Innovative rainfall measurement devices in tropical regions

A comparative data analysis for Yangon and Bago, Myanmar

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By

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in partial fulfilment of the requirements for the degree of

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Preface

This thesis is written as a final assignment for the Bachelor Civil Engineering. For the assignment a period of nine weeks is scheduled, of which eight are for writing the thesis and after that every student has to prepare and give a presentation.

The motivation for writing this thesis is that floods are a common problem during the heavy rainfall of the monsoon period in Myanmar. To design a proper sewer system, rainfall data is needed and has to be studied. This is the main focus within this thesis. First, this thesis will contain theoretical research on rainfall challenges within Myanmar. Second, historical data will be analysed to obtain a clear picture on the rainfall patterns in Myanmar. Third, different measurement techniques will be tested in the field and their results will be compared to each other.

During my stay in Myanmar I found some challenges with installing equipment and collecting data. An example is the cultural difference in handling and arranging. The director of the Yangon Technical University (YTU) already gave permission by email for installing the rain gauges at the YTU. Once I arrived in Myanmar, I had to wait a few weeks since my contact person was in the Netherlands and was difficult to reach. When she was in Myanmar again, she told me the email we got for the permission was not official, so we had to ask for permission by an official letter. This would take some time again, because the director was out of town. The difficulty is that you can't make concrete commitments and to get things settled, you have to visit the university very often and be very patient. Eventually, the rain gauges were installed after one and a half month, when the rainy season had already started. This is the reason why only 6 days of Yangon data could be analysed.

In addition to this difficulty, there were some problems with the equipment itself. The disdrometers were set to English time, so some steps had to be taken to convert this. However, one of the disdrometer was set to a different time zone, so therefore the difference between the two start times of the disdrometers had to be compared. Furthermore, power cuts occur on a regular basis in Myanmar. In order to have no breaks in the data results, the disdrometers are connected to an Uninterruptible Power Supply (UPS) system.

Doing this research did not only help me in study related development, but also gave me the opportunity for personal development due to a totally different environment and culture. For all of this, I would like to thank all the people who helped me during my investigation. In particular I would like to thank Dr. ir. Martine Rutten, who was not only my supervisor during my research, but also helped me with practical stuff for my research and trip to Myanmar and supported me when I was having trouble. Also, I would like to thank my other supervisor from the TU Delft Dr. ir. Marie-Claire ten Veldhuis and my co-supervisor in Myanmar Ir. Alwin Commandeur. Furthermore I would like to thank Dr. Win Win Zin, who was my contact person at the Yangon Technical University, and Mr. Wunna Sai, who was my contact persons Irrigation Technology Centre.

Dorien Honingh

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Contents

Nomenclature

Parameter	Explanation
$\boldsymbol{C}$	Skewness coefficient
$\boldsymbol{I}$	Rainfall intensity
$\boldsymbol{K}$	Gumbel frequency factor
$\boldsymbol{K_t}$	Log Pearson frequency factor
$\boldsymbol{n}$	Number of years of record
$\boldsymbol{P^*}$	The logarithm of the extreme precipitation value
$\boldsymbol{P_{ave}}$	Average of the maximum rainfall
$\boldsymbol{P_i}$	Extreme precipitation value
$\boldsymbol{P_t}$	Precipitation peak value
$\boldsymbol{S}$	Standard deviation of P
$\boldsymbol{S^*}$	Standard deviation of P^*
$\boldsymbol{T_R}$	Return period
$\boldsymbol{T_d}$	Rainfall duration

Abstract

In this thesis, the rain conditions of Yangon and Bago are studied. During the rainy season large rain quantities fall in a short period, which quite regularly causes major floods in Myanmar. The floods have a devastating impact on urban society, so it is important to address this problem. For forecasting these floods and designing a proper sewer system, it is important to know how much precipitation there will be, whereby the time and spatial variation have to be taken into account.

Firstly, the available historical data of both cities were studied. Of these datasets Intensity Duration Frequency (IDF) curves, which give an overview of the return periods of rain events, have been made. In addition, variations in monthly and annual rain amounts were investigated. This is very useful information, but the current number of stations is not enough to capture the spatial variation of precipitation. The amount of monitoring stations in Myanmar would thus have to be increased, whereby the desired ratio of measurements points will be 24 rain gauges per 1000 km^2. For creating this measurement network, automatic rain gauges should be used in order to also capture the variation in time.

In theory the Delft-disdrometer would be a proper measurement device for creating this network. The advantages over a traditional tipping bucket are that the Delft-disdrometer is good in measuring high rainfall amounts and it can also measure the kinetic and acoustic energy of the droplets by hitting the dives. These aspects can also be measured by the traditional disdrometer, but these are more expensive while the Delft-disdrometer is of the same price range of the Tipping bucket.

Though, the rainfall measurements in this research show different results for the Delft-disdrometer compared to the tipping bucket, for both Yangon and Bago. However, the tipping bucket has similar results with the manual rain gauge measurements. Therefore, on basis of the measurement results presented in this report, the preferential solution would be creating a measurement network with tipping buckets.

Furthermore, the use of the Social Weather App is investigated. At this moment, using the App in Myanmar is not a big success. Limited data is collected, because there were many problems with the internet so reports could not be uploaded. Nevertheless, after comparing the collected rain reports with measurement results, already rain intensity categories are visible. Within these categories, there is still overlap. However, the expectation seems that the rain reports can provide useful information.

Introduction

2.1. Societal relevance

More than half of the world's population lives in urban areas and the forecast for 2030 is a growth in cities of another 1.5 billion people. Especially in Asia and Africa this growth will take place, which will provoke huge social, economical and environmental changes. (United Nations Population Fund, 2015)

In many cities worldwide, floods are still a major problem. Especially in tropical regions, because during the monsoon period large rain quantities fall in a very short period. This brings extensive flooding, which has a devastating impact on urban society. In order to address this problem, authorities and citizens need real-time information on where floods are expected to occur. For forecasting these floods, it is important to know how much precipitation there will be, whereby the time and spatial variation have to be taking into account. After this identification, steps can be taken to prevent damage and casualties. (The World Bank Group Experience, 2014)

One of the countries with a tropical monsoon climate is Myanmar. During June and August 2015, there were severe floods in Myanmar. The country has always suffered from floods during the monsoon season, but this was one of the worst in decades. Not only did it affect around 1 million people, but also 0.5 million hectares of rice paddy were damaged and around 0.25 million livestock animals were killed (Floodlist, 2015).

Figure 1: ***Myanmar flooding in July 2015*** **(FMT News, 2015)**

In Myanmar there is a lack of monitoring stations, which is one of the reasons that Myanmar is facing water problems. In this thesis the rainfall in the cities of Yangon and Bago will be studied. The region of Yangon contains more than 7 million inhabitants and is the biggest region of Myanmar (City Population, 2015). Since this is the economic capital of Myanmar it doesn't only contain a high amount of inhabitants but is also of economic importance.

For Yangon and Bago two different causes for floods can be distinguished. The first reason is pluvial flooding. In this situation the extreme amount of water saturates the drainage system and the remaining water cannot be absorbed, leading to an excess of surface water. The second cause for floods to occur in this regions are that it is located in the delta region. During the monsoon season the rivers in this area are sometimes unable to handle the amount of water, causing severe flooding. For example, in 2014 the heavy rain flooded the Bago river and the Ngamoeyeik creek. As a result five villages in the Yangon region flooded, around 3 thousand people were affected and there were flood water heights up to 1 meter (Davies, 2014). The authorities of Myanmar thus have a keen interest in improving the rainfall and flooding information. The first step in setting up a proper rainfall flooding system is creating reliable rainfall data.

2.2. Scientific relevance

In Myanmar flood forecasting is done by the Department of Meteorology and Hydrology (DMH). DMH has the responsibility of 63 Meteorological Stations and 39 Meteorological & Hydrological Stations. It is important to mention that these stations don't have automatic rain gauges. (Sein, 2014) For forecasting and monitoring, the department uses of different global and regional Numerical Weather Forecast Prediction Model outputs. Furthermore, the department uses the Weather Research Forecast (WRF) model. In Myanmar this model has an accuracy of 30 km horizontal and 25 eta levels vertical (Thein, 2015). The weather forecast is updated within a 72-hour period. It is possible to make shorter range weather forecasts, for this the Diana Tool is applied (Thein, 2015).

The city of Yangon covers 598.75 km^2 (Myanmar delegation, 2009) and the city of Bago is even smaller (approximately 100 km^2), while the resolution of the forecast model is $30 \times 30 = 900$ km^2. The reason that the numerical weather predictions are set up at a coarse resolution is that there are no measurement data to make a more detailed model. For this reason, it is not possible to predict rainfall very accurately by this model. Therefore it is essential to increase the amount of rainfall measurements in this area. Having this data is important in order to make predictions about where the risk of flooding is high.

In this study multiple rainfall measurement devices will be placed in Yangon and Bago. These measurement devices will provide accurate rainfall data. It only provides data of that specific location. In order to get more measurement points, additional rainfall data will be obtained by crowdsourcing. The challenge now remains to combine these data sources with different time resolution. The data of crowdsourcing is discreet, while the rain gauges provide continuous data.

2.3. Objective

One of the main targets in this study is to create a better overview of the rainfall in Yangon and Bago. This information serves several important purposes. First of all, it is necessary to create more accurate weather forecasts for both cities, but this part will not be done in this research. Creating those maps has the purpose to provide information to authorities and citizens, by which they can take action to prevent damage and casualties in the future. So the first step to achieve this will therefore be done in this study. Secondly, having a better insight into the rainfall patterns in Myanmar is important for designing a proper sewer system.

Research questions

In this study, different types of rain data will be analysed, namely historical data and newly collected data. For the newly collected data two types of data are being considered; actual rainfall measurements and weather reports obtained by social media. Moreover, within the data category of actual rainfall measurements, there are also three different data sources. The purpose of collecting these different types of data is to combine the information where possible. Thus the main research can be formulated as follows:

> *What aspects are important for creating an accurate rainfall map and creating a proper sewer system for the city of Yangon and the city of Bago?*

To answer the main research question it is necessary to first work out the sub-questions below:

> *- What are appropriate locations to install measurement devices, in order to create an optimal rainfall measurement network in the Yangon city and Bago city?*
>
> *- What can be derived from historical data of Yangon and Bago?*
>
> *-What is an appropriate way to involve students to use the Social Weather App?*
>
> *- What is a good approach to process the data of the App?*

Materials and Method

4.1. Material

To create reliable weather maps, data has to be collected and handled by computer programs. The materials used for collecting data are; the Delft-disdrometer, the tipping bucket, traditional rain gauges and the Social Weather App. The specifications of these materials are explained below. Furthermore, the obtained data will be processed, which will be done with Excel 2007 and Python 2.7.0. For the data of the tipping bucket, there is an intermediate step in this process. Initially, the data is stored in a data logger. To collect this data, the data logger has to be connected with the ECH2O Utility program. This program then delivers the data in Excel files.

4.1.1. Delft-disdrometer

One of the main limitations in the use of rainfall measurement equipment is that they are quite expensive to buy or maintain. Recently, a new kind of disdrometer was designed, called Delft-disdrometer. The Delft-disdrometer is an acoustic disdrometer, of which the design details are explained in Hut, R. (2012) 4.2.1 Design. In R. Hut (Red.), *New Observational Tools and Datasources for Hydrology* (pp. 43). Delft: Technische Universiteit Delft. This device is a bit cheaper to buy than a tipping bucked rain gauge, which is a common measurement device because it has a relatively low purchase cost compared with other rain gauges. The main disadvantage of the tipping bucket is that it has high maintenance cost. This is where the disdrometer has its advantage, because of its low maintenance cost. The Delft-disdrometer is developed with the best of both, the costs are around €500 and there is not a lot of maintenance required. For this reason, it would be possible to create a dense network with Delft-disdrometers to gain more rainfall data. (Hut, 2013)

Figure 2: Delft-disdrometer (DisdroMetrics, n.d.)

In addition to the price tag difference, the Delft-disdrometer is useful because it measures the acoustic energy of the droplets by hitting the dives, which is directly related to the kinetic energy. The kinetic energy is the most important cause of erosion true rainfall and the other factor in this process is rainfall intensity (Moussouni, 2014).

Furthermore, the drop size distribution is measured, which is of very useful for different scientific purposes. For instance radar meteorology, cloud physics and satellite remote sensing could benefit from these kind of information. The interest in these kind of information has increased by, for example, the climate change and the increased frequency of extreme rainfall events. (Balthas, 2016)

The Delft-disdrometer has, for drops bigger than 1.75 mm, similar uncertainties as the industrial standards; Thies LPM and Ott Pasivel. Compared with the KNMI electronic rain gauge, the measurement difference falls within a 10% interval. (Hut, 2013)

4.1.2. Tipping bucket

The tipping bucket is one of the most used rain gauges for measuring rainfall. It delivers continuous rainfall data, with time resolution of 5 minutes. A tipping bucket has a bucket in which rainfall is collected, the collection area is 214 cm^2. At the downside of the bucket there is a small hole, where water goes through. Two small bowls, also called tipping spoons, are located under this hole. During a rain event, the rain passes the hole and falls in the bowl. After

Figure 3: Tipping bucket (Davis, n.d.)

the bowl is filled with 0.2 mm of water, the bowl will tip. Then the other bowl gets filled and the process will then repeat itself. The sensor that records the tips is a magnetic reed switch. To make sure this process will not be disturbed, it is important to install the rain collector at least 4 cm away from any steel or iron objects and surfaces. (Rain Collector # 7852 & 7852M, 2004)

The tipping bucket is a reliable measurement device, but just like any other field sensor, has the instruments systematic and random errors. The systematic errors consist of inaccuracies during the calibration and underestimation due to wind exposure or rain evaporation losses. (Ciach, 2010)

The accuracy of the tipping bucket is for rain rates up to 50 mm/hr, is equal to the greatest value of ±4% of total or 0.2 mm. For rain rates from 50 mm/hr until 100 mm/hr, the accuracy is equal to ±5% of total or 0.2 mm, whichever is the biggest value. (Rain Collector # 7852 & 7852M, 2004) On average will the tipping bucket underestimate the rainfall, especially during high rainfall intensities. For example, the underestimation for rainfall intensities higher than 200 mm/hr is commonly between 10 and 15%. (Lanza, n.d.)

4.1.3. Social Weather App

The Social Weather App is developed to collect qualitative data. Every person with a smartphone, both Android-phones and Apple-phones, are able to participate. The operations that need to be carried out are as follows:

- Upload a daily picture of the sky/rain. At the rainy day, more pictures during different intensities are desirable.
- Choose rainfall situation, the possibilities are; no rain, drizzle, light rain, moderate rain, heavy rain and extreme rain.

If possible, it is helpful to turn the GPS on while using the app. The location of the pictures will then automatically be saved. The alternative option is indicating your location on a map. (Veldhuis, 2014)

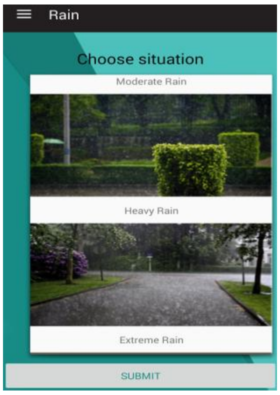


Figure 4: Print screen rain event report Social Weather App

4.1.4. Traditional rain gauge

At both Yangon and Bago a traditional rain gauge is present, of which data will be used.

A telemetric system is present at the YTU. This system is capable of measuring various different parameters such as temperature, humidity and rainfall. The University of Tokyo installed the system on the roof of the YTU in order to conduct some of their research. The original purpose of the station is investigating the weather influence on steel corrosion.

The rain gauge within this telemetric system is a tipping bucket rain gauge of the brand Texas Electronics. The model number is TR-525M, Metric Rainfall Sensor. The resolution of the model is 0.1 mm and the accuracy is 50 mm/hr. (Texas Electronics, 2016)

Figure 5: Telemetric system YTU

At the ITC in Bago there is a HOBO Logging Rain Gauge, which is a high quality tipping bucket. Just like the normal tipping bucket, 0.2 mm rainfall provokes a tip and data is stored every 5 minutes. However, this equipment distinguishes itself because of its ability to also measure the surrounding temperature. The HOBO Logging Rain Gauge has a collection area of 232 cm^2 and it can measure a maximum of 127 mm rainfall/hr. Furthermore, the HOBO rain gauge has a calibration accuracy of 20 mm/hr. Also, the rain gauge only works when the operating temperature is within a range of 0° to 50°. (HOBO Data Logging Rain Gauge - RG3-M, n.d.)

Figure 6: HOBO Logging Rain Gauge (HOBO Data Logging Rain Gauge - RG3-M, n.d.)

4.1.5. Manual rain gauge

Figure 7: Manual rain gauge (TFA DOSTMANN, 2016)

The analogue rain gauge that will be used is called Analoger Regenmesser of the brand TFA. It can measure rainfall up to 70 mm and has a marks of 1 mm until 50 mm. Furthermore, the rain gauge is equipped with a lid, which has a diameter of 100 mm. The lid is present to prevent quick evaporation and contamination. In addition, it is important that no leaves or dirt is blocking the lid, so this has to be cleaned regularly. (TFA DOSTMANN, 2016)

The manual rain gauge will be used in order to perform additional checks on the data obtained by the previously mentioned methods. In Bago, the daily rainfall amount is measured at 9.30. In Yangon, one check is performed during a rain event. For such a check is it important that the rain gauge is empty at the beginning of a rain event and is read out by favour at the end of during an intermission of the rain event.

4.1.6. Historical observed data of the DMH

The Myanmar Climate data Web Portal provides historical data starting from 1982. There is data of 25 weather stations available, these include weather stations in Yangon and Bago. The price for buying these data difference for students, other civilians and foreigners. (DMH, 2013) Students have to pay 2500 kyat per year of data and for other people it is more expensive. The data consists out of daily rainfall measurements, which are always done at 9.30 AM (DMH, 2016).

4.2. Method

In order to make it possible to answer the research question, a number of steps will be carried out. During those steps, answers for sub-questions will be found. Finally, after completion of the last step, the research question can be answered. The steps consist of:

1. Choosing locations for the measurement devices
2. Highlight and explain the Social Weather App
3. Data analysing and handling/ filtering
   - Study historical data of Yangon and Bago
   - Study the collected data

4.2.1. Choosing locations for the measurement devices

During the investigation, a limited number of rain gauges will be placed. Namely, four disdrometers, two tipping buckets and two manual rain gauges. The equipment will be placed at the YTU, which is located in Yangon, and the ITC, which is located in Bago. For the placement of measurement devices, the location should satisfy the following requirements;

- The environment may not disturb the measurements, so the equipment has to be placed in an open field/place (for example airports near the city or open parks with a low density of trees).
- The devices should not be located on roofs of buildings.
- The measurement devices have to be located in low density urban areas. If the equipment has to be placed at locations with a higher density, then the devices should be placed above roof level, for instance on a mast. As a result there will be higher influence of wind, so the error of estimation will be greater whereby the output will have to be corrected.

Those requirements are recommended for rain gauges in urban areas by the World Meteorological Organization. (Oke, 2006)

The demand of an optimal measurement network will not be fulfilled with the limited amount of available devices. So to be able to answer the first research sub-question, it is necessary to start with a theoretical investigation for creating an optimal measurement network. First, the number of equipment that has to be placed in order to get a high density measurement network should be determined. This depends on the available money and the possibilities/requirements for placement.

In this research, one of the aims is to increase the measurement resolution. At the moment this resolution is in Myanmar is 900 km^2, compared to 100 km^2 in the Netherlands. In the Netherlands there is 1 automatic rain gauge for every 1000 km^2 and 1 manual rain gauge for every 100 km^2. However, in the Netherlands both rain gauges and radar (resolution 6 km^2) are used to measure the rain intensity with a high resolution. (Overeem, 2012) The rain conditions in Myanmar and the Netherlands are quite different. In the Netherlands the yearly rainfall is between 700 and 900 mm (KNMI, n.d.), while in Myanmar the average annual rainfall in the delta region is 2500 mm (Yangon 2700 mm). Moreover, this amount of rain falls within the wet season, which is from May until October. (World Weather & Climate information, n.d.) Because of this large amount of rainfall in Myanmar, the spatial distribution and the time frame of a rain event are very important.

