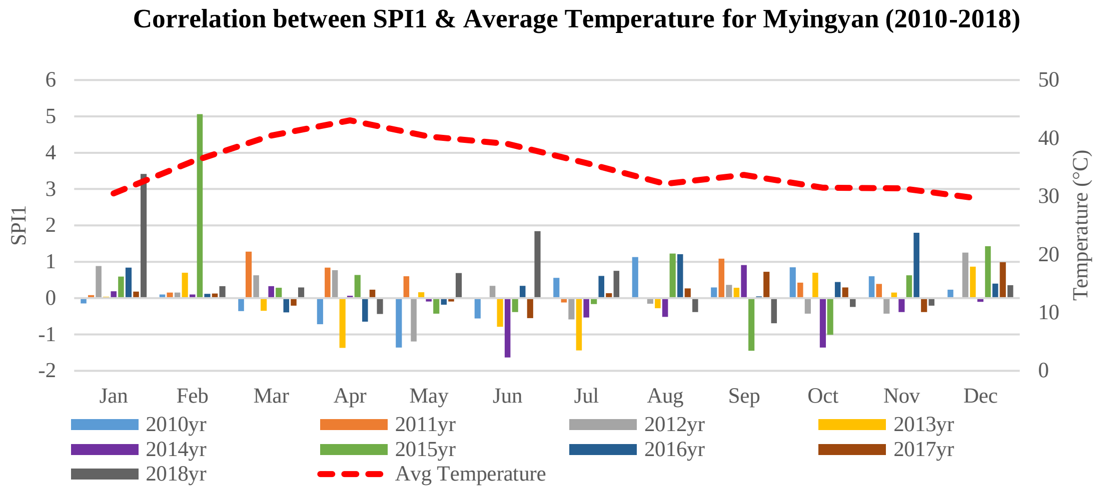
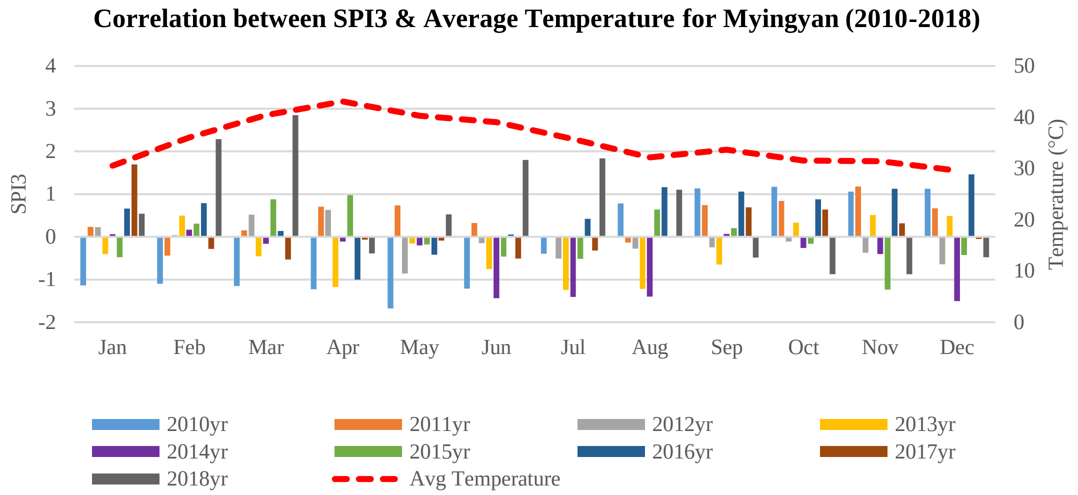


Figure A3. (a) Correlation between SPI 1 and averaged temperature for Mandalay (2010-2018), (b) Correlation between SPI 3 and averaged temperature for Mandalay (2010-2018), (c) Correlation between SPI 6 and averaged temperature for Mandalay (2010-2018)





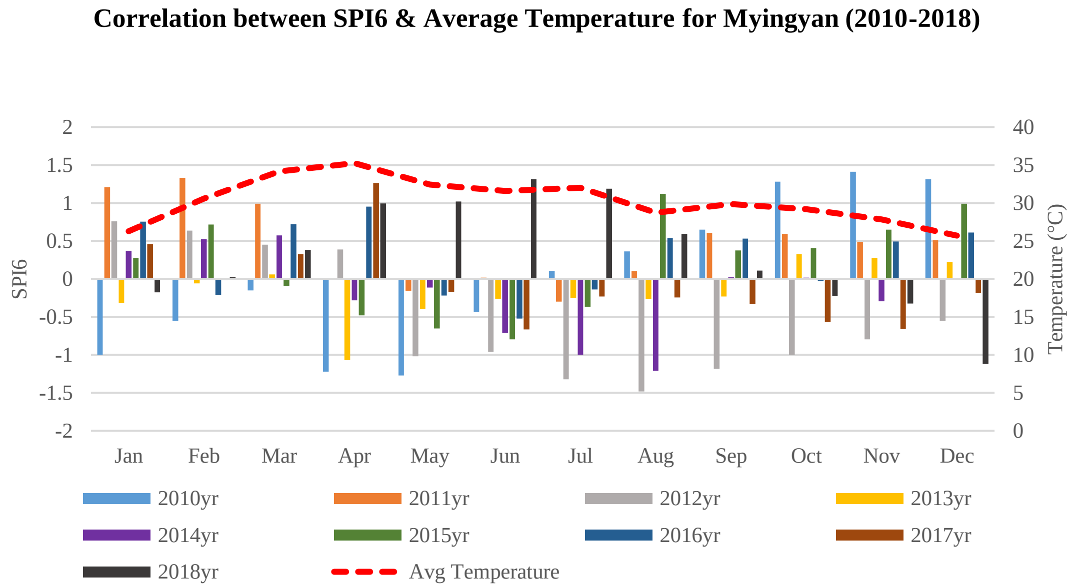
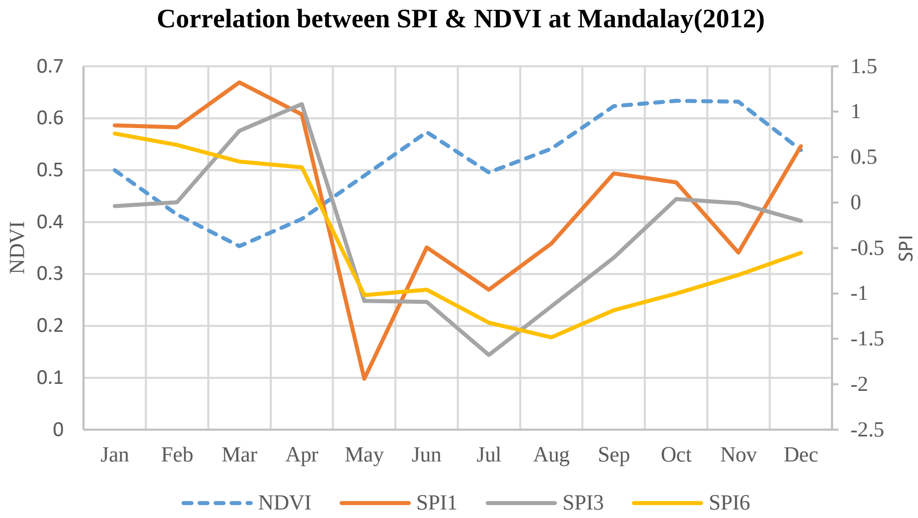
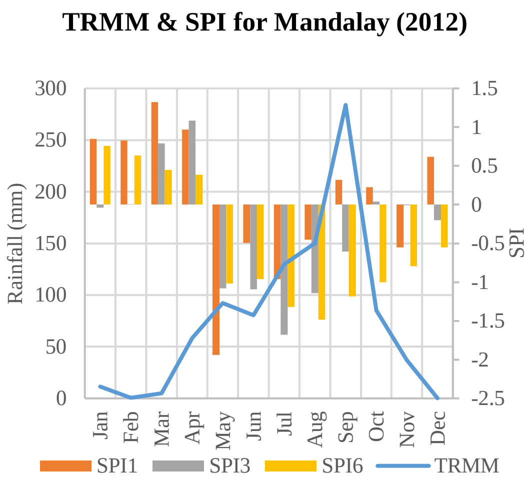


Figure A4. (a) Correlation between SPI 1 and averaged temperature for Myingyan (2010-2018), (b) Correlation between SPI 3 and averaged temperature for Myingyan (2010-2018), (c) Correlation between SPI 6 and averaged temperature for Myingyan (2010-2018)





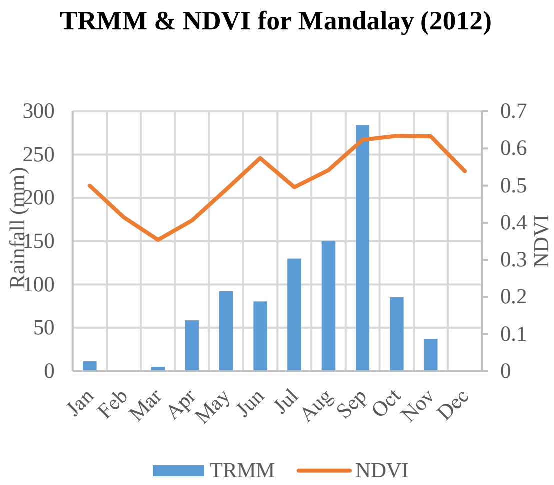


Figure A5. (a) Comparison between SPI and NDVI for Mandalay (2012) , (b) Correlation between rainfall and SPI for Mandalay (2012) , (c) Correlation between rainfall and NDVI for Mandalay (2012).

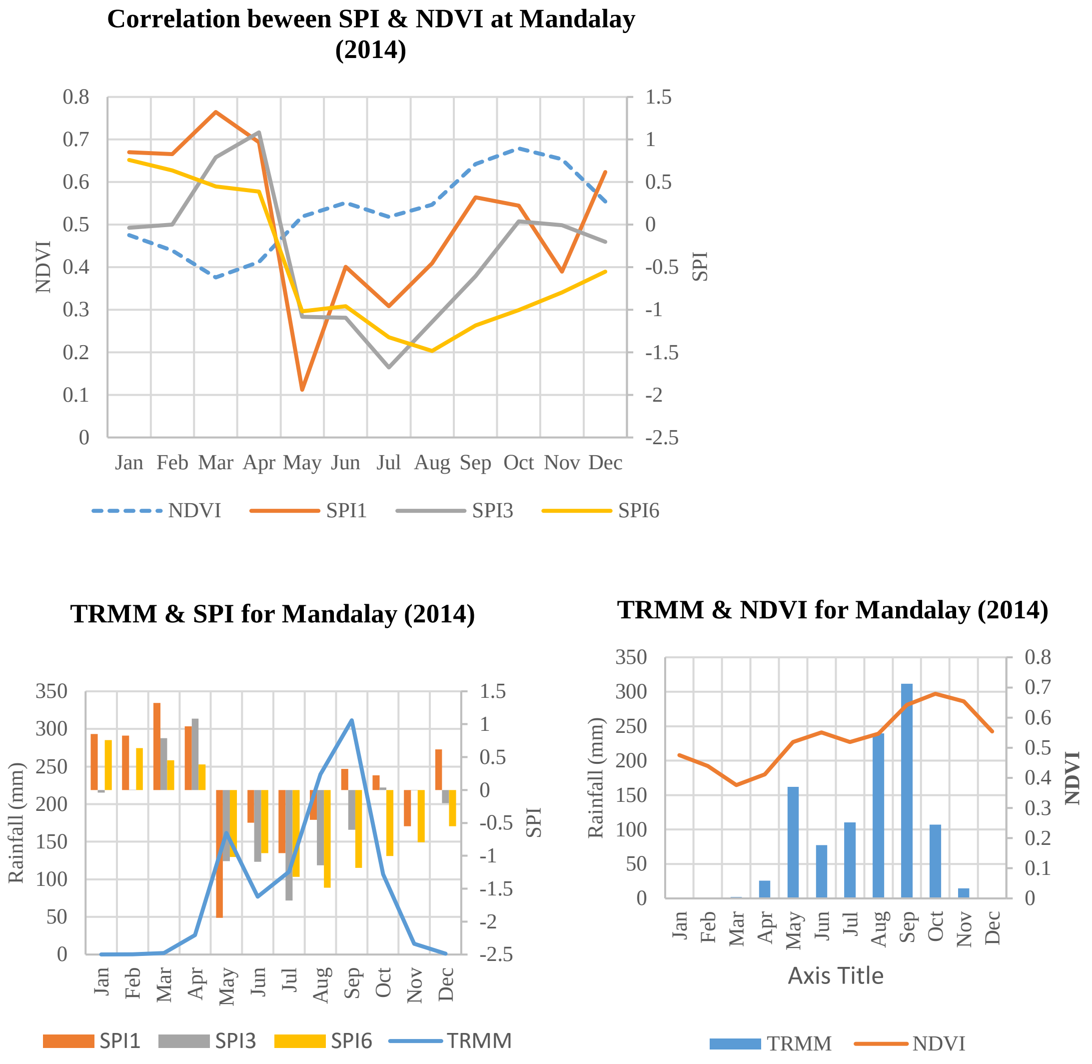


Figure A5. (a) Comparison between SPI and NDVI for Mandalay (2014) , (b) Correlation between rainfall and SPI for Mandalay (2014) , (c) Correlation between rainfall and NDVI for Mandalay (2014).

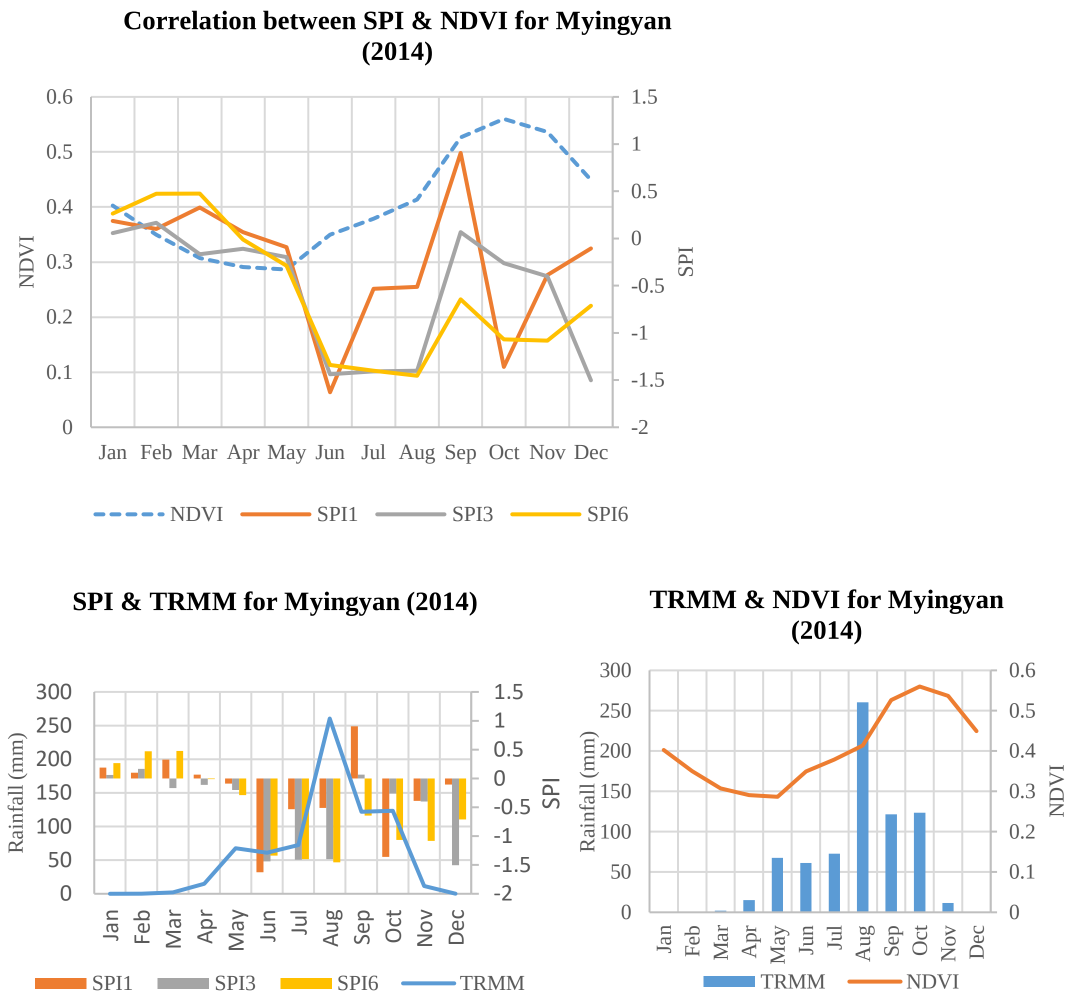


Figure A6. (a) Comparison between SPI and NDVI for Myingyan (2014) , (b) Correlation between rainfall and SPI for Myingyan (2014) , (c) Correlation between rainfall and NDVI for Myingyan (2014).