In the Thur river basin in Switzerland, research was done to find out what the optimum number of rain gauges is. This resulted in a number of 24 rain gauges per 1000 km^2, which is higher than the recommended minimum rain gauge density by the WMO. Beyond this number, the improvements were very small. In the Thur river basin, a dense rain gauge network is necessary because of the rainfall variability within the mountainous area. (Lopez, 2015)

In the study area in this paper, there are less height differences, but a very dense network is desirable to capture the spatial rainfall variability. For this reason, the same ratio of 24 rain gauges per 1000 km^2 will be used. Such a resolution is also enough to capture convective precipitation. These kind of rain events typically have high rainfall intensities and small horizontal dimensions (1-10 km). A denser rain gauge network is required to measure this kind of precipitation compared with the stratiform precipitation. (Schumacher, 2003) However, a region with a diameter of 4-5 km around a convective centre is defined as convective precipitation. Measuring smaller scales is not necessary because convective centres are close to each other, which causes overlap areas. All the different centres together, are able to cover regions of tens to hundreds of kilometres. (Robert, 1997) So for measuring the convective precipitation, 20 rain gauges would already be enough.

In order to select the optimum placement locations, it is of great importance to study the environment where the equipment will be placed. For a rural environment you can use for instance the Voronoi diagram (Aurenhammer, 1991) which is based on equal coverage of area, while for cities it is more suitable to look to the homogeneity within urban areas. Height differences, density and characteristics should be studied. Creating a land-use maps can be very helpful for illustrating the functions of areas. Also is it useful to mark locations where the measurement devises could be host, for example buildings of the government, universities, schools and businesses. These locations offer most of the time protection against vandalism and have the ability to deliver electricity. (WMO, 2016)

Many urban measurement devices are placed in open fields. At these places there are modified urban conditions, which are unrepresentative for the whole urban area (WMO, 2016). The different kinds of land use, provoke different effects on climate. For example, irrigation increases the amount of evaporation and transpiration, through which the temperature decreases and the moisture content increases. In contrast, urbanization causes an increase in heat release, this entails a local warmer climate. In addition, this local temperature increase is strengthened by the heat absorbed by pavements and roofs. The case of this temperature difference between the city and surrounding areas is often referred as *urban heat island*. The increased temperature causes changes in rainfall patterns and more frequent heavy rainfall events. (The Environmental Literacy Council, 2015)

In the state Atlanta, research was done to study the impact of urban heat islands on the precipitation. A significant percentage (56,8%) of the total rain events of Atlanta where within 5 km distance of major urban areas. (Dixon, 2003) It is not ideal to place the measurement devices within urban areas, because here it is hard to comply with the standard guidelines of the WMO. On the other hand, the WMO advises to place instruments within homogenous areas to get a representative image of that climate zone. For this reason, rain gauges will also be placed in major urban areas. It is important to take wind, trees and buildings into account. It is possible to place the measurement devices on roofs, but they should then be installed at a construction above the roof with sufficient height. This will be done in order to prevent wind disturbance due to the building itself. (WMO, 2016)

4.2.2. Highlight and explain the Social Weather App

The research should be brought to the local students/population's attention. It is important to explain that the aim of collecting data is creating better weather maps. These weather maps are important to understand floods in the region and reduce possible effects of floods. Familiarizing the local people with the importance of this research, will create additional motivation to help and collect data. Another important aspect in this step is explaining how to install the app and how to use the app, this will be done by presentations. Explanation of the use of the app makes it clear on how the data can be delivered.

4.2.3. Data analysing and handling/ filtering

First the available data of previous years of the YTU and the ITC will be studied, which consist out of incomplete data of three years of the ITC and two years of complete data of the YTU. The monthly data and the total rain quantity per hour per day will be compared for these years. Furthermore, the monthly temperature will be studied. This is done in order to see whether there is direct relationship with drier or wetter years.

Secondly, DMH data of a long time span are analysed in order to study the Intensity Duration Frequency (IDF) relationship of the rainfall. The knowledge of this relationship is for example very useful when designing a drainage system. (Elsebaie, 2011)

The IDF curve provides an overview of how rare a rain event is. The graph displays the probability that the rain event for example occurs one time in ten years. The intensity [mm/day] is placed at the vertical axis, the duration [day] is placed at the horizontal axis and combining these factors leads to the probability that rain event will occur. There are different frequency analyse techniques for creating the IDF curve. In this research the commonly used Gumbel and the Log Pearson type III (LPT III) are used.

The needed formula’s for Gumbel are:

$$P_t = P_{ave} + KS \qquad (1)$$

$$P_{ave} = \frac{1}{n}\sum_{i=1}^{n} P_i \qquad (2)$$

$$K = -\frac{\sqrt{6}}{\pi}\left[0.5772 + \ln\left[\ln\left[\frac{T_R}{T_R - 1}\right]\right]\right] \qquad (3)$$

$$S = \left[\frac{1}{n-1}\sum_{i=1}^{n}(P_i - P_{ave})^2\right]^{1/2} \qquad (4)$$

$$I_t = \frac{P_t}{T_d} \qquad (5)$$

The formula’s for Log Pearson type III are:

$$P^* = \log(P_i) \qquad (6)$$

$$P_t{}^* = P_{ave}{}^* + K_T S^* \qquad (7)$$

$$P_{ave}{}^* = \frac{1}{n}\sum_{i=1}^{n} P^* \qquad (8)$$

$$S^* = \left[\frac{1}{n-1}\sum_{i=1}^{n}(P^* - P_{ave}{}^*)^2\right]^{1/2} \qquad (9)$$

$$C_s = \frac{n\sum_{i}^{ni}(P^* - P_{ave}{}^*)^3}{(n-1)(n-2)(S^*)^3} \qquad (10)$$

$$I_t{}^* = \frac{P_t{}^*}{T_d} \qquad (11)$$

Log Pearson frequency factor (K_T) must be extracted from frequency factor tables, for example (reference (Oregon State University, 1977)).

After completing both techniques, equation (12) will be used to determine which technique fits better with the dataset. This technique will then be used for creating the IDF curve.

$$\chi^2 = \sum\frac{(O-E)^2}{E} \qquad (12)$$

For this equation, the result should be as small as possible, because then the technique fits the dataset. (Elsebaie, 2012)

Thirdly, the newly collected data will be studied. There will be four different types of data, three of them are measurements and one is the data of the Social Weather App. The first step is filtering the data, because it can be necessary to remove data outliers. For example it could be the case that some of the data of the Social Weather App is not consistent. Another possibility is that the data of one of the measurement devices is clearly not true, because it is not working properly. Before data is processed, it is of great importance to check this. After completing this, it is possible to start with handling the data. Different kinds of analyses will be applied.

Bivariate statistical analysis will be done on the datasets of the tipping bucket and the Delft-disdrometer to determine how well the measurements match. The same comparison will be done for the traditional rain gauge compared with the Delft-disdrometer and the traditional rain gauge compared with the tipping bucket. First, the measured quantities will be plotted against time. This will be done in the same figure to easily compare the measured peak moments and the peak sizes. Secondly scatter plots will be made for giving visual indication and a spearman rank correlation is used to determine the statistical dependence between two variables.

The formula for calculation the spearman rank correlation is:

$$r = 1 - \frac{6\sum d^2}{n^3 - n} \tag{13}$$

First of all, all datasets have to be ranked. Then the differences in rank number is the variable d. The number of samples is given by the variable n. (Royale Geographical Society, n.d.)

The rain reports of the Social Weather App will be compared with the measurement results of the tipping bucket and the disdrometer. The tipping bucket of the telemetry system will not be used by comparing, because it only measures one time in an hour. So the therefore it is not suitable to compare these results with weather reports. The aim is to interlink rain intensity categories to the possible rain categories. This will be done by comparing the rain reports with the measurements of that moment and then comparing the results for each category.

Results

5.1. Locations for the rain gauges

To be able to determine the locations of the rain gauges for an optimal measurement network, it is important to first analyse the city/area of interest. In this paper, the focus lies on two cities; Yangon and Bago.

5.1.1. Analysis of Yangon

The region of Yangon consist of 10,171 km^2 and is the smallest state of Myanmar. The region can be divided in 4 districts (North, West, South and East). The city of Yangon itself consist out of 45 townships. Below, an overview of the region is given by a general map of Yangon, next to it is a map of the four districts and finally there is a map of the 45 townships of the city. (MIMU, 2016)

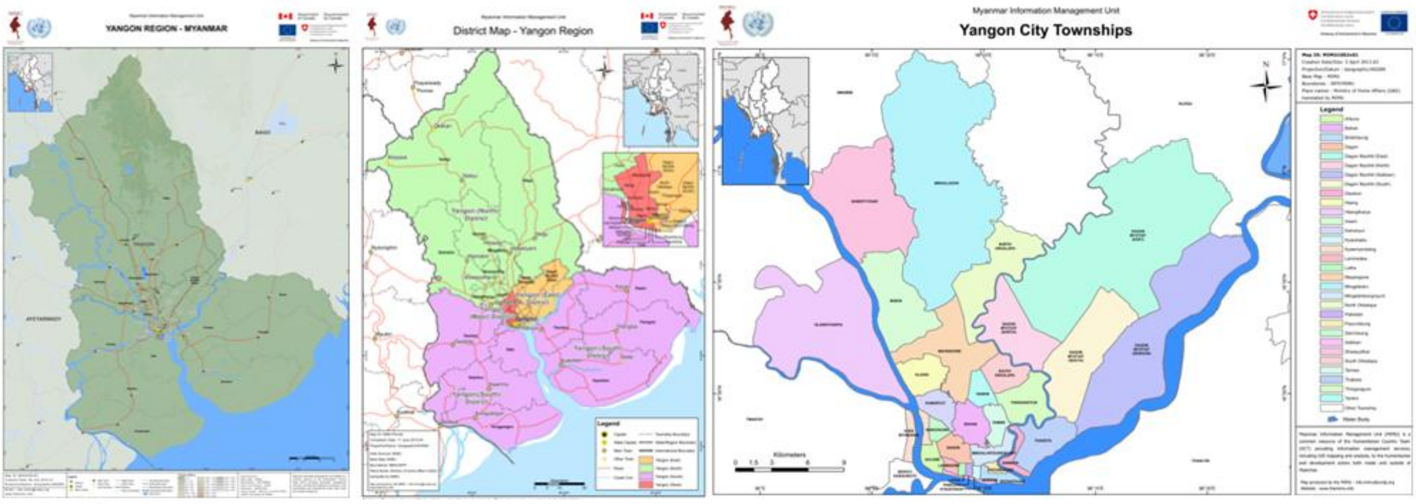


Figure 8: Overview of different levels in Yangon, on the left the region Yangon, in the middle the districts of the region and at the right the townships of Yangon city. Higher quality maps can be found in the Appendix.

Yangon is the most densely populated state of Myanmar and has an average density of 586 people per scared kilometre. The left image below shows the density, which is the highest in the middle. The ratio people living in urban area versus people living in rural area is 67% versus 33%. (MIMU, 2016)

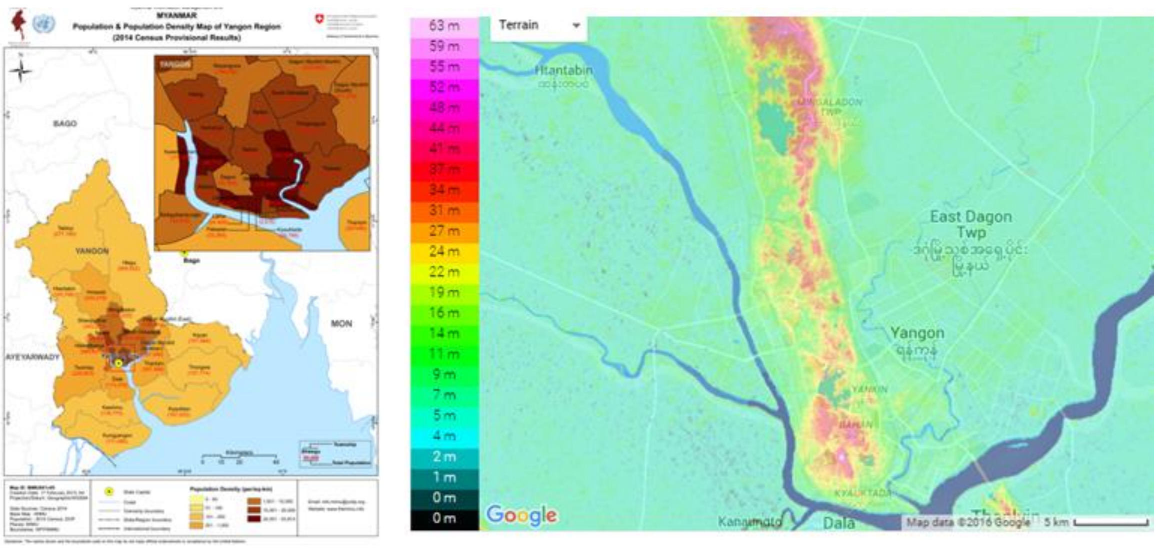


Figure 9: The left side shows the population density in Yangon region and the right side shows the height map of Yangon. Both images are also shown in the Appendix.

The height map (see Figure 9) gives a clear vision of where there are high buildings and where there is only low rise. Combining the information of both images of Figure 9 gives an indication of the type of building. For example, high buildings combined with a medium density presumes luxury apartments or office towers.

Beside this kind of general information about Yangon, it is also important to study the land use. For this a map is created, with the help of a Google maps satellite image.

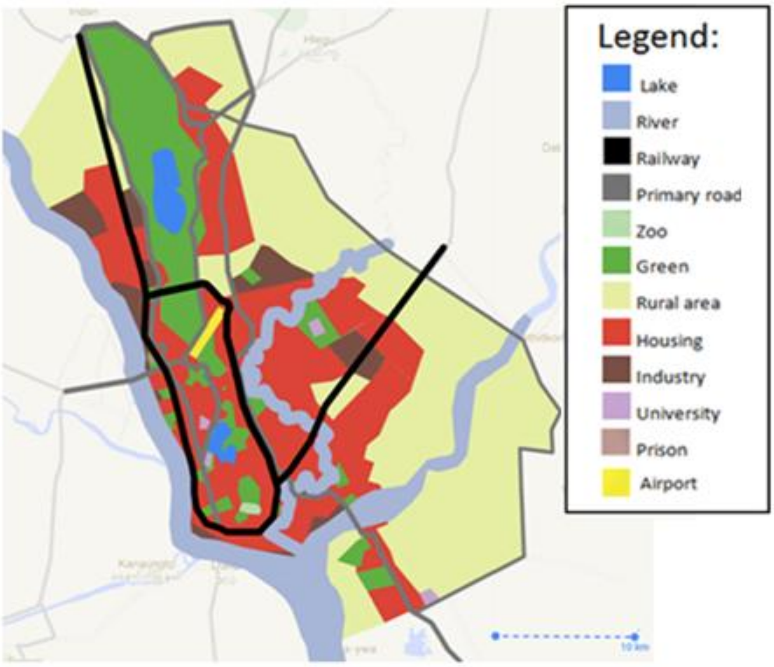


Figure 10: Constructed land use map of Yangon city based on Google maps imagery

5.1.2. Chosen locations in Yangon City

The city of Yangon covers thus 598.75 km^2, so 15 (ratio of 24 per 1000 km^2) rain gauges will be placed in this region. After combining the information of the height map, the density map and especially the land use map, there is enough information to choose suitable places for the rain gauges.

On basis of the recommended requirements of the World Meteorological Organization which are specified in section 4.2.1, the preference goes to placing the rain gauges in Yangon in the following areas:

- Yangon airport
- Parks with a low density of trees and good accessibility
- Rural areas
- Zoo
- Industrial areas, with lots of free space

However, some rain gauges will be placed in major urban areas, wherefore the reasons are also explained in 4.2.1.

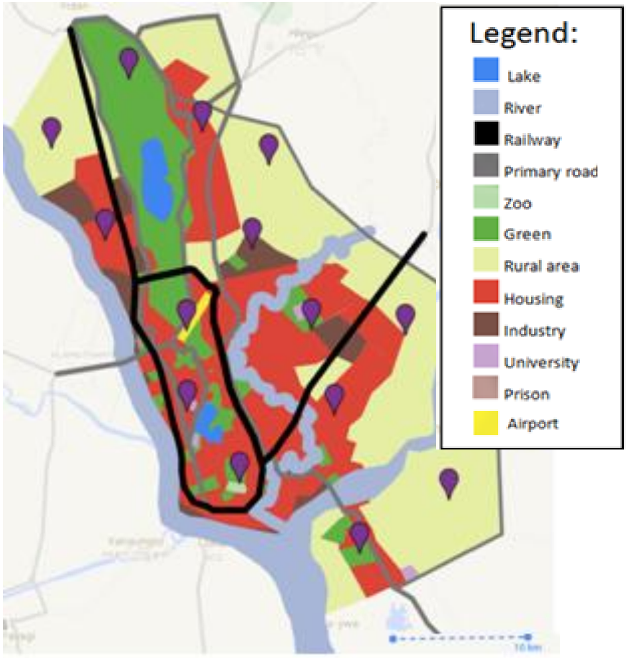


Figure 11: Land use map of Yangon city with selected positions for the rain gauges, image based on Google maps imagery

The chosen locations are shown in Figure 11. Some rain gauges are placed closer to each other, but they all cover roughly 40 km^2.

5.1.3. Analysis of Bago

The region of Bago covers 39,405 km^2, while the Bago city consist of approximately 30 km. Originally, there were two different regions, namely Bago East and Bago West. Those regions are combined since 2012 and are divided in 28 townships. (MIMU, 2016)

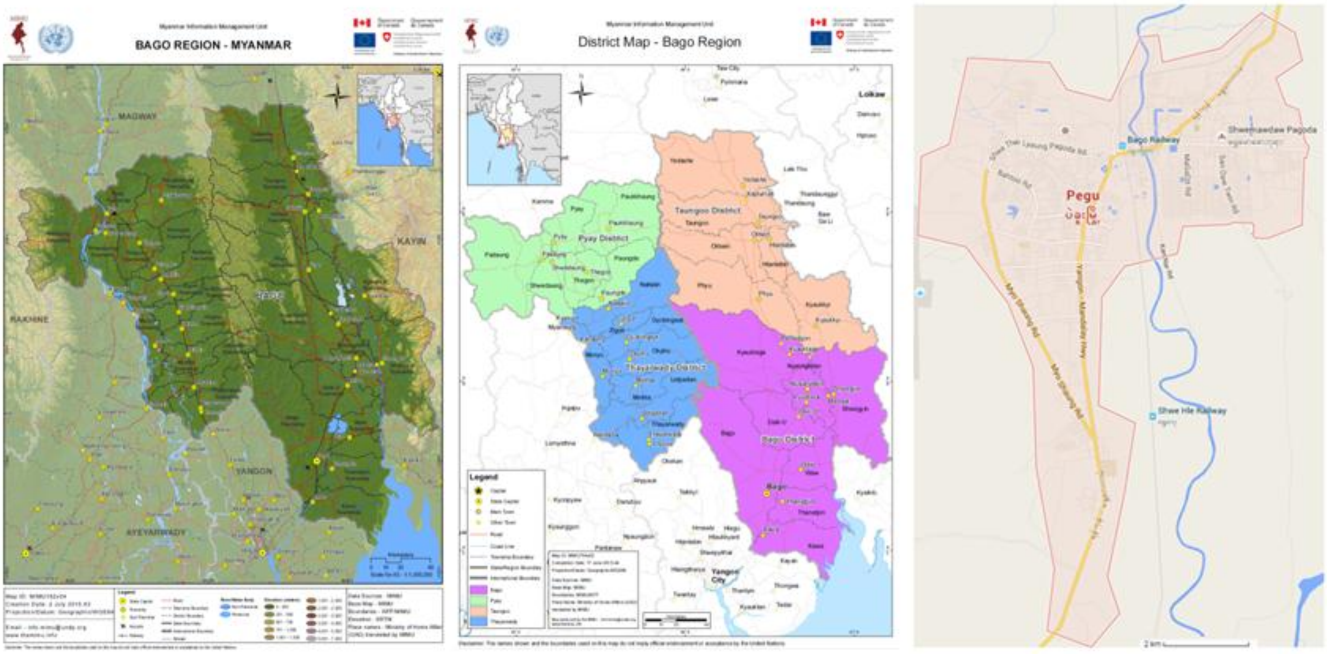


Figure 12: Overview of different levels in Bago, on the left the region Bago, in the middle the districts of the region and at the right the city of Bago. The maps are bigger visually in the appendix.