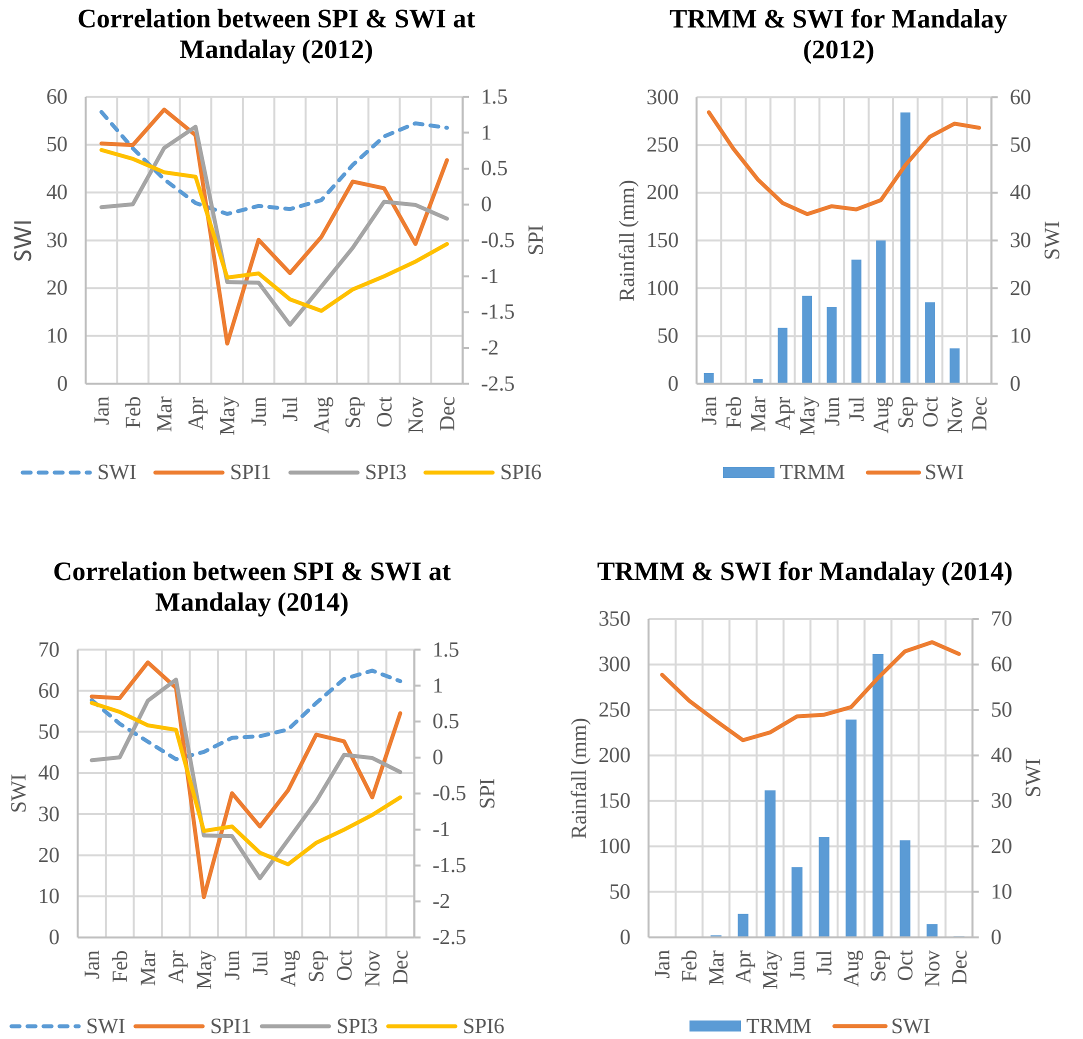


Figure A7 (a) Correlation between SPI & SWI at Mandalay (2012), (b) Correlation between observed rainfall and SWI for Mandalay (2012), Mandalay , (c) Correlation between SPI & SWI at Mandalay (2014), (d) Correlation between observed rainfall and SWI for Mandalay (2014), Mandalay

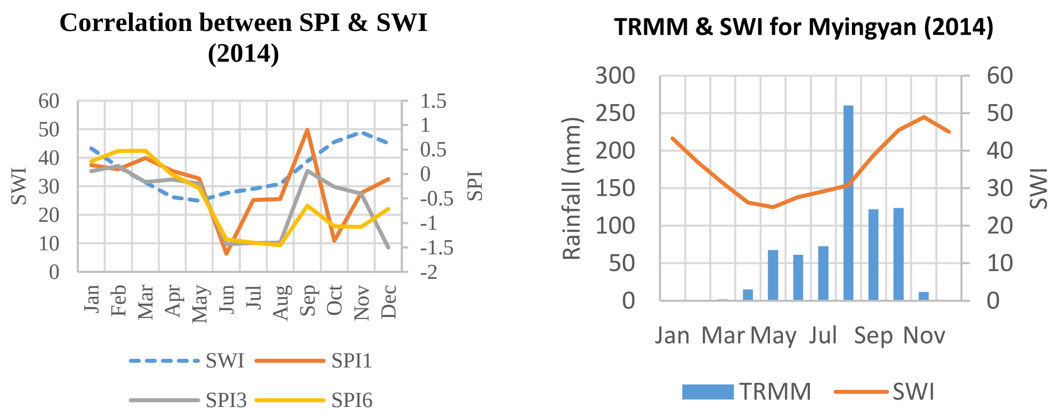


Figure A8 (a) Correlation between SPI & SWI at Myingyan (2014), (b) Correlation between observed rainfall and SWI for Myingyan (2014)