In this part of Myanmar, the average density is 123 people per m^2. Of those people, is 17% living in urban areas and 83% in rural areas. (MIMU, 2016) Figure 13 gives an impression of the density and height within Bago. It is clearly visible that the density and the height of the building are both very low compared with Yangon.

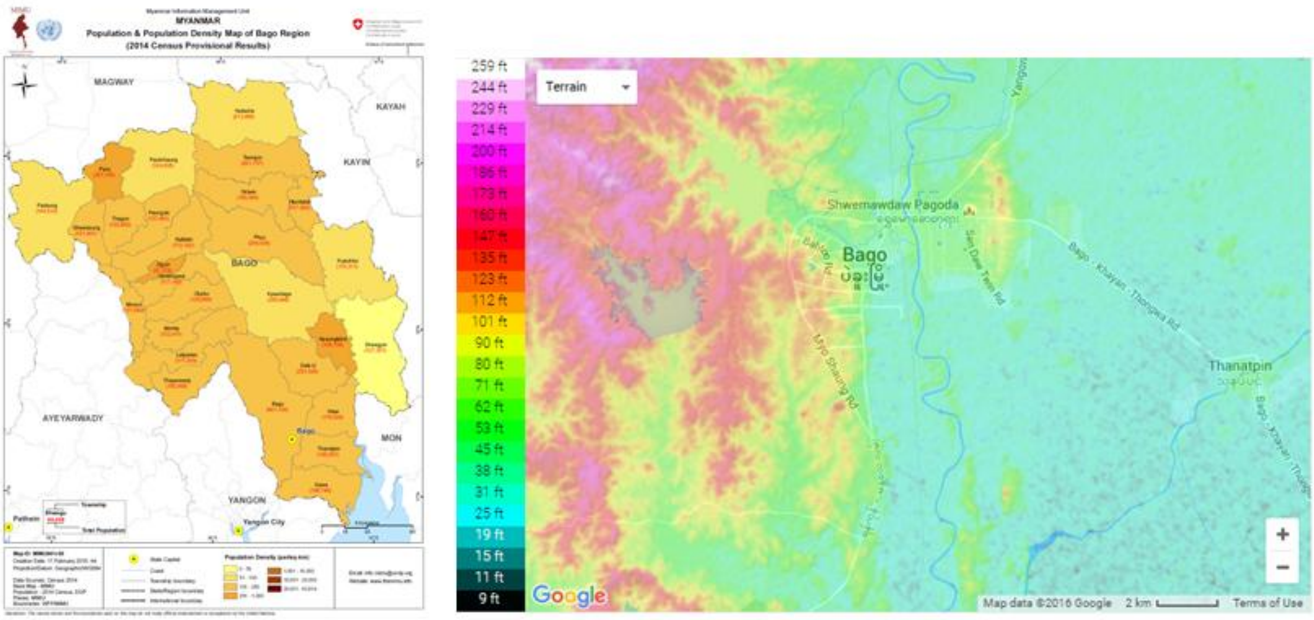


Figure 13: The left side shows the population density in Bago region and the right side shows the height map of Bago. Both images are also shown in the appendix.

Finally, the land use of the city is analysed, of which the result is shown in the figure below.

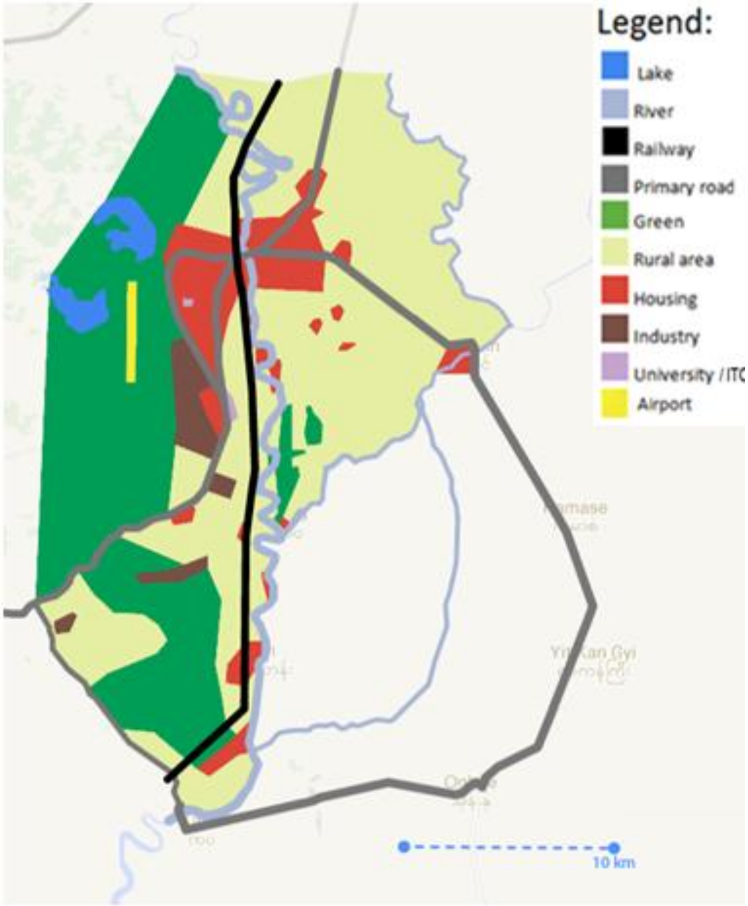


Figure 14: Constructed land use map of Bago city based on Google maps imagery

5.1.4. Chosen locations in the city of Bago

Bago city covers about 100 km^2, so 3 (ratio of 24 per 1000 km^2) rain gauges will be placed in this area. For choosing suitable locations for the measurement devices, again the information of the height map, the density map and especially the land use map are used.

Since the town has no high-rises and does not contain a very high density, the possible effect that a city could have on precipitation (mentioned in 4.2.1) will be very small in Bago. Combining this with the desire to spread the rain gauges through the area, results in not placing the rain gauges in the for this area relatively densely populated areas. The preferences (with keeping the recommendations of the WMO in mined) for placing the rain gauges in Bago is given to:

- Bago airport
- Rural areas
- Industrial areas, with lots of free space

Because of the many wooded areas within this region, totally equal coverage is not possible. The placement of the rain gauges is shown in Figure 15.

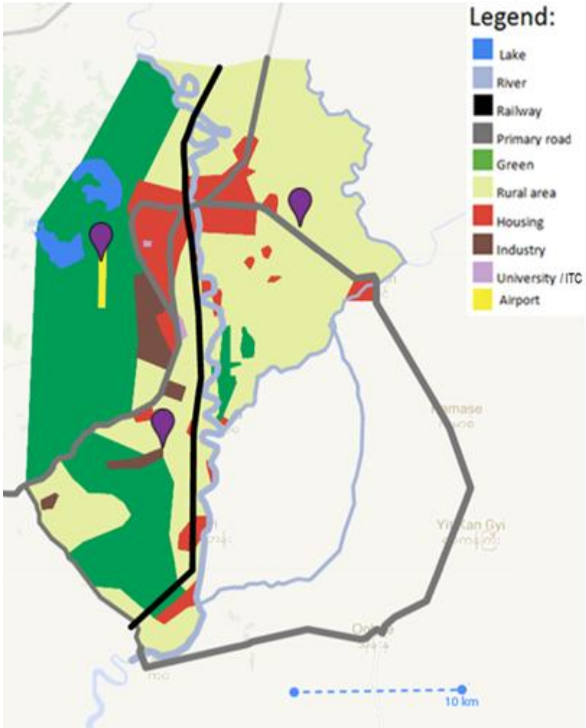


Figure 15: Land use map of Bago city with selected positions for the rain gauges, image based on Google maps imagery

5.1.5. Placement at the YTU in Yangon

At the YTU, there was no big open field with power supply. The rain gauges are located in a small open field. However, there are two palm trees nearby and also a building. The building is located at 1.5 times the height of the building and is not standing in the most common wind direction. The requirements of the KNMI are that buildings that are standing in the most common wind direction, may not be higher than 0.5 times the distance. (KNMI, 2016) The situation meets thus the KNMI requirement. The coordinates of the installed rain gauges are N 16 52 31.5, E 96 7 4.1. The figures below give an impression of the YTU setup.

Figure 18: Placement of the disdrometers at the YTU

Figure 16: Overview of the electricity box, with an UPS system and the data logger of the tipping bucket

Figure 17: Placement of the tipping bucket and manual rain gauge at the YTU

5.1.6. Placement at the ITC in Bago

The rain gauges at the ITC are in a low density urban environment. They are placed in an open field close to the ITC. The field is surrounded by relatively small tries, which are at one side located at a distance of 16 meters from the measurement devices. The coordinates of the placement location are N 17 18 51.8, E 96 27 6.8. Below is a short overview of pictures of the placement at the ITC.

Figure 19: Placement Delft-disdrometer at the ITC

Figure 21: Overview of the electricity box, with an UPS system and the data logger of the tipping bucket

Figure 20: The placement of the tipping bucket and the manual rain gauge at the ITC

5.2. Analysing available historical data YTU and ITC

For both YTU and ITC, data of previous years are collected and available. The data of the YTU is of the past two years and the data of the ITC of the past three years.

5.2.1. Historical data YTU in Yangon

First the monthly rainfall between the two different years are compared. The year 2014 was with a total amount of 2493.3 mm a much drier year than the year 2015 with a total amount of 5392.4 mm. The biggest differences are in the months July, August, September and October. Surprisingly, there was a bit more rainfall in November 2014 compared with November 2015.

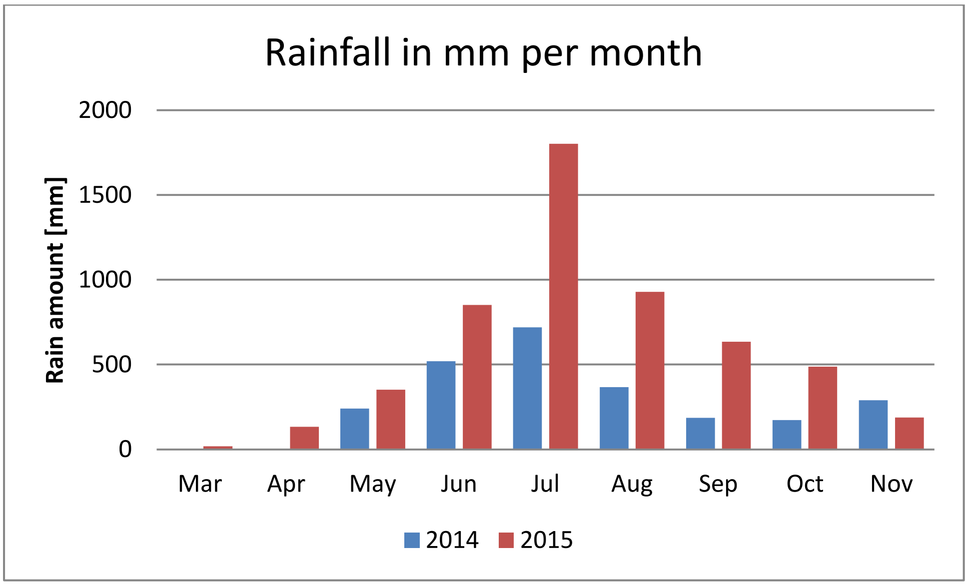


Figure 22: Rainfall in mm per month for the YTU location

Secondly, the annual amount of rainfall within an hour are compared. Especially for the year 2015, there are higher peaks visible during the afternoon and in the beginning of the evening.

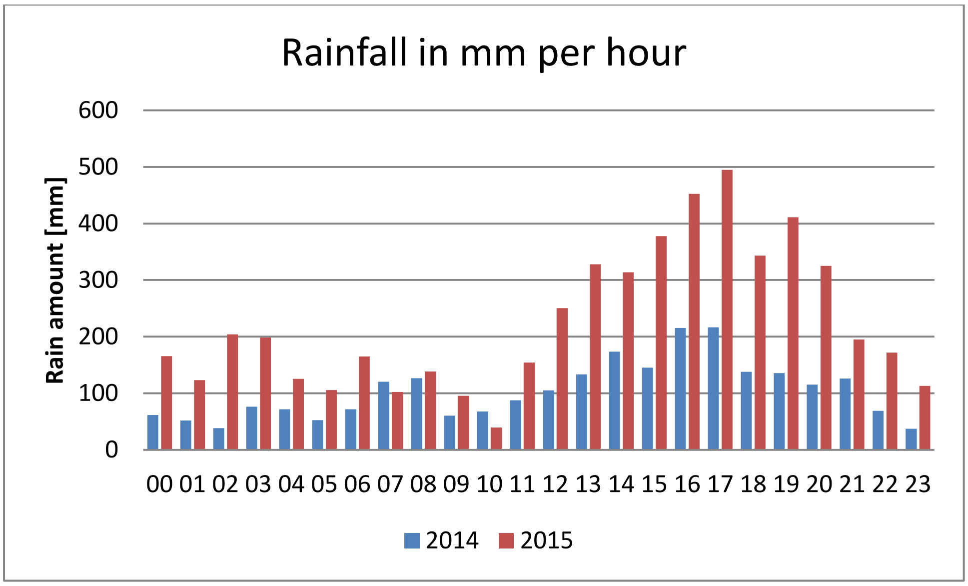


Figure 23: Rainfall in mm per hour for the YTU location

5.2.2. Historical data ITC in Bago

The dataset of the ITC was not complete, some data of both 2013 and 2014 were missing. Nevertheless, an obvious trend is visible in Figure 24. The rainy season always start in May, but the amounts are quite different because of the variance in starting date. In 2013 the rainy season started at May 13, in 2014 on May 26 and in 2015 on May 1. In June and July, there is an increasing line in terms of rain. After the peak month July, the amount of rain decreases again.

The rain amount in June 2014 has a remarkable low value. This is because no rain is measured between June 1 and June 25. It is likely that this value is not correct, caused by a blockage of the rain gauge or the rain gauge or a power shortage of the rain gauge.

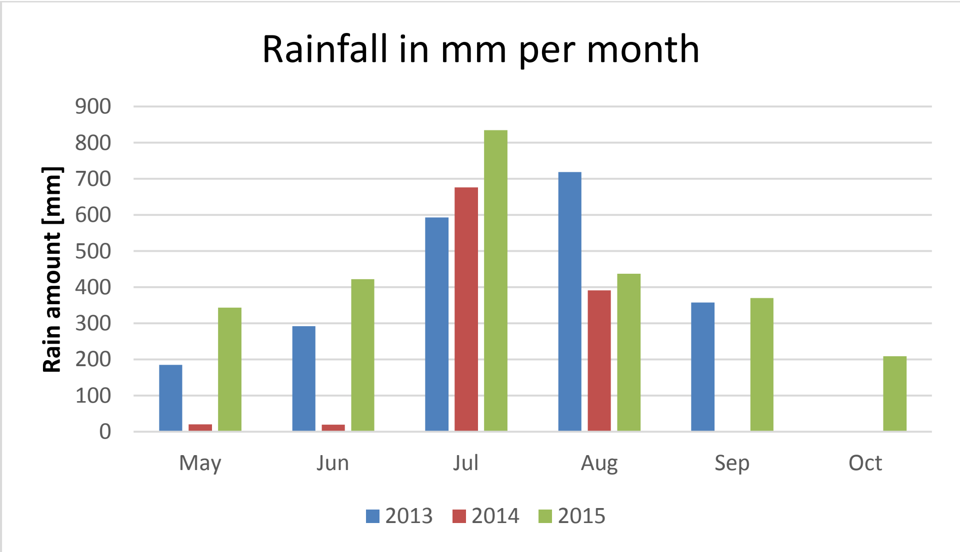


Figure 24: Rainfall in mm per month

Figure 25 shows clear peak moments. The total amount of rainfall is lower during the night. However, the peak moments are not the same for the different years. Furthermore, there are much more and bigger outliers in 2013 and 2015 compared with 2014.

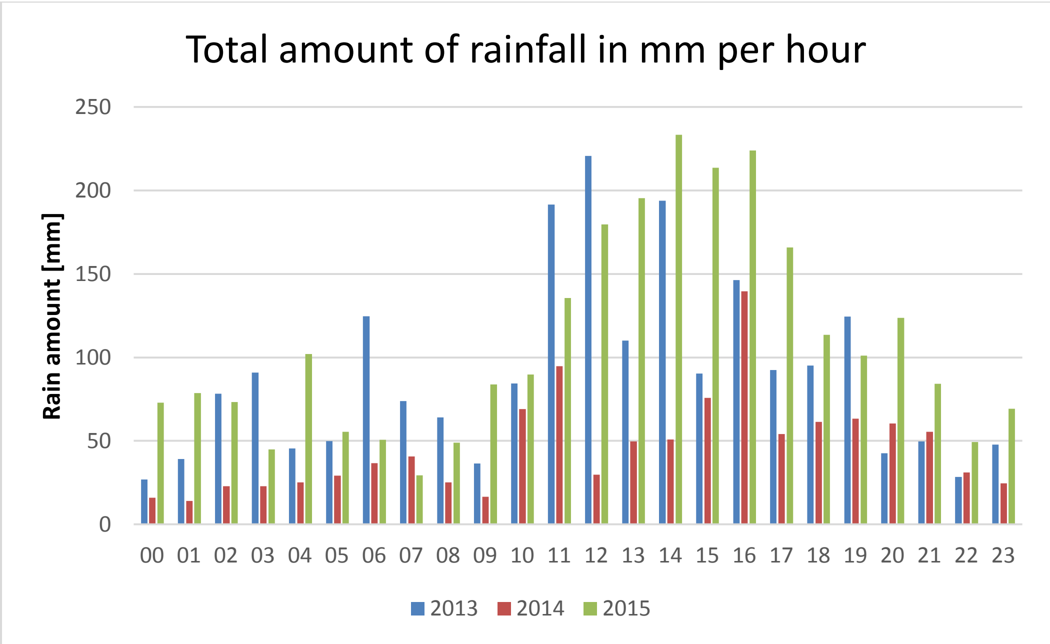


Figure 25: Total amount of rainfall in mm per hour

Finally, a table with the average temperature per month. For the measured months, the temperature differences are small. Though, 2015 was the warmest year. So the relatively lower amount of precipitation is not caused by extreme heat.