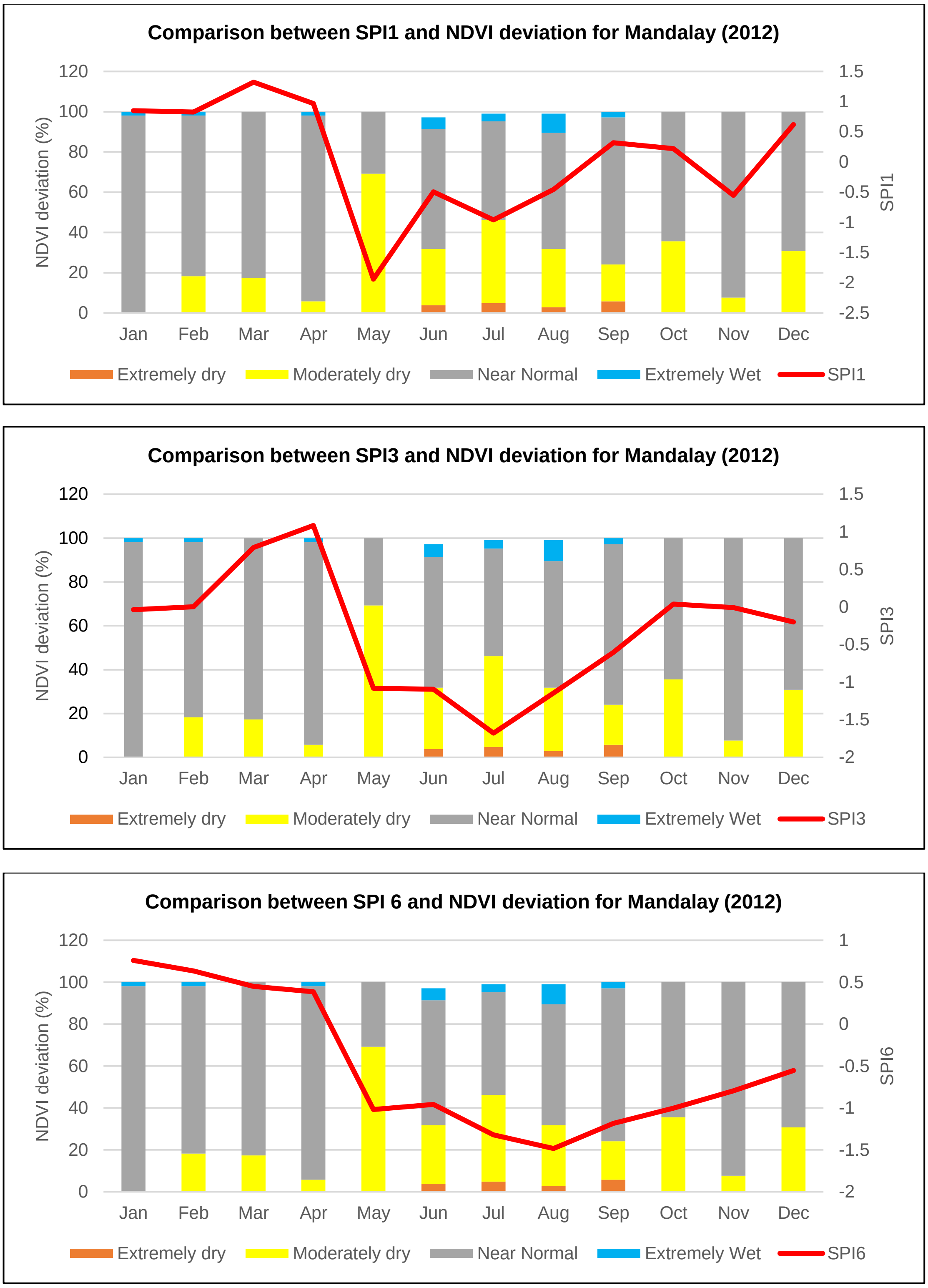
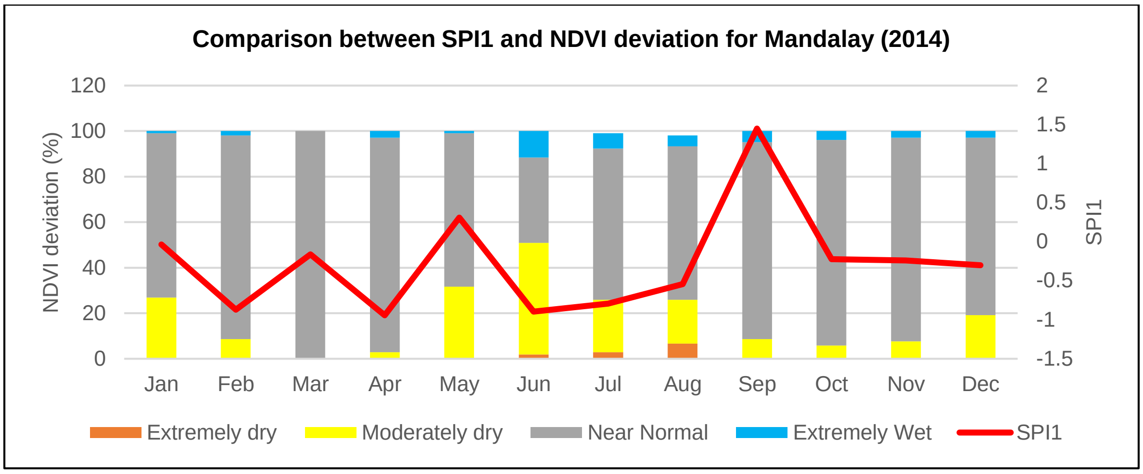
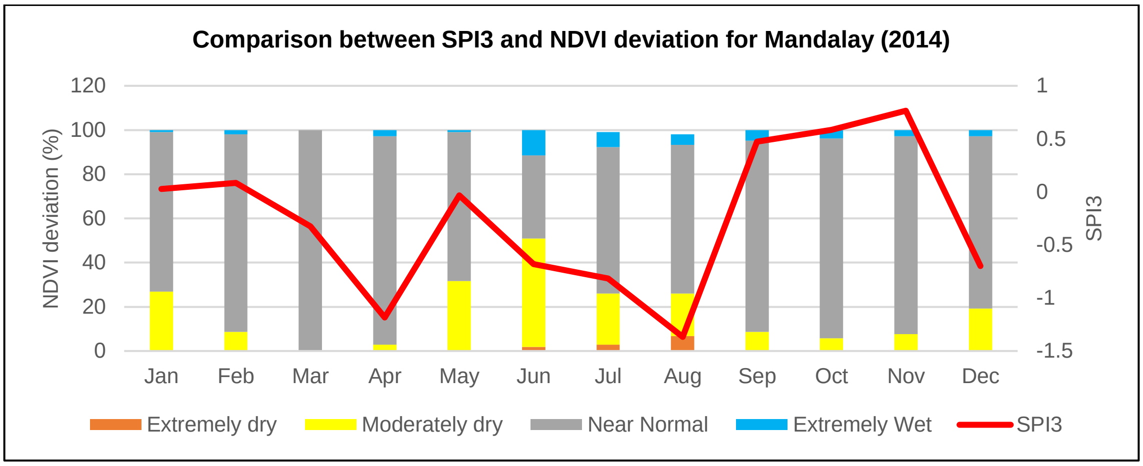


Figure A9 (a) Comparison between SPI1 and NDVI deviation for Mandalay (2012), (b) Comparison between SPI3 and NDVI deviation for Mandalay (2012), (c) Comparison between SPI6 and NDVI deviation for Mandalay (2012)