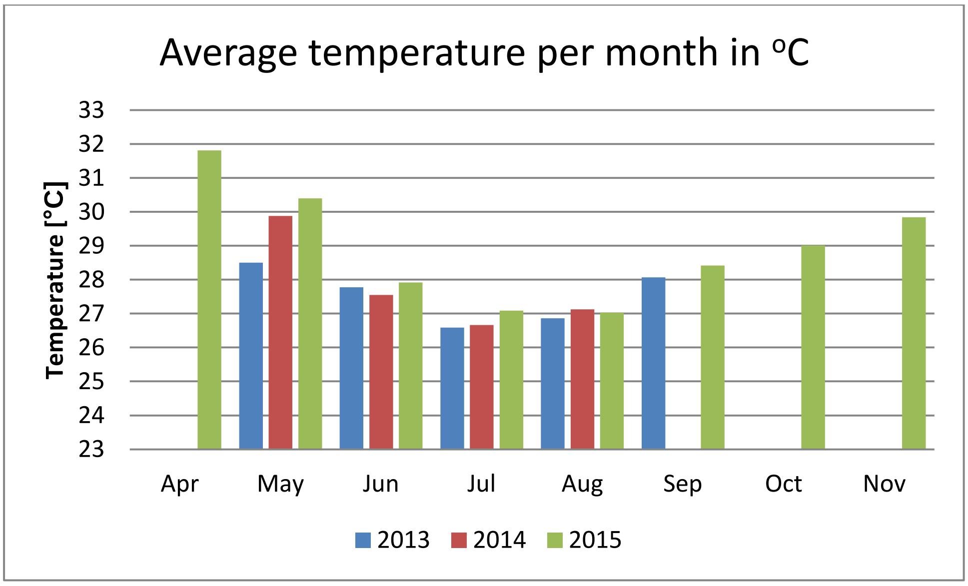


Figure 26: Average temperature per month in °C

5.3. Analysing available historical data of the DMH

The DMH has historical data of 25 weather stations. Thirty years of data of the Bago and Yangon stations are bought and with this data, IDF curves have been made.

5.3.1. Historical data of the DMH station in Yangon

The DMH station in Yangon is located at the following coordinates; N 16 51 52.9, E 96 9 15.1. Figure 27 is made to get a good picture of where the measurements of the DMH are done compared to the measurement of this research. The left point indicate the YTU measurement location and the right point the measurement location of the DMH station in Yangon. The distance between those locations is about 4 km.

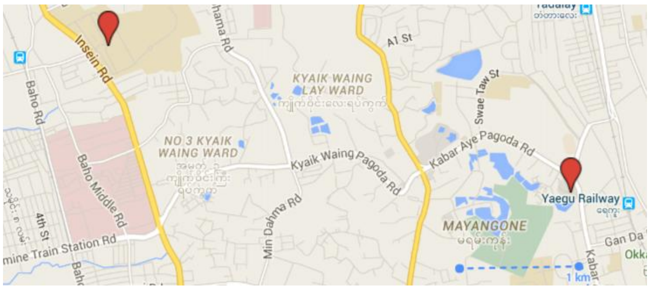


Figure 27: Measurement locations in Yangon based on Google maps imagery

The data of the DMH station in Yangon consists of daily rainfall data of the period 1983 until 2013. For analysing the data, attachment 8.2. Python script for analysing the DMH data is used. First is the python script making a matrix of the maximum amounts of each year. These maximum amounts are seven values, namely the maximum amount per day until the maximum amount per week. Subsequently, the values of the different years are compared and sorted from highest value to lowest. Through this, an overview of how often certain rainfall intensities occur was created.

The formula's 1 to 11 are used to calculate the intensities for Gumbel and for Log Pearson Type III, of which the results are visible in appendix 8.3.1. In the subsequent step is formula 12 comparing the measured values with the expected values of both techniques. The one with the smallest outcome, and thus the smallest deviation, is the technique that predicts the data the best. The results for Yangon are shown in appendix 8.3.2. From these results, it appears that the LPT III technique is given better predictions for the Yangon dataset, so this technique is used for the IDF curve of Figure 28.

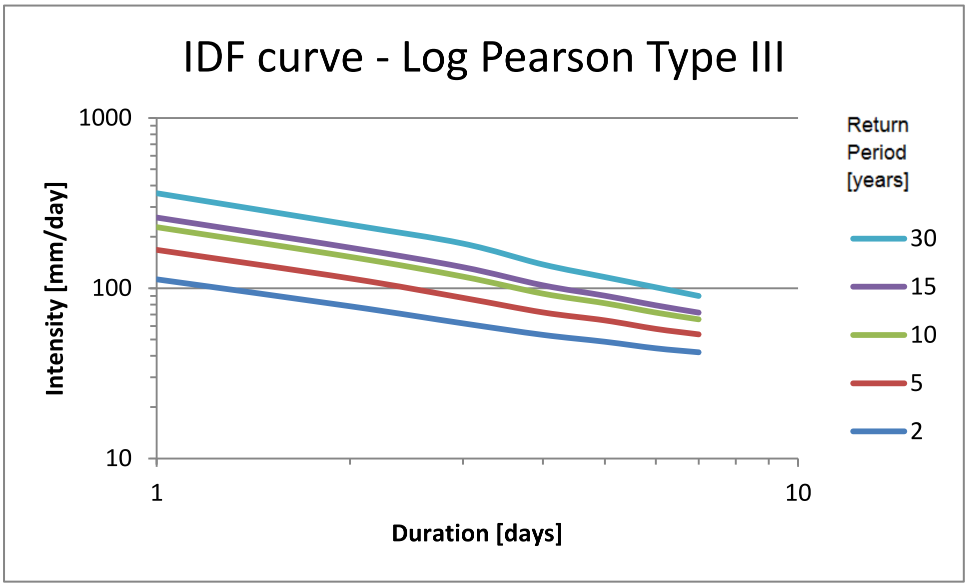


Figure 28: IDF curve of rainfall amounts of Yangon

The IDF curve gives thus an overvieuw of the return period. In addition to this, rainfall distribution box plots are made to get a more complete picture of the daily rainfall. In Figure 29 the distribution of the annual maxium of a day is plotted. The lowest black line, represents the minimum value, then the blue line stands for the first quartile, the red line is the median, the second blue line is the third quartile, the second black line stands for the highest value without outliers and the crosses are the outliers.

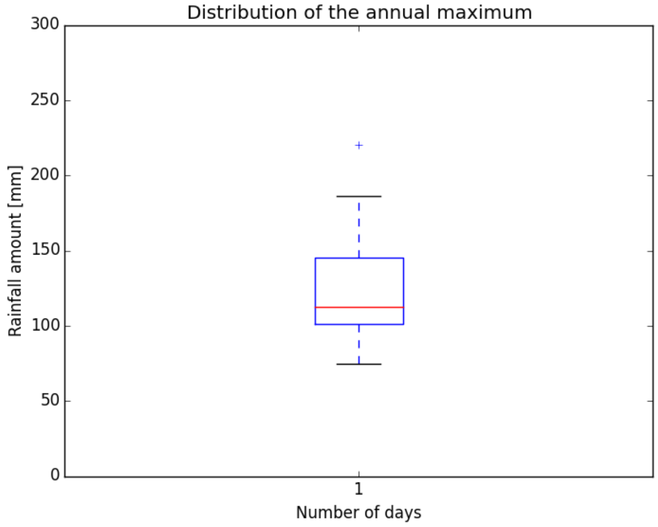


Figure 29: Box plot of the distribution of the annual maximum amount of daily rainfall

More interesting is the monthly variation in rainfall amounts that is measured during the 30 years. Especially the variation within the monsoon months, because in the other months there is almost no rain. Therefore only box plots of the months May until October are made and presented below.

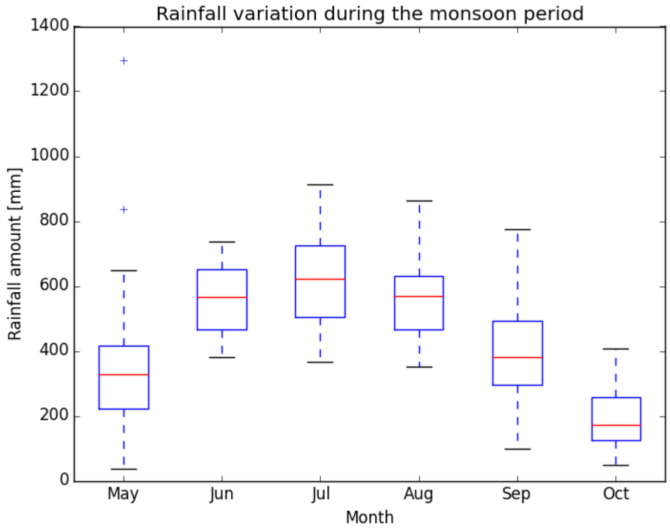


Figure 30: Box plot of the variation in rainfall amounts during the monsoon period

Furthermore, a box plot of variation of the total amount of rainfall within a year is made. In the year 1991 the lowest amount of rainfall is measured, with a value of 2115 mm. The year in which the highest precipitation is measured is 2006, with an amount of 3889 mm. The annual average is 2835 mm.

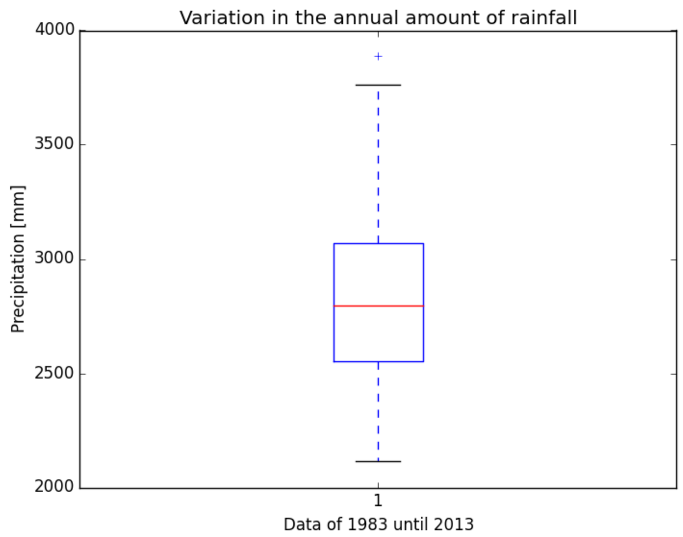


Figure 31: Box plot of the variation in annual rainfall amounts

Finally, the annual amount of rain is plotted in time. The trend line shows an increasing line in the amount of precipitation.

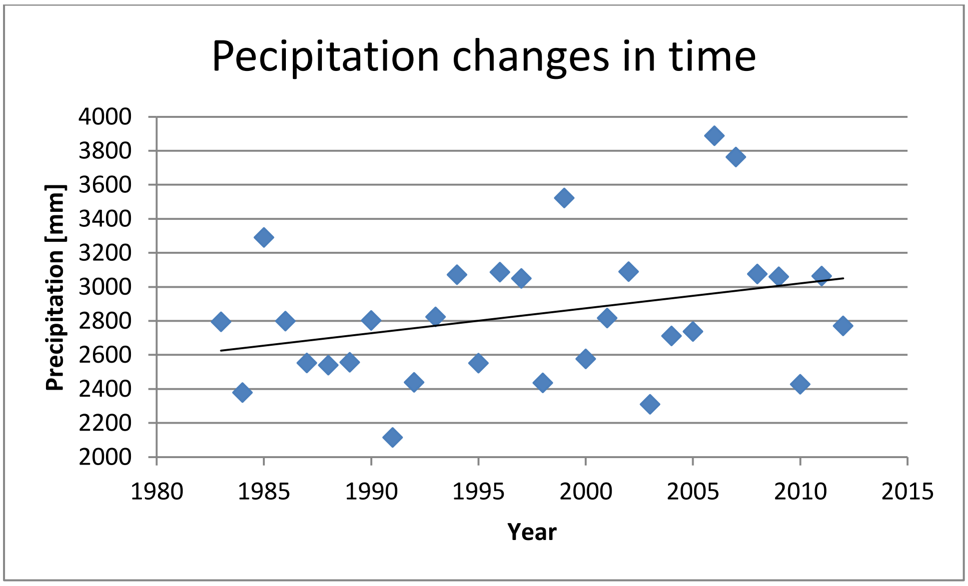


Figure 32: Representation of the changes in annual amount of rainfall

5.3.2. Historical data of the DMH station in Bago

The location of the DMH station in Bago has the following coordinates; N 17 20 15.0, E 96 29 4.9. In Figure 33 both measurement locations in Bago are indicated. In this figure is the ITC represented by the left point and the right point indicates the DMH station. The distance between these locations is similar to the one for the Yangon placement, approximately 4 km.

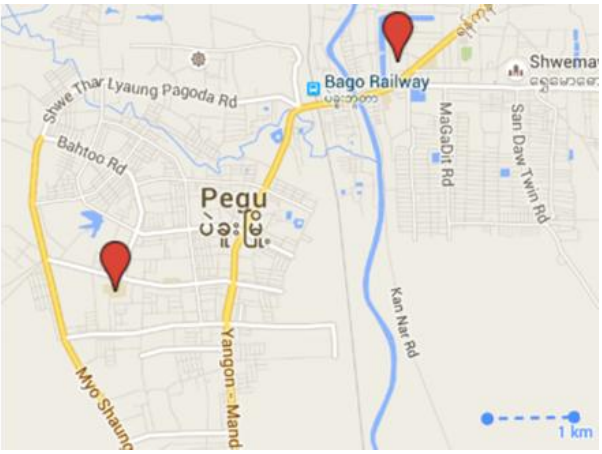


Figure 33: Measurement locations in Bago based on Google maps imagery

The DMH data of Bago is of the period 1984 until 2014. For analysing the data of Bago, the same steps are taken as for the data of Yangon. The results of the Gumbel and LPT III calculations are in appendix 8.3.3 and the results of comparing these techniques with the measured intensities are in appendix 8.3.4. It was found that the Gumbel technique is better for predicting the Bago dataset. So on basis of the results is an IDF curve created with the Gumbel technique, which is visible in Figure 34.

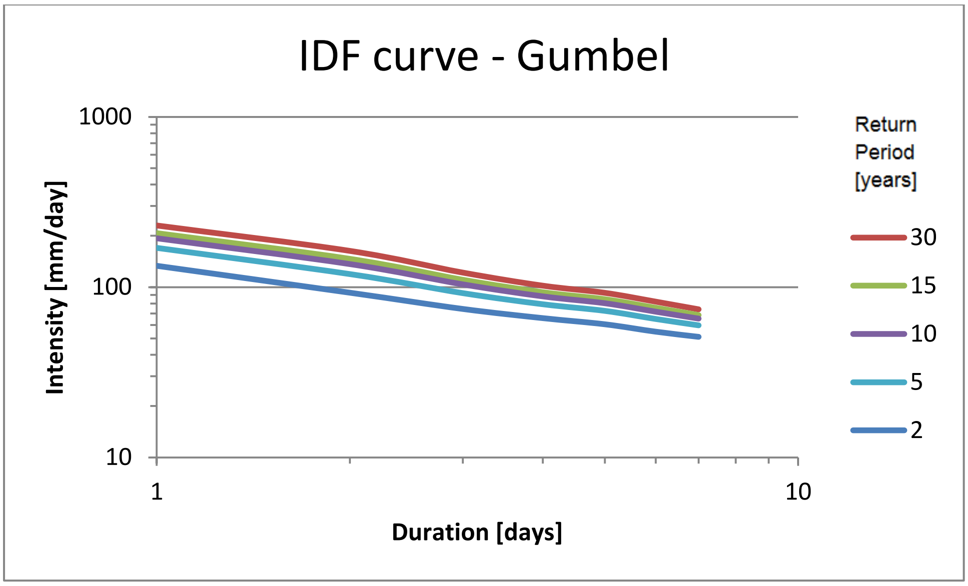


Figure 34: IDF curve of rainfall amounts of Bago

Furthermore, rainfall distribution box plots are created to get a more complete picture of the daily rainfall. In Figure 35 the distribution of the annual maxium of a day is plotted.

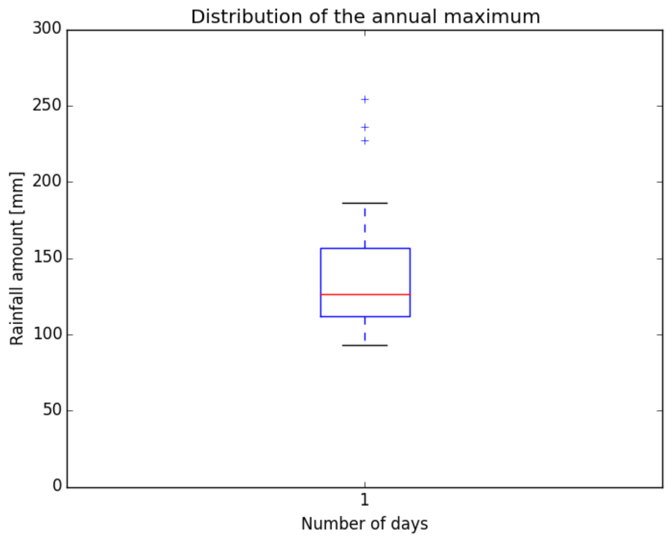


Figure 35: Box plot of the distribution of the annual maximum amount of daily rainfall

In Figure 36, box plots are made of the variation within the monsoon months. The month with the highest amount of rainfall is July and this is also the month with the biggest variation. Furthermore, in May and October there is sometimes almost no rain and sometimes quite a lot. This is partly caused by a late start or an early end of the rainy season.

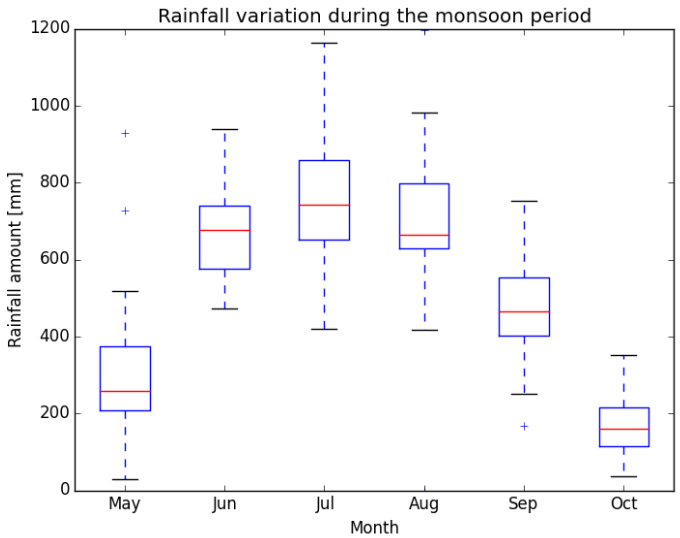


Figure 36: Box plot of the variation in rainfall amounts during the monsoon period

Furthermore, a box plot of variation of the total amount of rainfall within a year is made. In the year 2005 the lowest amount of rainfall is measured, with a value of 2281 mm. The year in which the highest precipitation is measured is 1997, with an amount of 3989 mm. The annual average is 3218 mm.

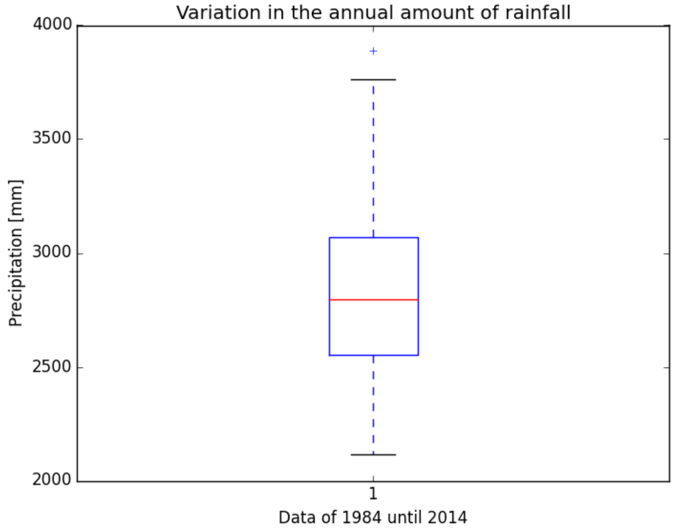


Figure 37: Box plot of the variation in annual rainfall amounts for Bago

Finally, the annual amount of rain is plotted against the time. The trend line shows a increasing line in the annual amount of precipitation.

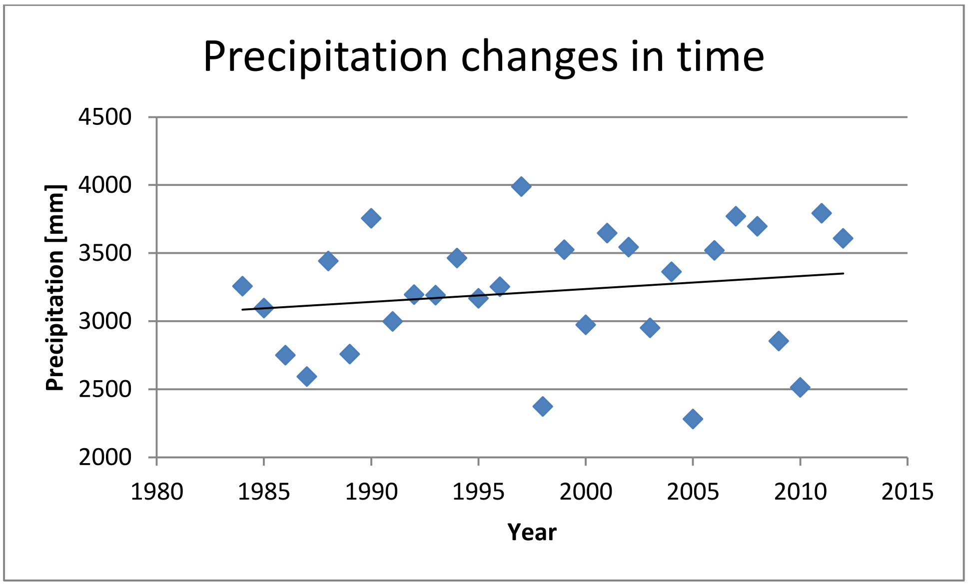


Figure 38: Display of the changes in annual amount of precipitation

5.4. Analysing collected data

5.4.1. Analysing collected data YTU (Yangon)

Due to administrative procedures the rain gauges could not be installed before the rainy season. The collected data of the YTU location is from June 3 until June 9. The daily measurements amounts are visible in appendix 8.4.1.

The start of the rainy season measured by the tipping bucket of the telemetry system is May 19.

Rain gauge type	Total measured amount of rainfall [mm]	Highest measurement day [date] +amount [mm]	Lowest measurement day [date] +amount [mm]
Disdrometer 1	43.7	June 8, 25.6 mm	June 4, 0.1 mm
Disdrometer 2	99.8	June 8, 50.6 mm	June 4, 0.5 mm
Tipping bucket	62.4	June 8, 36.8 mm	June 4, 0 mm
Tipping bucket of the telemetry system	56.3	June 8, 31.2 mm	June 4, 0 mm

Table 1: Basic data comparison of the different kinds of measurement equipment

5.4.1.1. Measurement check by manual rain gauge

In order to check the measurement results of the automatic equipment, a check was preformed with the manual rain gauge. The results are shown in Table 2.

	Manual rain gauge [mm]	Tipping bucket [mm]	Disdrometer 1 [mm]	Disdrometer 2 [mm]	Tipping bucket of the telemetry system [mm]
June 3, 12:00-14:00	3	2.6	0.7	1.9	2.9

Table 2: Measurement check by comparing the results of the automatic rain gauges with the manual rain gauge on June 3

5.4.1.2. Comparing peak moments and peak sizes of the different measurement results

In Figure 39 is all the measured precipitation plotted against the time. The aim is to get a picture whether the peak moments and intensities are similar. For the times on which the peaks are measured is this the case, but for the intensities not. Especially the peaks of disdrometer 2 are remarkably higher.

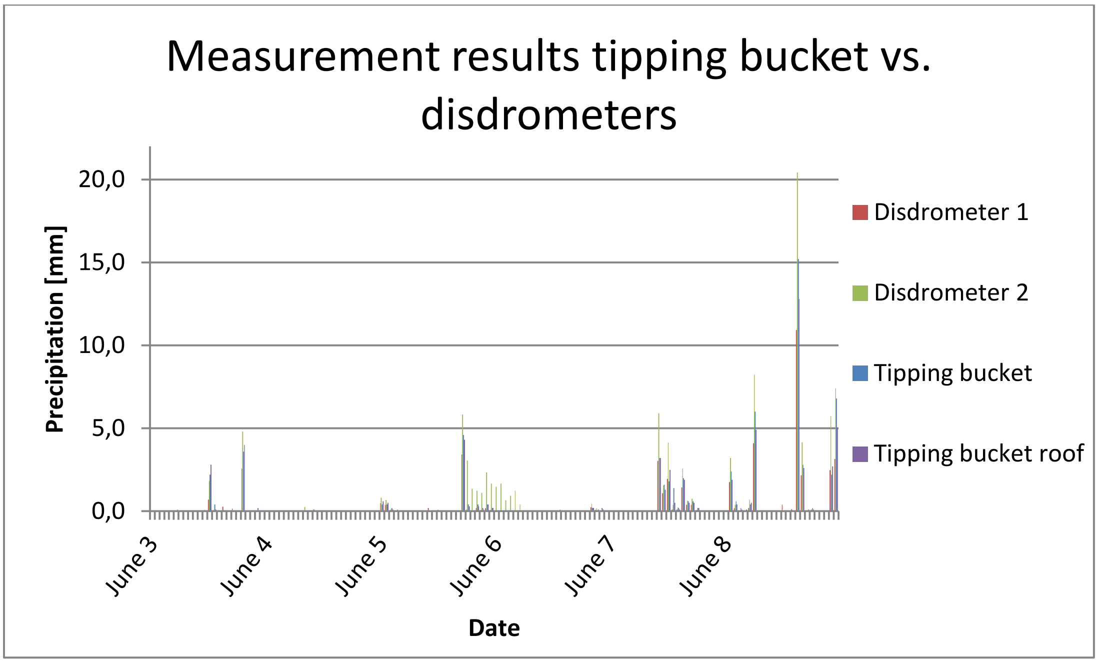


Figure 39: Comparing the peaks of the different measurement devices

In order to get a better view of the differences in measured peak intensity, shows Figure 40 the rain event of one day. June 8 is chosen, because this is the day with the highest amount of precipitation.

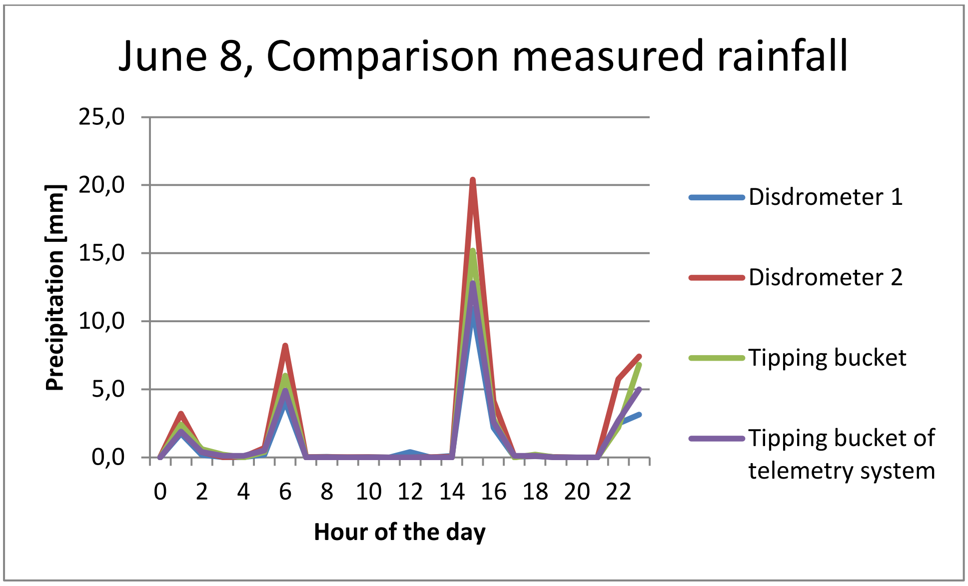


Figure 40: Comparing the peak moments of June 8

5.4.1.3. Scatter plots for visual indication of relationships between two datasets

There are four different measurement instruments and for all the combinations are scatter plots made to show the relationship.

First a scatter plot of the relation between the two disdrometers is made.

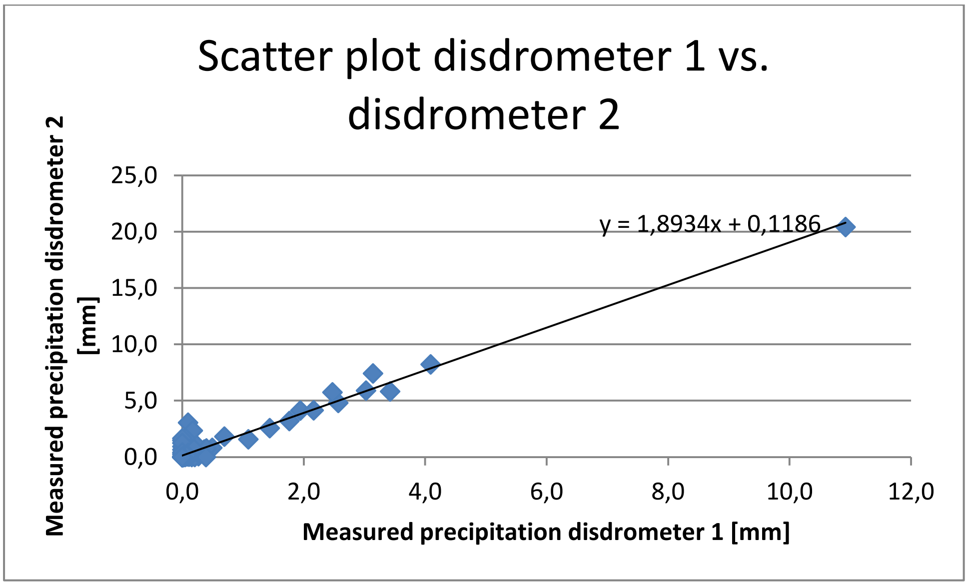


Figure 41: Scatter plot disdrometer 1 vs. Disdrometer 2 (hourly data)

Secondly, a scatter plot of the relation between the two tipping buckets is made.

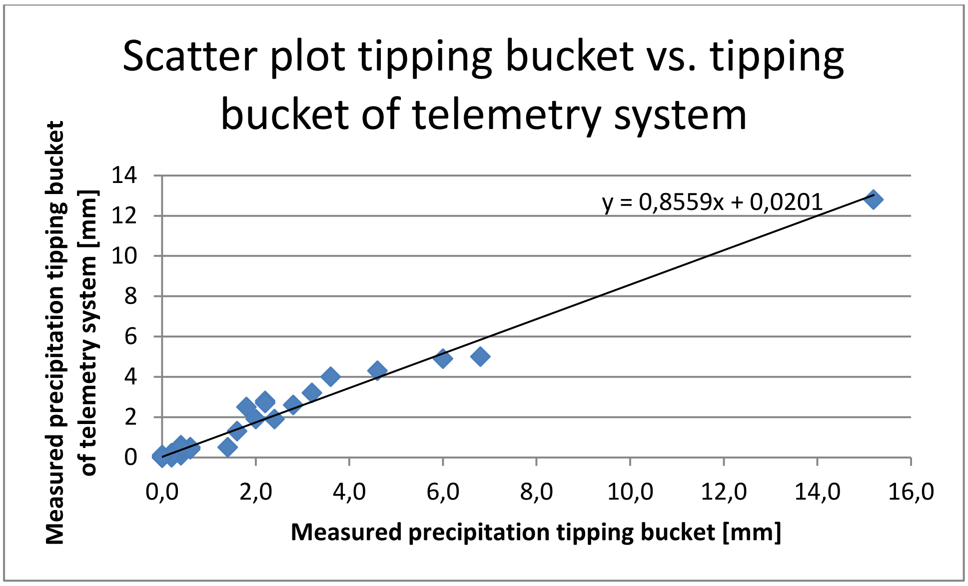


Figure 42: Scatter plot tipping bucket vs. tipping bucket telemetry system (hourly data)

The third scatter plot shows the relationship between the tipping bucket and disdrometer 1.

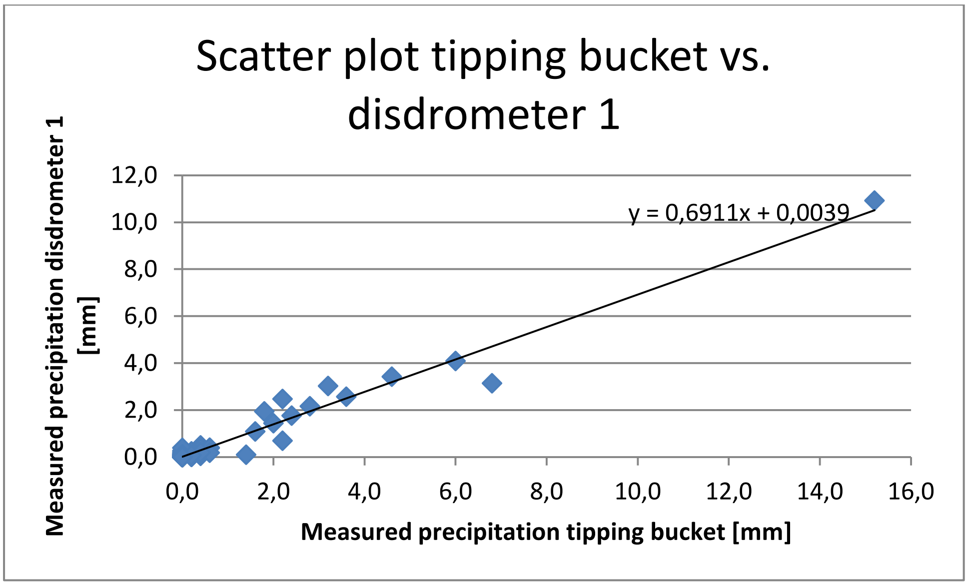


Figure 43: Scatter plot tipping bucket vs. disdrometer 1 (hourly data)

The fourth scatter plot does the same for the relationship between the tipping bucket and disdrometer 2.

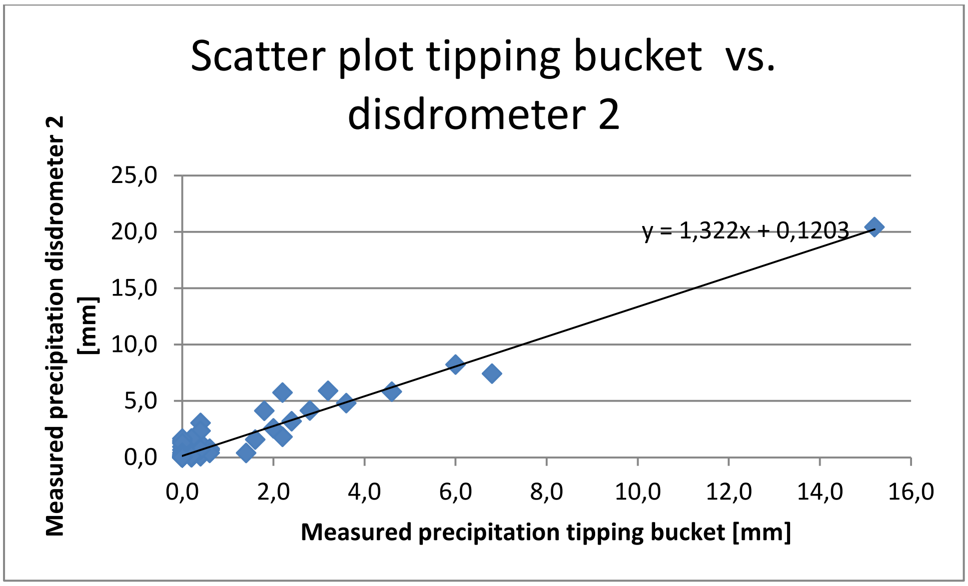


Figure 44: Scatter plot tipping bucket vs. disdrometer 2 (hourly data)

Scatter plot number five does the same for the tipping bucket of the telemetry system vs. disdrometer 1.

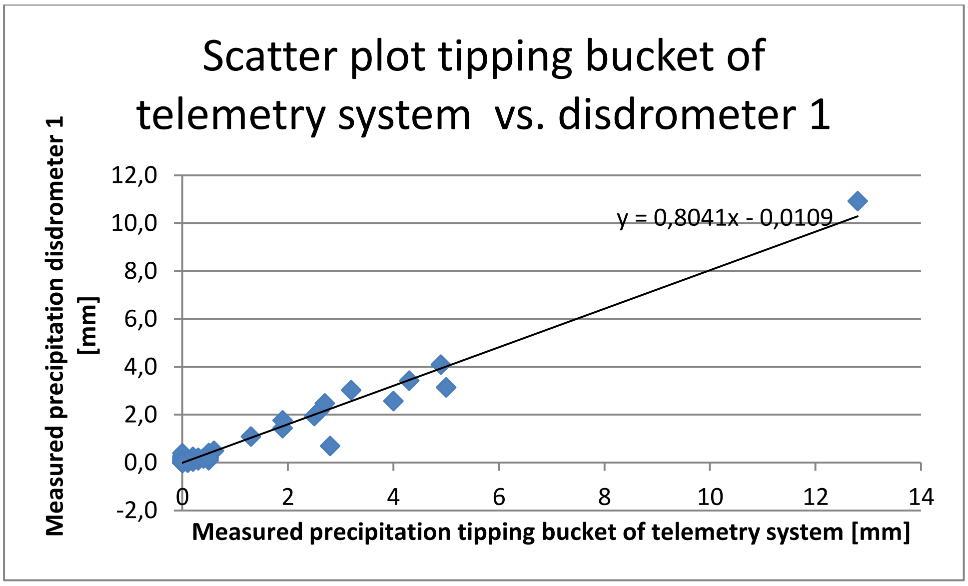


Figure 45: Scatter plot tipping bucket of telemetry system vs. disdrometer 1 (hourly data)

Finally, the last plot shows the relationship between the tipping bucket of the telemetry system vs. disdrometer 2.

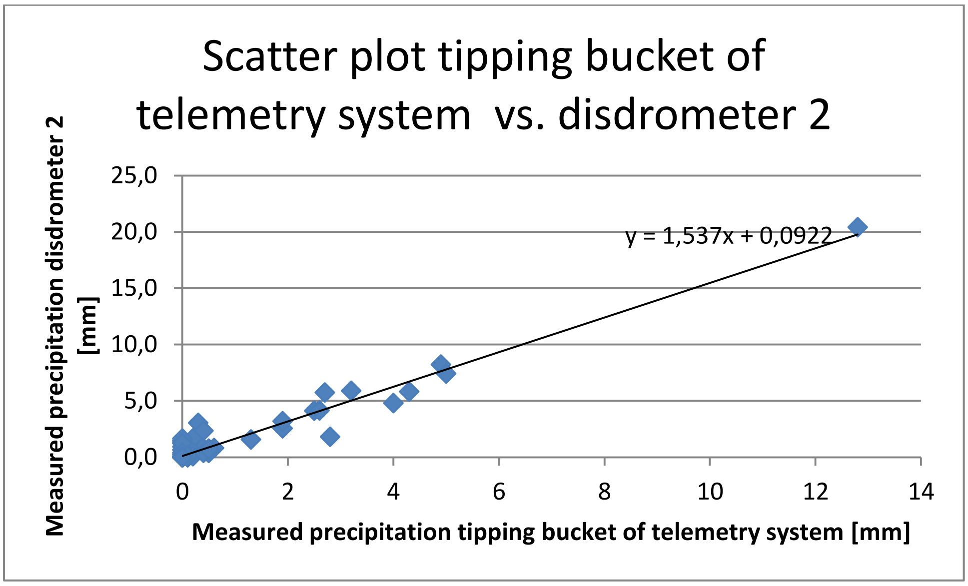


Figure 46: Scatter plot tipping bucket of telemetry system vs. disdrometer 2 (hourly data)

5.4.1.3. Spearman rank correlation for statistical dependence between two variables

The strength of the relationships between the different datasets is tested with the spearman rank correlation. Formula 13 is used to calculate all the spearman rank correlation values and the results are presented in Table 3.