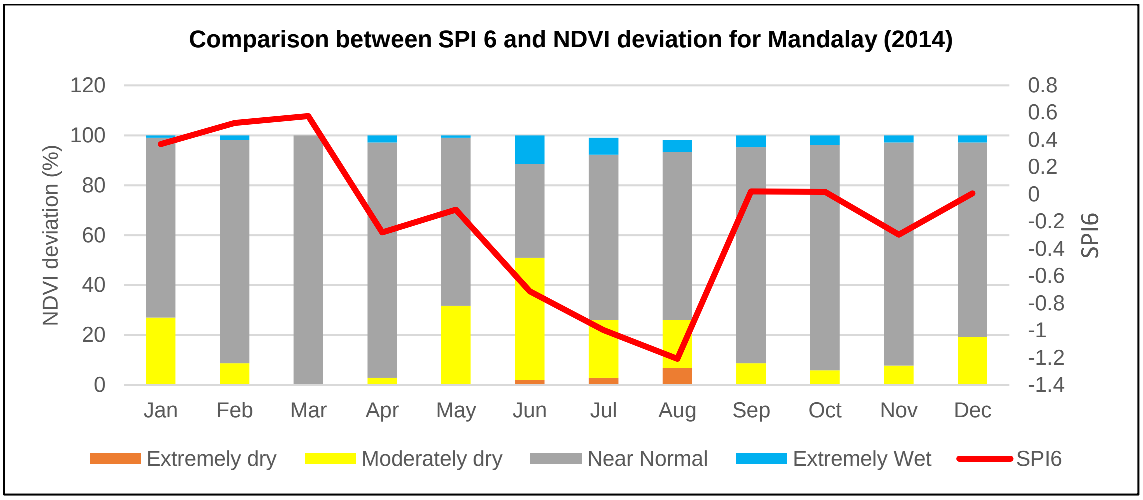
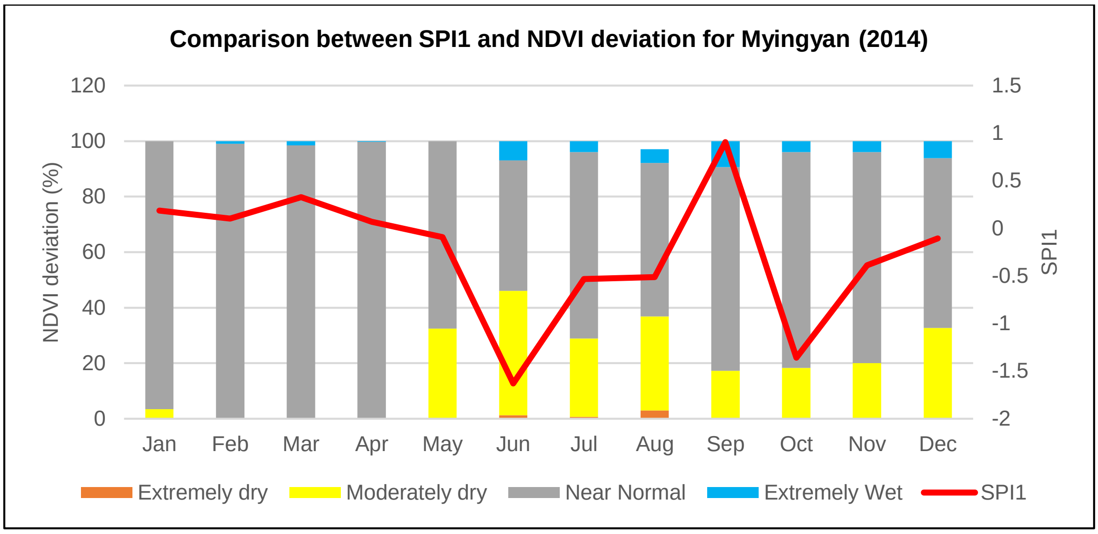
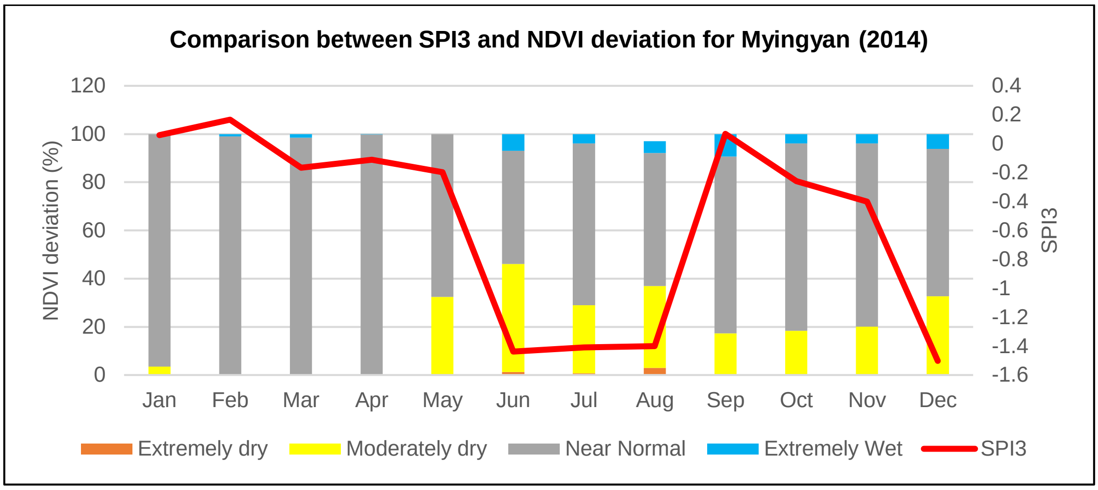


Figure A10 (a) Comparison between SPI1 and NDVI deviation for Mandalay (2014), (b) Comparison between SPI3 and NDVI deviation for Mandalay (2014), (c) Comparison between SPI6 and NDVI deviation for Mandalay (2014)





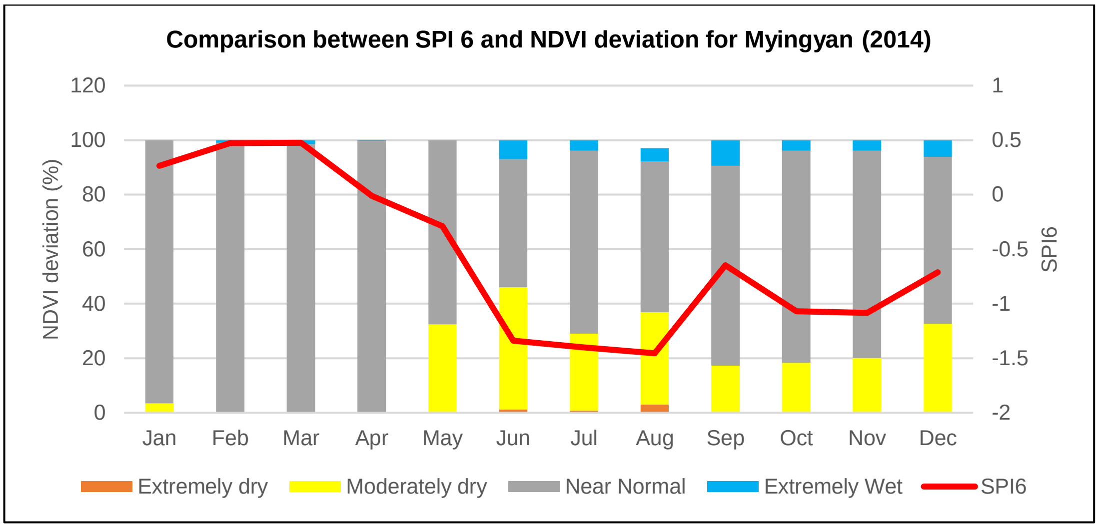


Figure A11 (a) Comparison between SPI1 and NDVI deviation for Myingyan (2014), (b) Comparison between SPI3 and NDVI deviation for Myingyan (2014), (c) Comparison between SPI6 and NDVI deviation for Myingyan (2014)