Two datasets:	**Spearman rank correlation:**
Disdrometer 1 - Disdrometer 2	r = 0.86
Tipping bucket - Tipping bucket of telemetry system	r = 0.99
Disdrometer 1 - Tipping bucket	r = 0.81
Disdrometer 1 - Tipping bucket of telemetry system	r = 0.86
Disdrometer 2 - Tipping bucket	r = 0.55
Disdrometer 2 - Tipping bucket of telemetry system	r = 0.62

Table 3: Spearman rank correlation between the different datasets

5.4.2. Analysing collected data ITC (Bago)

The rainy season started this year on May 18. This is quite late because in the previous 32 years, the rainy season started only 5 time from this day or later. The collected data is from May 18 until June 8, so this is exactly three weeks. The data of the HOBO Logging rain gauge is missing, due to technical problems. The different installed measurement devices, measured different rainfall amounts. The daily precipitation measured is in appendix 8.4.2. First some basic information is collected in Table 4.

Rain gauge type	**Total measured amount of rainfall [mm]**	**Highest measurement day [date] +amount [mm]**		**Lowest measurement day [date] +amount [mm]**	
Disdrometer 1	789.3	May 24	153.1 mm	May 26	0.6 mm
Disdrometer 2	129.6	May 23	31.3 mm	May 26	0 mm
Tipping bucket	453.4	May 23	116.8 mm	May 26	0 mm
Manual rain gauge	357.6+	May 23	70+ mm	May 26-28,June5	0 mm

Table 4: Basic data comparison of the different kinds of measurement equipment

5.4.2.1. Measurement check by manual rain gauge

In order to check the measurement results of the automatic equipment, there is a daily check done with the manual rain gauge. The results are shown in Table 5.

Date and time	Measured amount of precipitation by the manual rain gauge [mm]	Measured amount of precipitation by the tipping bucket [mm]	Measured amount of precipitation by the disdrometer 1 [mm]	Measured amount of precipitation by the disdrometer 2 [mm]
May 19, 9:30	4	4	8.4	0.1
May 20, 9:30	-	1.2	3.9	0.5
May 21, 9:30	3	2.2	3.6	0.5
May 22, 9:30	47	50	33.4	14.9
May 23, 9:30	6	6.4	1.3	1.9
May 24, 9:30	70+	126.2	166.1	33.8
May 25, 9:30	55	55.8	120.6	15.0
May 26, 9:30	0	0	1.6	1.2
May 27, 9:30	0	0	0.3	0
May 28, 9:30	0	7	13.8	1.6
May 29, 9:30	3.1	3.2	8.5	1.0
May 30, 9:30	7.5	8.4	15.3	1.8
May 31, 9:30	23	41,8	79	9.9
June 1, 9:30	37	24,4	54,1	6.4
June 2, 9:30	13	13.8	32.1	3.8
June 3, 9:30	1	1	3.3	0.4
June 4, 9:30	27	27	11.3	8.9
June 5, 9:30	0	0.2	0.7	0.1
June 6, 9:30	46	45.2	128	15.5
June 7, 9:30	15	15.4	44.8	5.3
Total	*357.6+*	*433.2*	*730.4*	*122.7*

Table 5: Comparing data results of the manual rain gauge, the tipping bucket and the disdrometers

5.4.2.2. *Comparing peak moments and peak sizes of the different measurement results*

First the data is plotted to see if the peaks correspond. The peak moments are quite similar, however the measured peak height is quite different. Disdrometer 1 measures usually the highest peaks, disdrometer 2 the lowest peaks and the measurement of the tipping bucket is usually between those values.

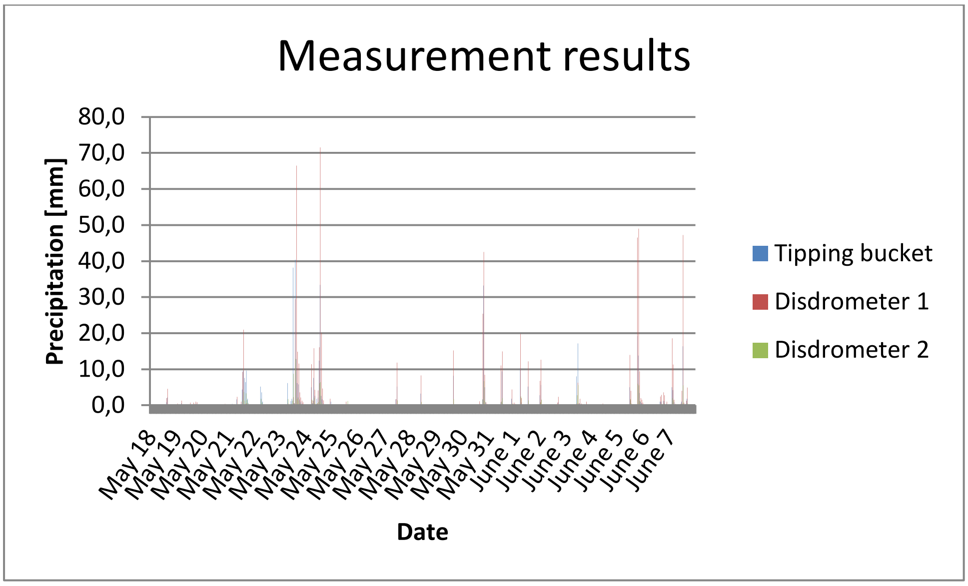


Figure 47: Measurement results tipping bucket vs. disdrometers

On May 24, one of the highest rainfall amounts is measured. This specific day is plotted, to zoom in on three events, making the differences clearer.

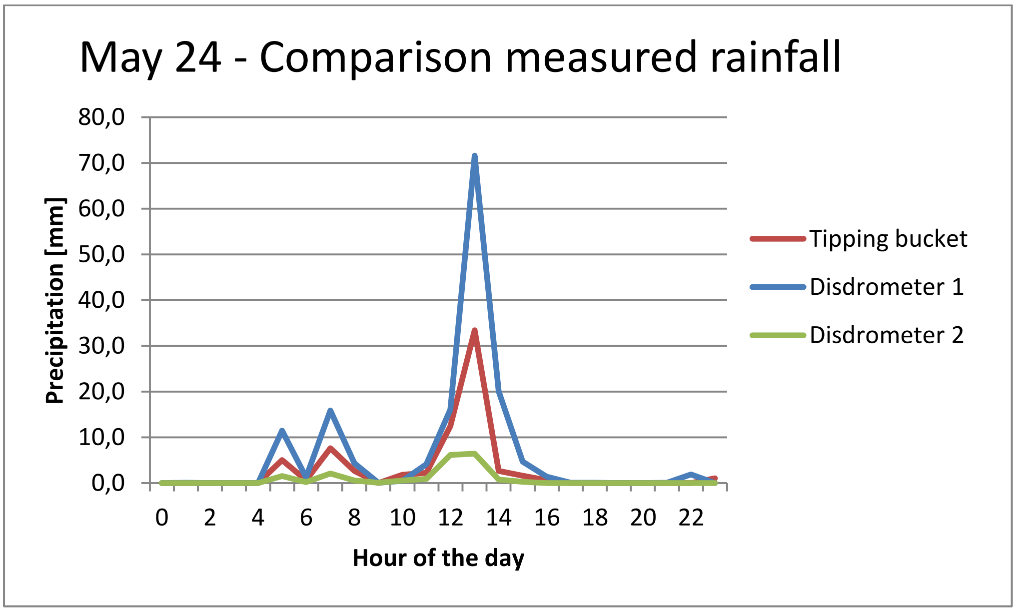


Figure 48: Comparison measured rainfall amounts on May 24

5.4.1.3. Scatter plots for visual indication of relationships between two datasets

Scatter plots are made for the combinations between the three different measurement instruments. First a scatter plot of the relation between the two disdrometers is made.

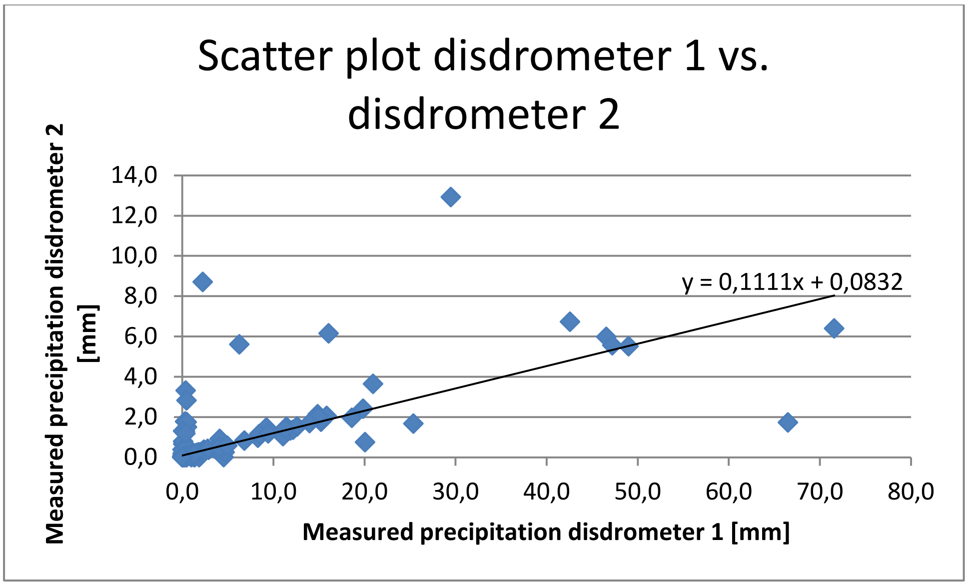


Figure 49: Scatter plot disdrometer 1 vs. disdrometer 2 (hourly data)

Subsequently, a scatter plot is made whereby the data of the tipping bucket is plotted versus the data of the disdrometer 1.

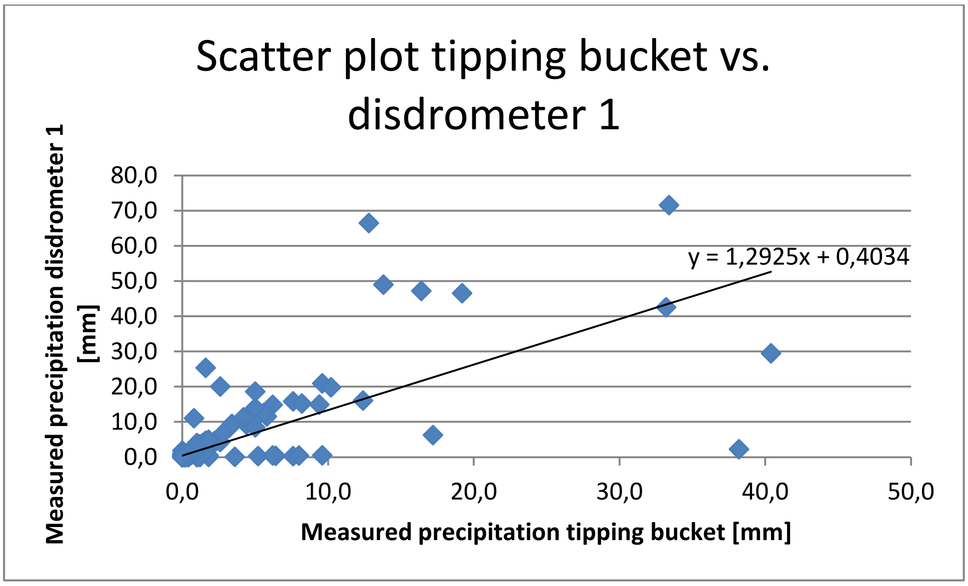


Figure 50: Scatter plot tipping bucket vs. disdrometer 1 (hourly data)

Finally, a comparable scatter plot is made for the data of the tipping bucket versus the data of the disdrometer 2.

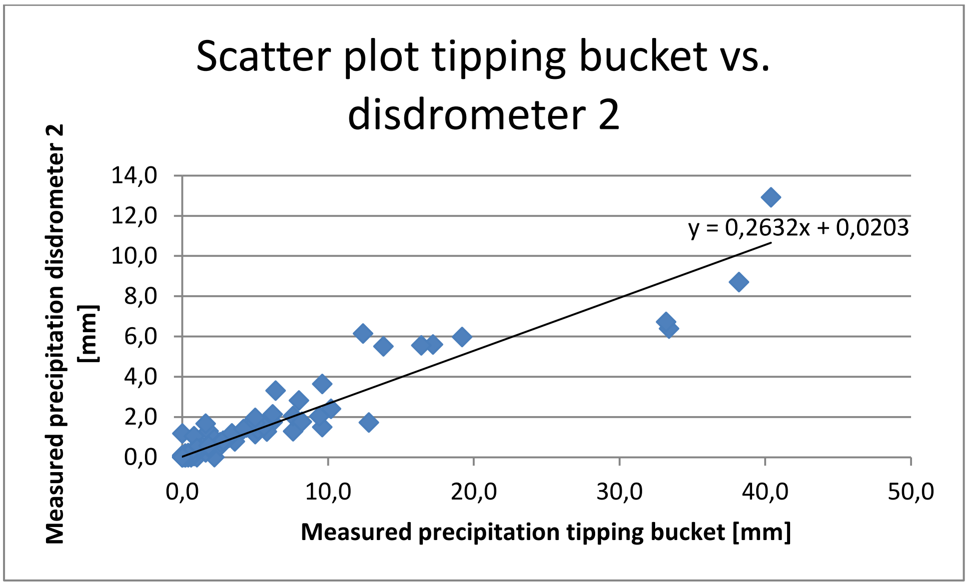


Figure 51: Scatter plot tipping bucket vs. disdrometer 2 (hourly data)

5.4.2.3. *Spearman rank correlation for statistical dependence between two variables*

The spearman rank correlation is calculated with formula 13. The results are given in Table 6.

Two datasets:	**Spearman rank correlation:**
Disdrometer 1 - Disdrometer 2	r = 0.94
Disdrometer 1 - Tipping bucket	r = 0.70
Disdrometer 2 - Tipping bucket	r = 0.84

Table 6: Spearman rank correlation between the different datasets

5.4.3. Analysing collected data Social Weather App

To link a rain status to a rain intensity, as much data as possible has to be compared with measurement data. In appendix 8.5 are the weather report listed on date. These reports are compared with the intensities measured by the tipping bucket and the Delft-disdrometers. The telemetric system of the YTU is only measuring the rainfall amounts ones in an hour. So this is a fairly large time range and can therefore not provide an accurately comparison with the rain reports.

Rain type	**Rain intensity category**
No rain	0.0 mm
Drizzle	0.0-0.4 mm
Light rain	0.2-0.6 mm
Moderate rain	0.4-1.6 mm
Heavy rain	1.8 mm - higher intensities

Table 7: Resulting rain intensity categories for the Social Weather App

Discussion

The measurements in Yangon and Bago bring similar results. The peak moments are for example for all the different equipment a pretty good mach. Furthermore are the results of the (two) tipping bucket(s) and the manual rain gauge corresponding well. The two tipping buckets that are located in Yangon are having a very strong spearman rank correlation, namely r = 0.99. The small differences in results between those two tipping buckets can be explained by differences in location. The wind could have a bigger influence on the results of the tipping bucket of the telemetric system, because it is located on the roof.

In contrast with the previous corresponding results are the disdrometers having a conspicuous deviation. At both locations, there is one disdrometer measuring strikingly over the tipping bucket and the other disdrometer a lot less compared with the tipping bucket. The remarkable thing about this result is that the disdrometers are not only having a deviation in the measured amount of rain, but also the measured precipitation amounts of the two disdrometers are not of the same order.

However, the measurement results of the two disdrometers are still having a reasonably strong relationship, namely 0.94 for the situation in Bago and 0.86 for the situation in Yangon. Only the coupled amount of rain differs by a factor of almost 2 for the situation in Yangon and almost a factor 10 for the situation in Bago.

Furthermore are the rain reports of the Social Weather App compared with the results of the measurements. From this, rainfall intensity categories are coupled to the rain reports. However, there are too few rain reports to mount real reliable conclusions. There are a number of reasons why there are not so many rain reports. At both research locations did my contact person arrange my audience. At the YTU I got a group of master students who would help me with my research and at the ITC a group of employees. Both groups were having trouble with installing the App. As a result personal guidance had to be in place to install the application. After that I explained how it worked and during the test a lot of people faced internet problems. If the internet connection is not strong enough, the app sometimes closes automatically. This doesn't stimulate students to try again at a later time. Furthermore, a trend is visible in the reports of Bago. In the beginning there are quite a lot reports, but after some time there are not so many updates anymore. The moment you are there to remind people, you again get a few reports but this stops soon again.

6.1. Recommendations for future studies

The disdrometers will have to be recalibrated in the Netherlands. In this way it can be determined if the disdrometers are not properly calibrated or that the disdrometers are not working well by tropical rain intensities.

To make the disdrometers also user-friendly for the local population, the English time that is programmed now should be changed to Myanmar time. In this way, right days are stored and less steps have to be taken for analysing the data.

The Social Weather App should be more easily to download, this will be the case if the App is in the Play Store. However, in the mean time it would already be handy to change the link, because some special characters are hard to find on a Burmese keyboard.

Furthermore, if there is a poor internet connection, the rain reports should still be saved and passed if the internet connection is better.

Conclusion

In order to create accurate rainfall data for Yangon city and Bago city a denser network of rain gauges is required. It is important that this network is constructed in such manner, that the resolution of the network is capable of capturing convective precipitation. This can be done with 24 rain gauges per 1000 km^2, which is the optimum ratio found in another research. Furthermore, it is required that the network can measure different rain events occurring during the day. Therefore, the network must consist out of automatic rain gauges. In theory, the Delft-disdrometer would be the most appropriate device for this network, because of the fact that the results can be better compared with satellite images than tipping bucket results can be compared with satellite images.

Furthermore, social media can be well used to densify the measurement network. On basis of comparing the rain reports with the measurement results, rain intensity categories are made. There is overlap within these intensity categories. To make a sharp distinction between these categories, more rain reports are needed. For getting these reports, it is really important to give presentations, whereby people can ask for help with installing the Social Weather App. The reason for this is that during the given presentations, were people asked to install the app and lots of them were facing trouble to do this and needed help.

Based on historical data return periods were determined. These return periods are for instance important for designing a proper sewer system. Further, the variation between yearly and monthly rainfall amounts were studied. This is for example interesting for comparing with new measurements results.

During this study, this was also done for Bago measurement results for May. The results showed that extreme amounts of rainfall were measured by one of the disdrometers. An average amount of rainfall was measured by the tipping bucket and an extremely low amount of rainfall was detected by the second disdrometer. From this it can be concluded that the disdrometers are not (yet) capable of producing reliable results in tropical regions. The expectation that the results of the tipping bucket were the most plausible, were afterwards supported during a comparison with the manual measured rain amount per day.

After further comparisons it can be concluded that the results of both tipping buckets have a large spearman rank correlation ($r = 0.99$) and that the results of these rain gauges are comparable with the manual measured rain amount. The disdrometers however, are measuring peaks at the right time, but are unable to produce similar intensities compared to the tipping buckets and manual measurement devices.