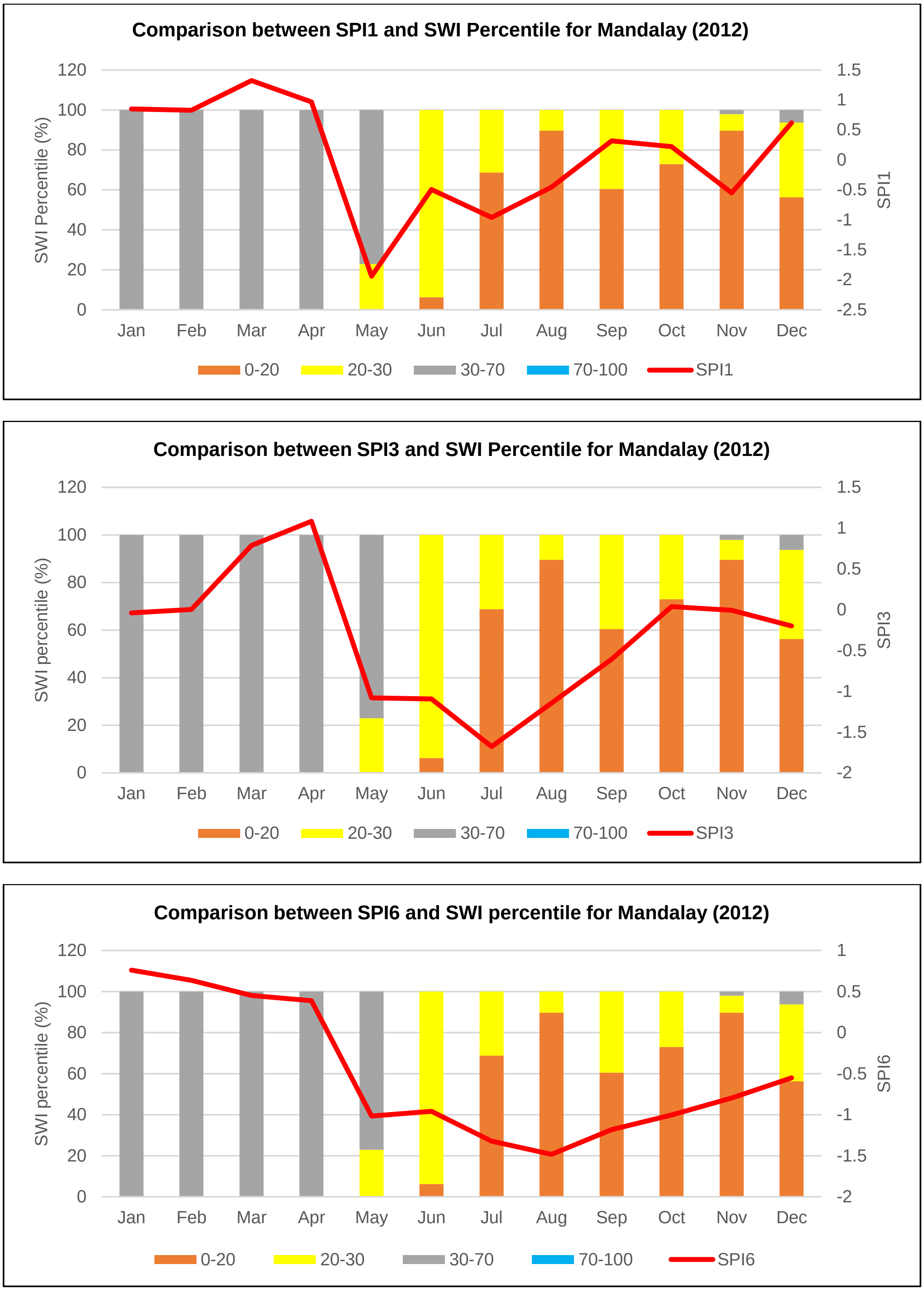
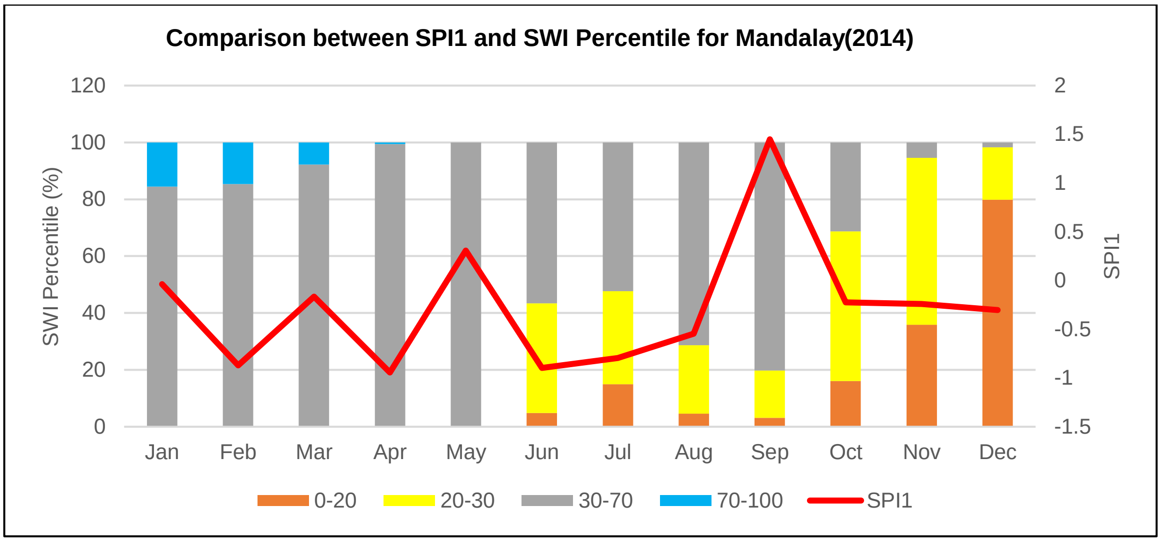
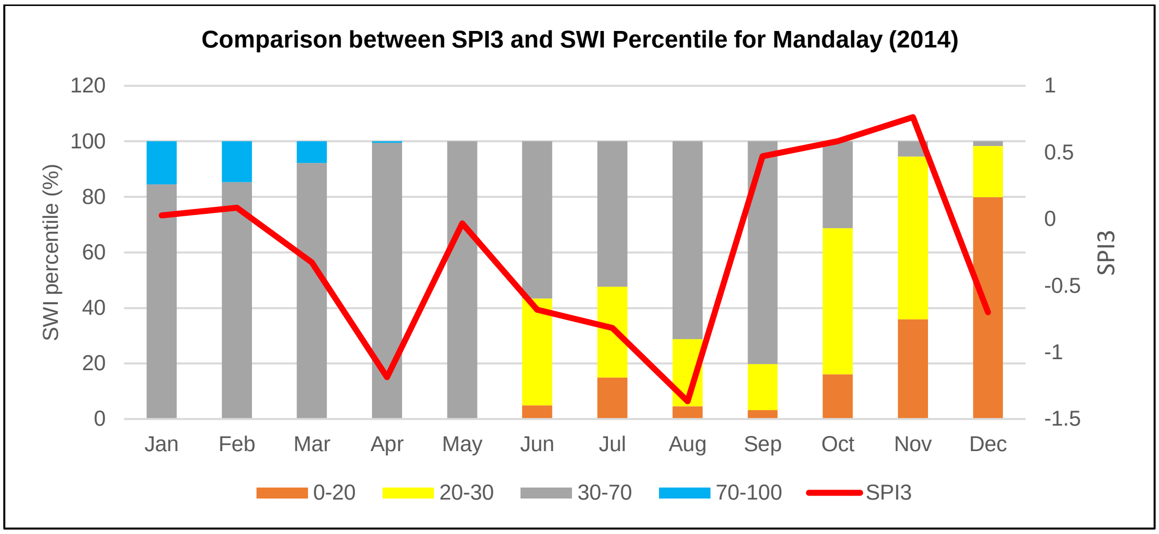


Figure A12 (a) Comparison between SPI1 and SWI percentile for Mandalay (2012), (b) Comparison between SPI3 and SWI percentile for Mandalay (2012), (c) Comparison between SPI6 and SWI percentile for Mandalay (2012)