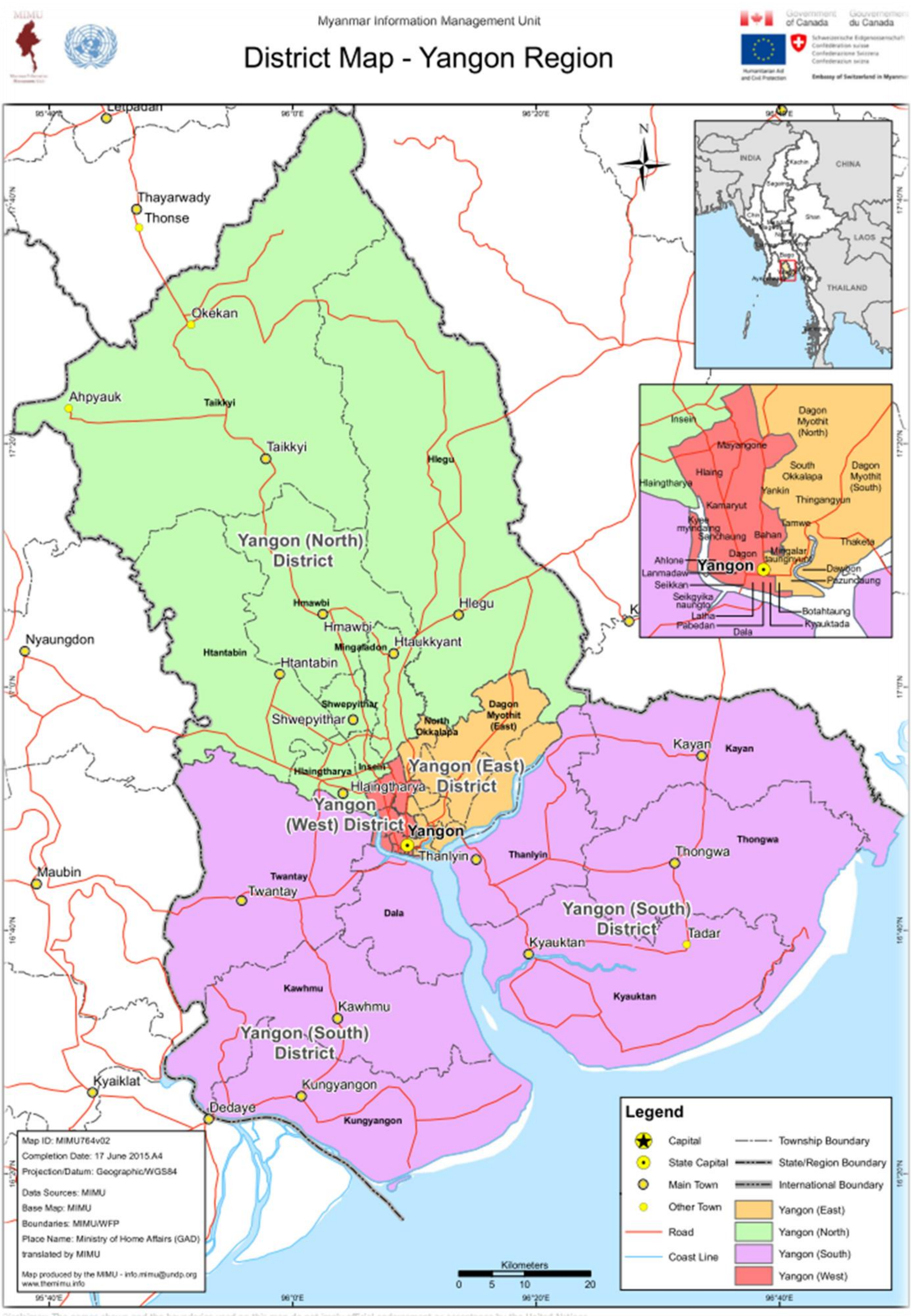
It cannot yet be stated that Delft-disdrometers are failing in tropical regions. Calibration of the devices will show whether this is indeed the case. Further research should be done in order to claim that Delft-disdrometers are not working properly for tropical intensities. It can be concluded however, that the tipping bucket seems to be better for measuring tropical intensities in Yangon and Bago.

Appendix

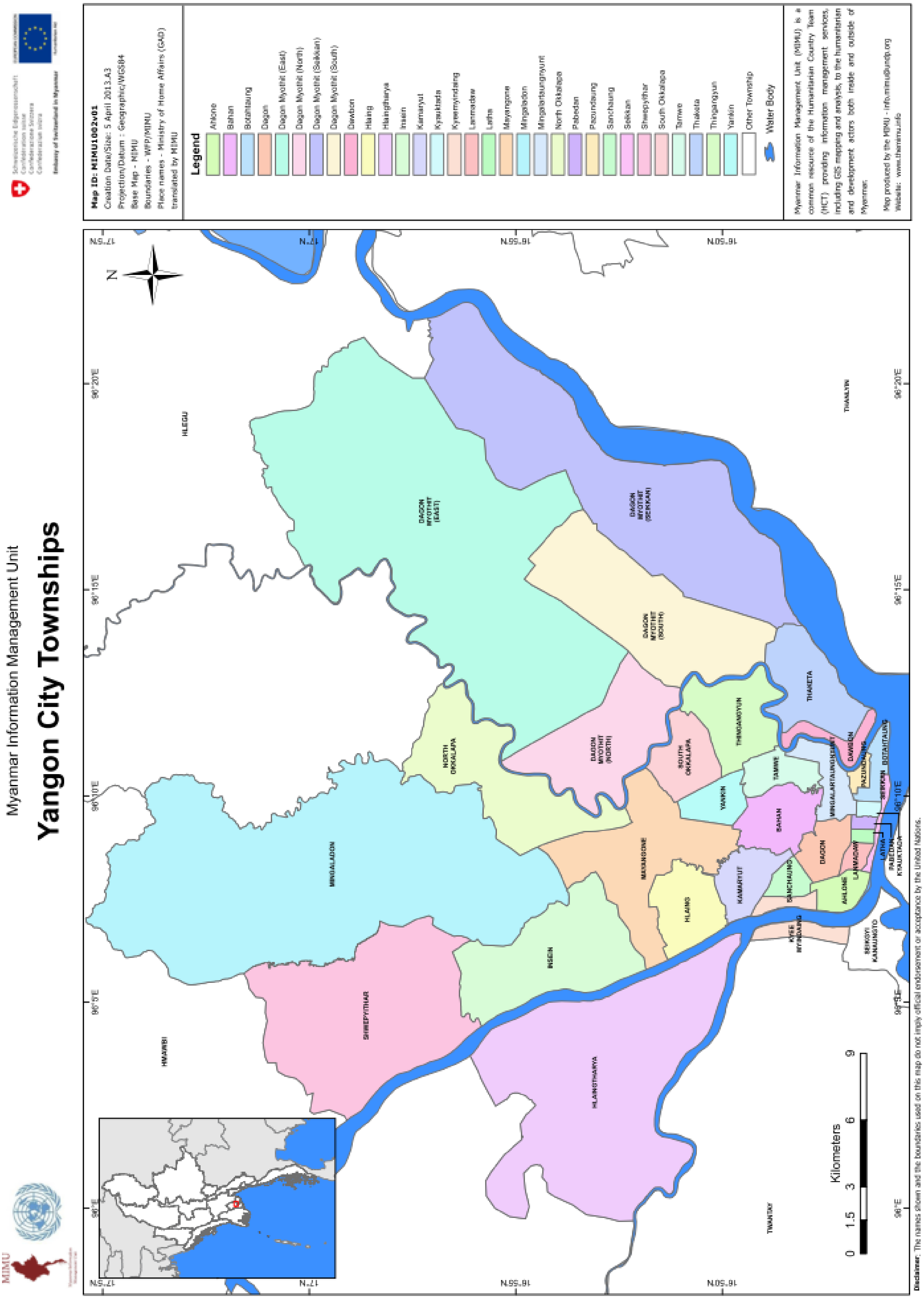
8.1. Maps of chapter: Locations for the rain gauges

8.1.1. Map: Yangon region (MIMU, 2005)

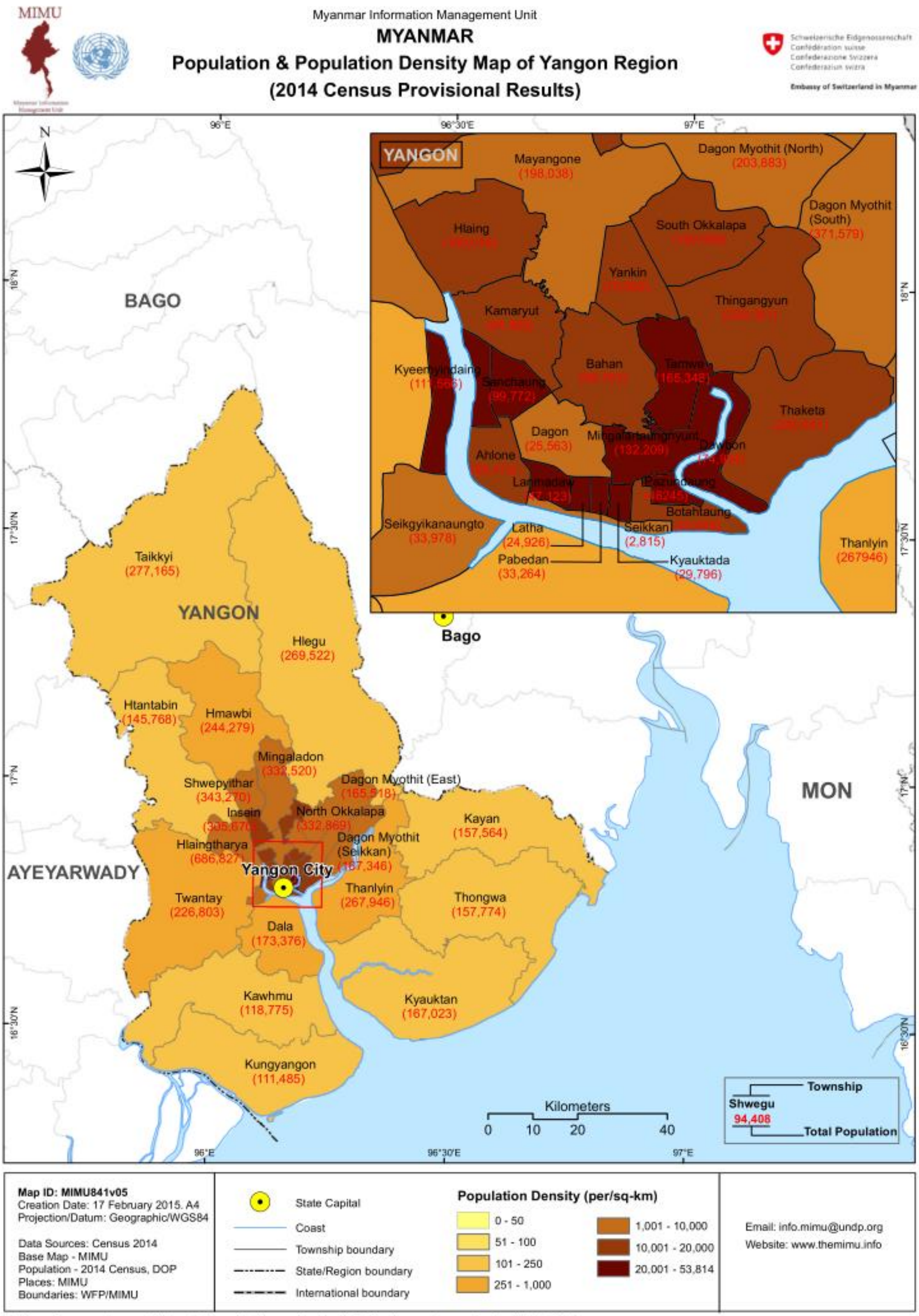
8.1.2. Map: Yangon region, districts (MIMU, 2015)



8.1.3. Map: Townships of Yangon city (MIMU, 2013)

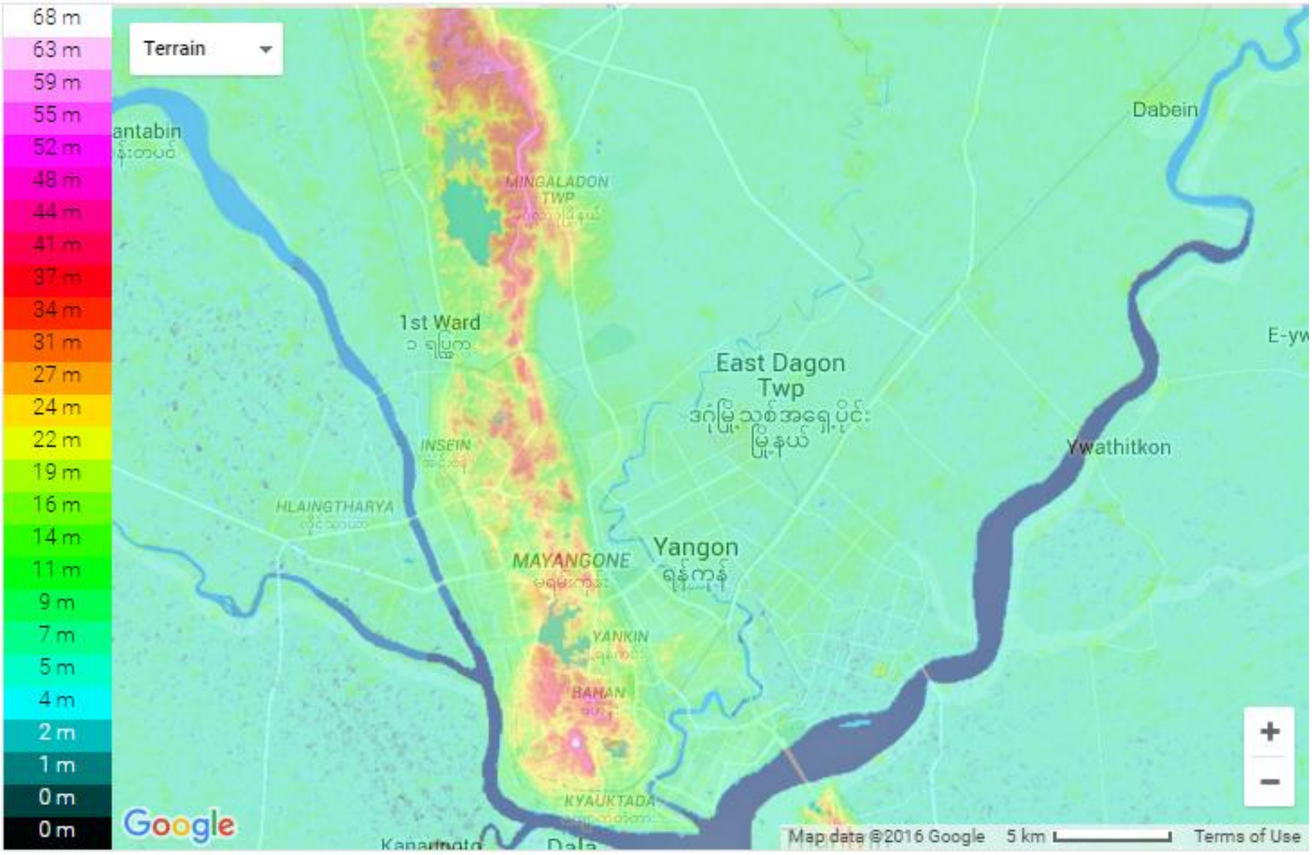


8.1.4. Map: Population density in Yangon region (MIMU, 2014)

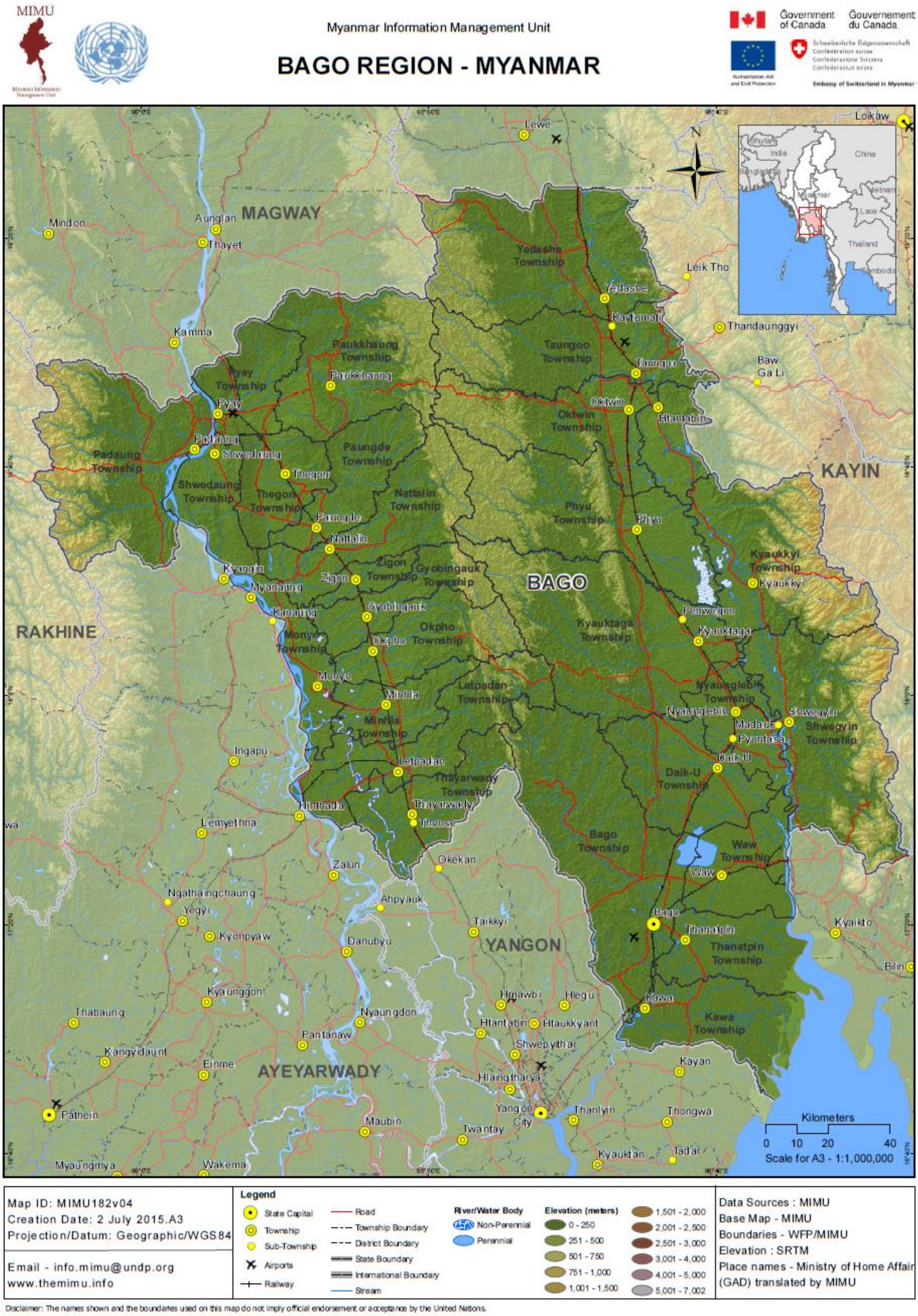


Disclaimer: The names shown and the boundaries used on this map do not imply official endorsement or acceptance by the United Nations.