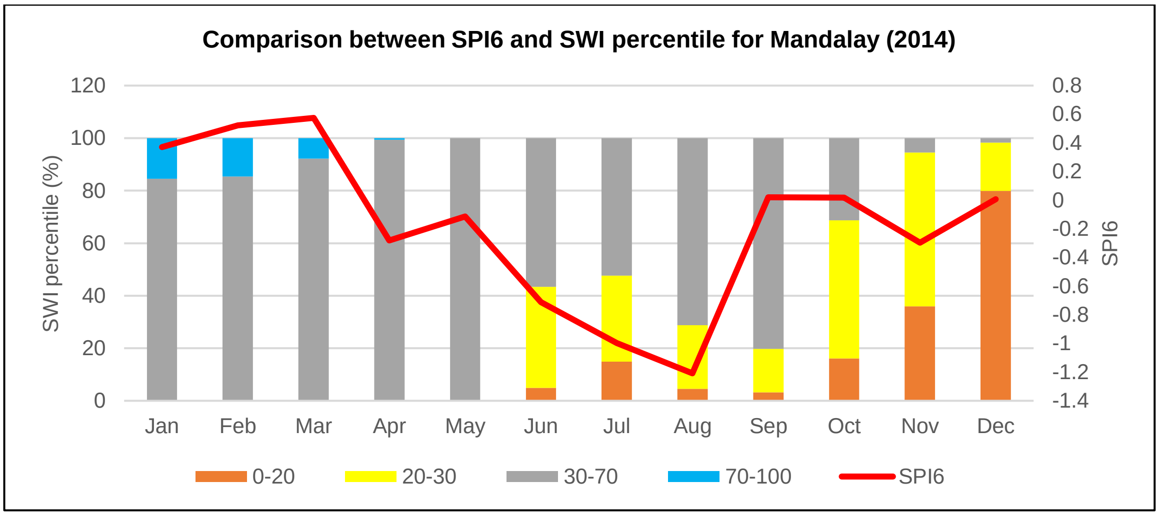
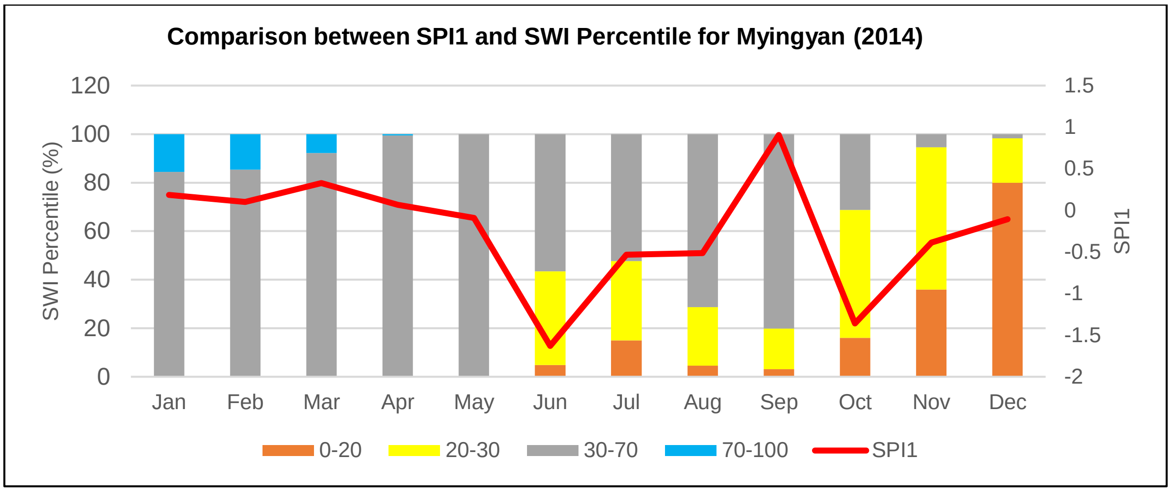
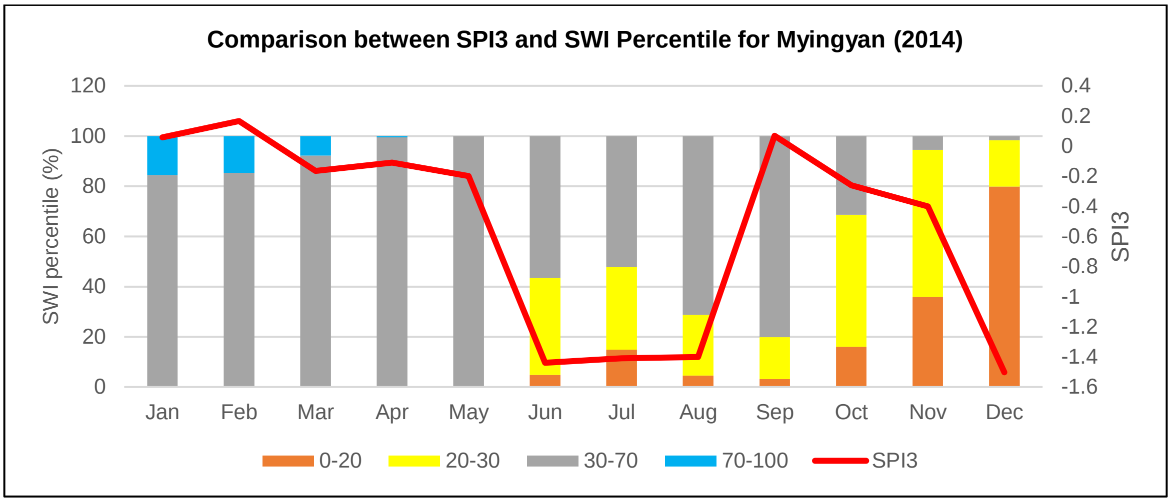


Figure A13 (a) Comparison between SPI1 and SWI percentile for Mandalay (2014), (b) Comparison between SPI3 and SWI percentile for Mandalay (2014), (c) Comparison between SPI6 and SWI percentile for Mandalay (2014)





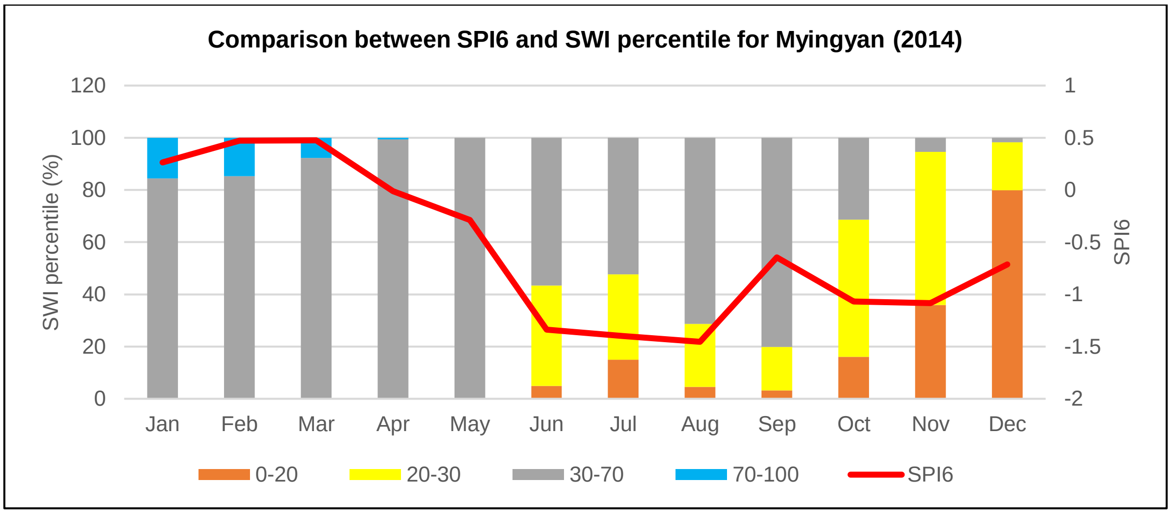


Figure A14 (a) Comparison between SPI1 and SWI percentile for Myingyan (2014), (b) Comparison between SPI3 and SWI percentile for Myingyan (2014), (c) Comparison between SPI6 and SWI percentile for Myingyan (2014)

APPENDIX B

Agendas

Strengthened drought and flood management through improved science-based information availability and management in Myanmar
Project upscaling meeting, 1st April 2019 MONREC

Time	Title	Entity
09.30 – 09.40	**Introduction and purpose of the meeting**	ECD
09.40 – 10.00	**Demonstration of the portal**	DHI
10.00 – 10.40	**The existing platforms in Myanmar** *The invited institutions present a description of their platform, if possible following the table annexed to this letter which has been filled out for the portal.* • Understanding of all platforms • Demo of each of them if possible • Overlap and synergies Outcome: Knowledge of the current situation in Myanmar and collect information to make an informed decision for the upscaling project.	All
10.40 – 11.00	Tea break	
11.00 – 12.30	**Planning the way forward** *Outline of a plan for the upscaling of the portal, where the overlaps are addressed, and the synergies are taken advantage of.* • Outline of upscaling • Next steps Outcome: outline of the plan with next steps for the potential preparation of a GCF Concept Note.	All

မြန်မာနိုင်ငံတွင် အဆင့်မြင့်သိပ္ပံနည်းကျ သတင်းအချက်အလက်များနှင့် စီမံခန့်ခွဲမှုမှတဆင့် မိုးခေါင်းရေရှားခြင်းနှင့် ရေကြီးရေလျှံမှုများကို စီမံခန့်ခွဲမှုအားကောင်းလာရေးစီမံကိန်း၏ ဒုတိယအကြိမ် နည်းပညာဆိုင်ရာသင်တန်း(၂.၄.၂၀၁၉) မှ (၄-၄-၂၀၁၉)အထိ

(Second Technical Training for Flood and Drought Portal)

Time	Title	Entity
Draft Agenda - 2nd April 2019		
09.00 - 09.20	Opening Remarks	Dr. Ye Myint Swe, Deputy Minister, Ministry of Natural Resources and Environmental Conservation (MONREC)
09.20-09.30	Remarks	Mr. Hans Christian Ammentorp, Senior Officer, Danish Hydraulic Institute (DHI)
09.30-09.40	Photo Session	All
09.40-10.10	Tea break	All
10.10- 11.10	**The Myanmar Flood and Drought portal** The portal and status of the technical assistance. Outcome: Knowledge of the different portal components, what they are and can be used for Knowledge of status of implementation.	DHI
11:10 - 12:00	**Remote sensing** Overview and understanding of remote sensing: Applications of Earth Observation (EO) for IWRM. Outcome: understanding of the data sources in the portal	DHI
12:00 - 13.00	Lunch	
13:00 - 15:00	**Data and Information** Practical exercise to learn how the available data could be used to identify and locate historic and current climate hazards. The objective is to identify and locate climate related hazards of relevance for seasonal planning with focus on drought impact on the agricultural sector.	Participants
15:00 -15:20	Tea break	
15:20 -16:00	**Wrap -up** Feedback and questions from participants.	

Time	Title	Entity
Draft Agenda - 3rd April 2019		
09:00 - 10:20	**Data and Information** Recap from previous session. In-depth understanding for key indicator to be used for drought assessment. - Hand - on exercises - drought hazard exercise. - Specific examples from Myanmar Outcome: Knowledge and understanding of available data to be used for drought assessment.	DHI Participants
10:20 -10:40	Tea break	
10:40 - 11:00	**Validation status** Status of technical assistance including data collected and presentation of results.	HAII
11:00 – 12:00	**Data and Information** Finalizing the previous session exercise focusing on drought hazard in Myanmar.	
12:00 -13:00	Lunch	
13:00 -15:00	**Crop application** Introduction to crop modeling using remote sensing data - Hands-on exercise-use and setup of the crop application Outcome: To identify the growing season of specific crop with information in the data portal. Key steps will be described.	DHI
15:00 - 15:20	Tea break	
15:20 - 16:00	**Wrap -up** Continuation of previous exercise. Feedback and questions from participants.	
Draft Agenda - 4rd April 2019		
09:00 - 10:20	**Crop application** Recap of previous day and finalizing the exercise	DHI Participants
10:20 - 10:40	Tea break	
10:40 - 12:00	**Crop application** Introduce the module of the Crop application that allows the users to calculate irrigation demand and crop yield using remote sensing input data as input to the AquaCrop tool. - Hand-on exercise - use and setup of the crop application Outcome: Capacity and Knowledge to evaluate the impact on crop production from drought events.	DHI
12:00 - 13:00	Lunch	
13:00 - 14:45	**Crop application** Completion of previous session.	
14:45 - 15:00	Tea break	
15:00 - 15:30	**Wrap -up** Feedback and questions from participants. Course Evaluation & Certificates	DHI

Strengthened drought and flood management through improved science-based information availability and management in Myanmar
5th April 2019, AIRBM Training Room, Yangon

Draft Agenda Outcome: Update on Myanmar Flood and Drought Portal and Technical training		
Time	**Title**	**Entity**
09.00 – 09.20	Welcome and Presentation of participants	DHI
09.20 – 10.20	**The Myanmar Flood and Drought portal** *The portal and status of the technical assistance.* • Recap on the portal • Status of technical assistance including the Data validation Outcome: Knowledge of the different portal components, what they are and can be used for. Knowledge of status of implementation.	DHI
10.20 – 10.40	Tea break	
10.40 – 12.00	**Data and Information** *Overview and understanding of available near real time data for flood and drought assessment.* • Feedback from participants on what they have been using the portal for • Hands-on exercises – based on the Data and Information app. Outcome: Usability and testing of the portal. Knowledge and understanding of available data to be used for flood and drought assessment.	DHI Participants
12.00 – 13.00	Lunch	
13.00 – 15.00	**Crop application** *Understand how a crop model could be used to forecast drought impact on crops. Include the uncertainty in the climate forecast in the assessment.* • Hands-on exercises – use and setup of the crop application Outcome: Capacity and knowledge to evaluate the impact on the crop production from drought events.	DHI
15.00 – 15.20	Tea break	
15.20 – 16.00	**Wrap-up** *Feedback and questions from participants. Course Evaluation.*	

APPENDIX C

Attendance Registers

Project upscaling meeting 1st April 2019 – ECD, MONREC

No	Name	Gender	Department	Ministry	Job Title	Phone	E-mail
1	U Hla Maung Thein	Male	ECD	MONREC	DG	67431322	hlamaungthein.env@gmail.com
2	Dr.San Oo	Male	ECD	MONREC	DDG (A/P)	067431326	sthandaroo@gmail.com
3	Daw Tin Tin Aye	Female	ECD	MONREC	AD	09420702221	ecdtintin@gmail.com
4	Daw Thandar Wint Wint Khaing	Female	ECD	MONREC	AD	09450028742	tdwindwrm@gmail.com
5	U San Win	Male	ECD	MONREC	AD	09788259959	sanwin.ecd@gmail.com
6	U Paing Hsu Lwin	Male	ECD	MONREC	SO	0943016782	painghsulwin.env@gmail.com
7	Daw Zin Mar Phyu	Female	ECD	MONREC	SO	09250969549	zinmarphyu123@gmail.com
8	Daw Kyi Kyi Win	Female	ECD	MONREC	DSO	09769073544	kyikyiwin.ecd@gmail.com
9	U Kyaw Moe Aung	Male	ECD	MONREC	Project Manager	09970541056	kyawmoeaung@nationalcommunication.org
10	U Win Shwe	Male	Survey Dept.	MONREC	Director	067413679	winshweko@gmail.com
11	Daw Thiri Maung	Female	DDM	MOSWRR	Dy Director	0673404540	thirimaung.rrd@gmail.com
12	Daw Htay Htay Than	Female	DMH	MOTC	Director	09250954638	HHThan.DMH@gmail.com
13	Daw Sandar Myint	Female	DOP	MOLIP	Deputy Director	067431368	sandar6869@gmail.com
14	U Myo Tun Oo	Male	DMH	MOTC	A.D	067411224	myotunoo2009@gmail.com
15	Sílvia Leirião	Female	DHI		Project Manager	+4550 333182	sls@dhigroup.com
16	Bertrand Richaud	Male	DHI		Water Resources Expert	+33240487447	ber@dhigroup.com

Technical training 2nd to 4th April 2019 – Nay Pyi Taw

No	Name	Gender	Department	Ministry	Job Title	Phone	E-mail	No Days
1	Daw Aye Aye Khaing	Female	DOA	MOALI	Staff Officer	943017225	aayekhaing2016@gmail.com	3
2	Daw Kyi Kyi Win	Female	ECD	MONREC	D.S.O	9769073544	kyikyiwin.ecd@gmail.com	1
3	Daw Marlar Aung	Female	ECD	MONREC	Director	9784066228		1
4	Daw May Eaindra Kyaw	Female	ECD	MONREC	D.S.O	9454316548	mayeaindrakyaw.ecd@gmail.com	3
5	Daw May Htay Su Kyi	Female	DMH	MOTC	Deputy Superintendent	9257802700	mayhtaysukyi86@gmail.com	3
6	Daw May Myat Mon	Female	ECD, EIA	MONREC	S.O	9420719076	Maylay.yau1981@gmail.com	3
7	Daw Nway Nway Soe	Female	DDM	MSWRR	AD	9422203910	Nwaynwaysoe1976@gmail.com	3
8	Daw Sandar Myint	Female	ECD	MONREC	Staff Officer	9799800413	Sandarmyint23888@ gmail.com	3
9	Daw Swe Swe Yee	Female	DOA	MOALI	Staff Officer	9795433919	swesweyee16@gmail.com	3
10	Daw Thandar Wint Wint Khaing	Female	ECD	MONREC	Assistant Director	9450028742	tdwindwrm@gmail.com	3
11	Daw Thin Thuzar Win	Female	ECD	MONREC	DD	9250186101	Thinthuzar1981@gmail.com	3
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