8.1.5. Map: Yangon height map (Topographic map, 2016)



8.1.6. Map: Bago region (MIMU, 2015)

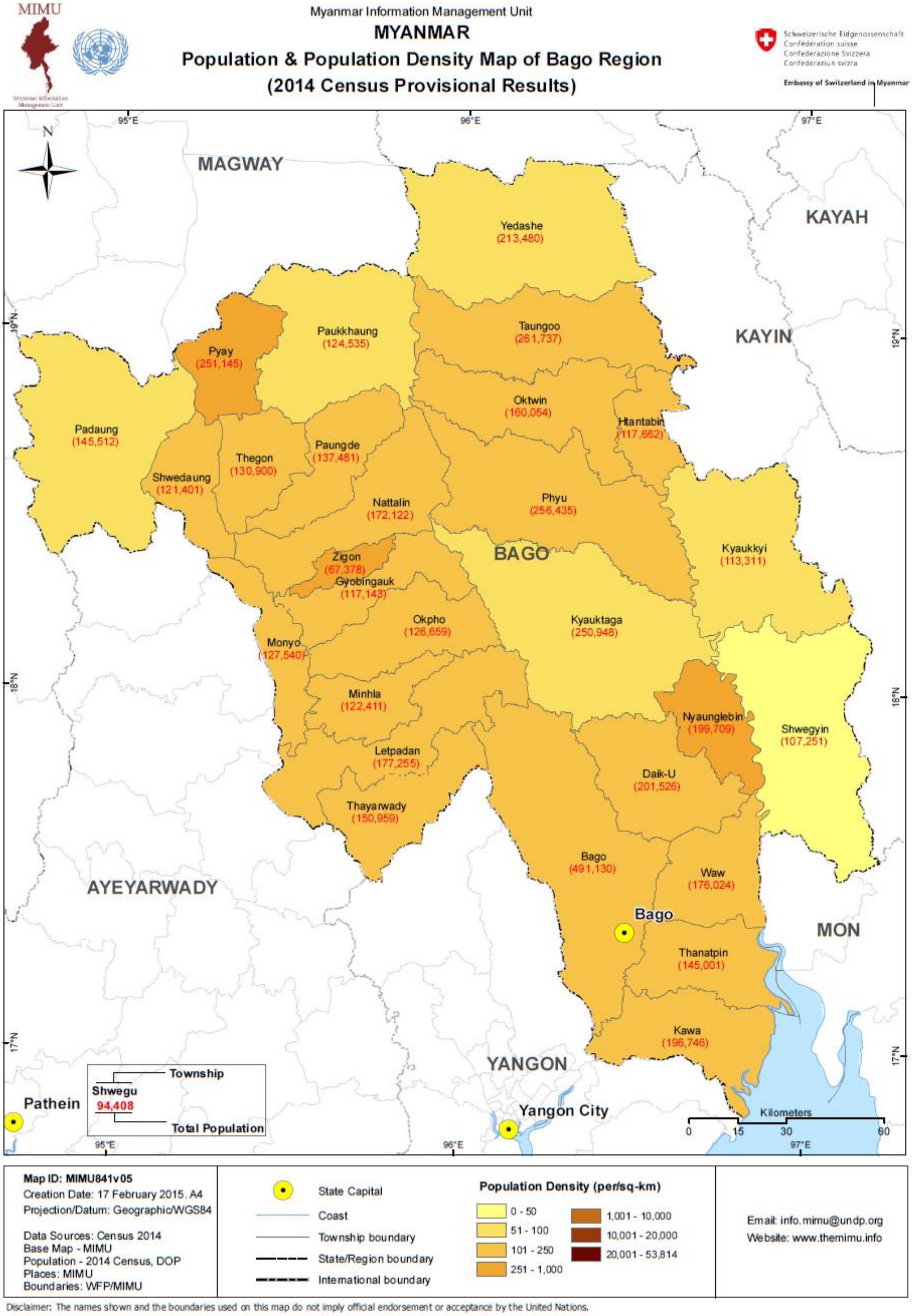


8.1.7. Map: Bago region, districts (MIMU, 2015)

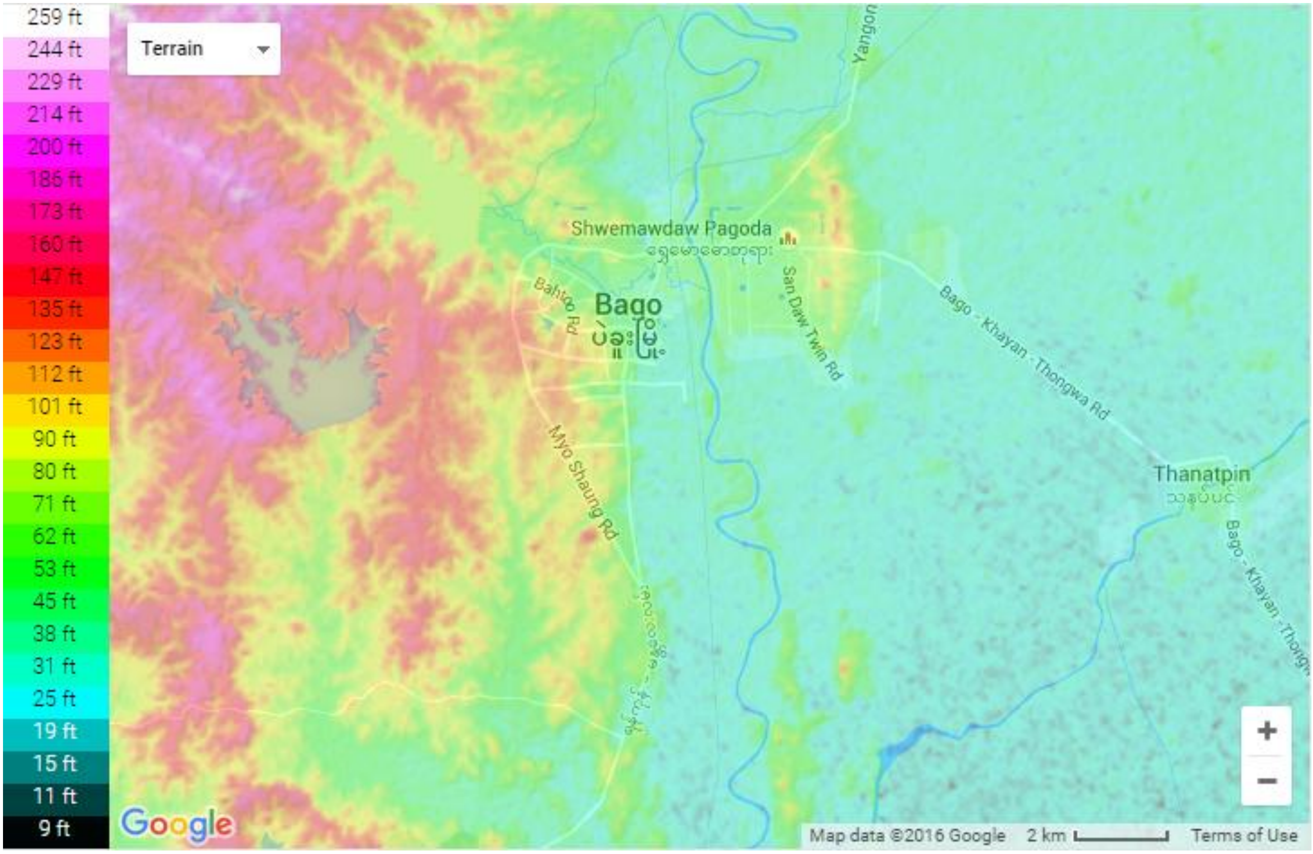
Disclaimer: The names shown and the boundaries used on this map do not imply official endorsement or acceptance by the United Nations.

8.1.8. Map: Bago city (Google Maps, 2016)

8.1.9. Map: Bago region, density map (MIMU, 2015)



8.1.10. Map: Bago height map (Topographic map, 2016)



8.2. Python script for analysing the DMH data

In [1]:
```
import xlrd
workbook = xlrd.open_workbook('Bago30years.xlsx')
worksheet = workbook.sheet_by_name('30yearsdata')

Maxlist=[]
for j in range(30):
    data = worksheet.col_values(j)


    twodays = []
    threedays = []
    fourdays = []
    fivedays = []
    sixdays = []
    sevendays = []

    for i in range(len(data)-1):
        twodays.append(data[i]+data[i+1])
    for i in range(len(data)-2):
        threedays.append(data[i]+data[i+1]+data[i+2])
    for i in range(len(data)-3):
        fourdays.append(data[i]+data[i+1]+data[i+2]+data[i+3])
    for i in range(len(data)-4):
        fivedays.append(data[i]+data[i+1]+data[i+2]+data[i+3]+data[i+4])
    for i in range(len(data)-5):
        sixdays.append(data[i]+data[i+1]+data[i+2]+data[i+3]+data[i+4]+data[i+5])
    for i in range(len(data)-6):
        sevendays.append(data[i]+data[i+1]+data[i+2]+data[i+3]+data[i+4]+data[i+5]+data[i+6])

    Maxlist.append([max(data),max(twodays),max(threedays),max(fourdays),max(fivedays),max(sixdays),max(sevendays)])
```

In [2]:
```
oneday=[]
for i in range(30):
    oneday.append(Maxlist[i][0])

twodays=[]
for i in range(30):
    twodays.append(Maxlist[i][1])

threedays=[]
for i in range(30):
    threedays.append(Maxlist[i][2])

fourdays=[]
for i in range(30):
    fourdays.append(Maxlist[i][3])

fivedays=[]
for i in range(30):
    fivedays.append(Maxlist[i][4])

sixdays=[]
for i in range(30):
    sixdays.append(Maxlist[i][5])

sevendays=[]
for i in range(30):
    sevendays.append(Maxlist[i][6])

oneday.sort(reverse=True)
twodays.sort(reverse=True)
threedays.sort(reverse=True)
fourdays.sort(reverse=True)
fivedays.sort(reverse=True)
sixdays.sort(reverse=True)
sevendays.sort(reverse=True)
```

In [3]:
```
plt.boxplot(oneday)
plt.ylim(0,300)
plt.ylabel('Rainfall amount [mm]')
plt.xlabel('Number of days')
plt.title('Distribution of the annual maximum')
plt.show()
```

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
import xlrd
workbook = xlrd.open_workbook('Bago30years.xlsx')
worksheet = workbook.sheet_by_name('Rainseason')
data = []
for i in range(6):
    data.append(worksheet.col_values(i))
```

In [2]:
```
plt.figure(1)
plt.boxplot(data)
plt.labels = ( 'May', 'Jun', 'Jul', 'Aug', 'Sep', 'Oct')
plt.xticks(range(1,7),labels)
plt.xlabel('Month')
plt.ylabel('Rainfall amount [mm]')
plt.title('Rainfall variation during the monsoon period')
plt.show()
```

8.3. Excel sheets Gumbel and LPT III

8.3.1. Gumbel and LPT III calculations for Yangon

return	1 day			2days			3days			4days			5days			6days			7days		
	Pave =	S =		Pave =	S =		Pave =	S =		Pave =	S =		Pave =	S =		Pave =	S =		Pave =	S =	
	144,41	98,25		197,57	126,67		235,67	153,12		261,96	150,11		288,60	147,55		313,81	142,88		337,31	138,41	
	K	PT	IT	K	PT	IT	K	PT	IT	K	PT	IT	K	PT	IT	K	PT	IT	K	PT	IT
2	-0,16	128,27	128,27	-0,16	176,76	88,38	-0,16	210,52	70,17	-0,16	237,30	59,33	-0,16	264,36	52,87	-0,16	290,34	48,39	-0,16	314,57	44,94
5	0,72	215,10	215,10	0,72	288,70	144,35	0,72	345,83	115,28	0,72	369,96	92,49	0,72	394,76	78,95	0,72	416,61	69,43	0,72	436,89	62,41
10	1,30	272,58	272,58	1,30	362,82	181,41	1,30	435,42	145,14	1,30	457,79	114,45	1,30	481,09	96,22	1,30	500,21	83,37	1,30	517,87	73,98
15	1,63	305,02	305,02	1,63	404,63	202,32	1,63	485,97	161,99	1,63	507,34	126,84	1,63	529,80	105,96	1,63	547,37	91,23	1,63	563,57	80,51
30	2,19	359,45	359,45	2,19	474,81	237,41	2,19	570,80	190,27	2,19	590,50	147,63	2,19	611,54	122,31	2,19	626,53	104,42	2,19	640,25	91,46
-0,78																					

return	1 day				2days				3days				4days				5days				6days				7days			
	Pave =	S =	C =		Pave =	S =	C =		Pave =	S =	C =		Pave =	S =	C =		Pave =	S =	C =		Pave =	S =	C =		Pave =	S =	C =	
	2,11	0,19	2,00		2,25	0,18	2,00		2,33	0,17	2,40		2,38	0,15	2,40		2,43	0,14	2,20		2,47	0,13	2,40		2,51	0,12	2,40	
	K	PT*	PT	IT	K	PT*	PT	IT	K	PT*	PT	IT	K	PT*	PT	IT	K	PT*	PT	IT	K	PT*	PT	IT	K	PT*	PT	IT
2	-0,31	2,05	112,63	112,63	-0,31	2,19	156,58	78,29	-0,35	2,27	186,35	62,12	-0,35	2,33	212,50	53,12	-0,33	2,38	241,99	48,40	-0,35	2,42	265,69	44,28	-0,35	2,47	293,68	41,95
5	0,61	2,23	168,16	168,16	0,61	2,36	228,89	114,44	0,54	2,42	263,81	87,94	0,54	2,46	288,77	72,19	0,57	2,51	323,86	64,77	0,54	2,54	346,59	57,76	0,54	2,57	375,35	53,62
10	1,30	2,36	227,71	227,71	1,30	2,48	305,04	152,52	1,26	2,54	350,38	116,79	1,26	2,57	370,94	92,73	1,28	2,61	407,16	81,43	1,26	2,63	430,59	71,76	1,26	2,66	458,61	65,52
15	1,61	2,42	260,33	260,33	1,61	2,54	346,29	173,15	1,59	2,60	398,85	132,95	1,59	2,62	415,86	103,97	1,60	2,65	451,25	90,25	1,59	2,68	475,43	79,24	1,59	2,70	502,53	71,79
30	2,36	2,56	361,43	361,43	2,36	2,67	472,54	236,27	2,41	2,74	548,95	182,98	2,41	2,74	551,25	137,81	2,39	2,76	580,82	116,16	2,41	2,78	606,97	101,16	2,41	2,80	629,62	89,95

8.3.2. Comparing the results of Gumbel and LPT III with the observations for Yangon

Gumbel									(O-E)^2 / E							X^2	X
	1	2	3	4	5	6	7										
2	128,2703	88,38083	70,17222	59,32528	52,87233	48,3898	44,93902		1,372883	1,10466	0,289289	0,352855	0,008549	0,030917	0,003007		
5	215,0967	144,3518	115,2778	92,48944	78,95119	69,43435	62,41287		9,040205	7,70579	7,778338	5,71432	2,9076	2,22675	1,785263		
10	272,5833	181,4095	145,1416	114,447	96,21766	83,36767	73,98208		10,14371	9,452358	8,347805	2,084893	1,171663	1,289331	0,956166		
15	305,0168	202,3171	161,9905	126,8353	105,9593	91,22873	80,50934		4,484199	0,013998	4,170028	3,673455	2,525738	2,065993	1,943669		
30	359,4481	237,4052	190,267	147,6258	122,308	104,4215	91,46365		140,2805	100,6699	99,70394	66,8937	47,58858	36,51036	28,39842		
																612,6888	24,75255
PT3																	
	1	2	3	4	5	6	7										
2	112,6341	78,29067	62,11675	53,12391	48,39829	44,28114	41,95483		0,049695	0,00056	0,202874	0,049774	0,298627	0,188032	0,16319		
5	168,1551	114,4432	87,93641	72,19216	64,7724	57,7642	53,62187		0,048131	0,103594	0,077056	0,100395	0,014598	0,01011	0,058078		
10	227,7089	152,5211	116,7935	92,73422	81,43104	71,76435	65,51518		0,260978	1,027914	0,357331	0,423361	0,213435	0,021276	4,83E-05		
15	260,3275	173,145	132,9501	103,9657	90,25058	79,23896	71,78967		25,62312	5,498453	0,069964	0,015866	0,00469	0,038163	0,200051		
30	361,4265	236,2708	182,9822	137,8129	116,1636	101,1623	89,94602		137,0651	102,6432	114,9302	86,50721	58,50167	41,77016	30,62301		
																607,1599	24,64062
Metingen																	
	1	2	3	4	5	6	7										
2	115	78,5	65,66667	54,75	52,2	47,16667	44,57143										
5	171	111	85,33333	69,5	63,8	57	51,85714										
10	220	140	110,3333	99	85,6	73	65,57143										
15	342	204	136	105,25	89,6	77,5	68										
30	584	392	328	247	198,6	166,1667	142,4286										

8.3.3. Gumbel and LPT III calculations for Bago

return	1 day			2days			3days			4days			5days			6days			7days		
	P_{ave} =	S =		P_{ave} =	S =		P_{ave} =	S =		P_{ave} =	S =		P_{ave} =	S =		P_{ave} =	S =		P_{ave} =	S =	
	140,28	41,14		195,45	59,94		233,37	60,21		273,21	61,49		313,77	68,02		340,03	69,75		368,66	68,29	
	K	P_T	I_T	K	P_T	I_T	K	P_T	I_T	K	P_T	I_T	K	P_T	I_T	K	P_T	I_T	K	P_T	I_T
2	-0,16	133,52	133,52	-0,16	185,60	92,80	-0,16	223,48	74,49	-0,16	263,11	65,78	-0,16	302,60	60,52	-0,16	328,57	54,76	-0,16	357,44	51,06
5	0,72	169,88	169,88	0,72	238,57	119,29	0,72	276,69	92,23	0,72	317,45	79,36	0,72	362,71	72,54	0,72	390,21	65,04	0,72	417,79	59,68
10	1,30	193,95	193,95	1,30	273,65	136,82	1,30	311,92	103,97	1,30	353,43	88,36	1,30	402,51	80,50	1,30	431,02	71,84	1,30	457,75	65,39
15	1,63	207,53	207,53	1,63	293,43	146,72	1,63	331,79	110,60	1,63	373,73	93,43	1,63	424,96	84,99	1,63	454,05	75,67	1,63	480,29	68,61
30	2,19	230,32	230,32	2,19	326,64	163,32	2,19	365,15	121,72	2,19	407,79	101,95	2,19	462,64	92,53	2,19	492,69	82,12	2,19	518,13	74,02
-0,78																					

return	1 day				2days				3days				4days				5days				6days				7days			
	P_{ave} =	S =	C =		P_{ave} =	S =	C =		P_{ave} =	S =	C =		P_{ave} =	S =	C =		P_{ave} =	S =	C =		P_{ave} =	S =	C =		P_{ave} =	S =	C =	
	2,13	0,11	0,95		2,27	0,12	0,71		2,36	0,10	0,79		2,43	0,09	0,47		2,49	0,09	0,27		2,52	0,09	0,12		2,56	0,08	-0,07	
	K	P_{T*}	P_T	I_T	K	P_{T*}	P_T	I_T	K	P_{T*}	P_T	I_T	K	P_{T*}	P_T	I_T	K	P_{T*}	P_T	I_T	K	P_{T*}	P_T	I_T	K	P_{T*}	P_T	I_T
2	-0,16	2,11	129,41	129,41	-0,12	2,26	180,33	90,17	-0,13	2,35	222,23	74,08	-0,08	2,42	264,56	66,14	-0,05	2,49	305,84	61,17	-0,02	2,52	329,97	54,99	0,02	2,56	364,22	52,03
5	0,76	2,21	163,45	163,45	0,79	2,36	231,63	115,82	0,78	2,44	274,16	91,39	0,81	2,50	318,21	79,55	0,82	2,56	366,57	73,31	0,84	2,60	393,77	65,63	0,85	2,63	424,31	60,62
10	1,34	2,28	189,41	189,41	1,33	2,43	269,13	134,56	1,34	2,49	311,60	103,87	1,32	2,55	354,05	88,51	1,31	2,61	405,33	81,07	1,29	2,64	432,79	72,13	1,27	2,66	458,78	65,54
15	1,57	2,30	200,77	200,77	1,54	2,46	285,29	142,64	1,56	2,52	327,72	109,24	1,52	2,57	368,73	92,18	1,49	2,62	420,74	84,15	1,46	2,65	447,75	74,63	1,42	2,67	471,54	67,36
30	2,14	2,37	232,13	232,13	2,06	2,52	328,55	164,27	2,55	2,61	411,62	137,21	1,99	2,61	406,54	101,63	1,92	2,66	460,14	92,03	1,85	2,69	485,75	80,96	1,77	2,70	503,32	71,90

8.3.4. Comparing the results of Gumbel and LPT III with the observations for Bago

Gumbel									(O-E)^2 / E							X^2	X
	1	2	3	4	5	6	7										
2	133,5218	92,80177	74,49306	65,77723	60,51924	54,762	51,06312		0,318558	0,189923	0,030484	1,13E-05	0,000235	0,003356	0,022831		
5	169,8785	119,2871	92,22951	79,36236	72,5415	65,03536	59,68454		0,007404	0,647294	0,51564	0,043703	0,004042	0,006128	0,069028		
10	193,9497	136,8228	103,9726	88,3569	80,50128	71,83721	65,39266		5,631976	0,039432	0,004633	0,998568	0,5912	0,075537	0,000954		
15	207,5305	146,7162	110,5979	93,43154	84,99212	75,67476	68,61314		3,905502	3,234364	4,537634	1,371138	0,545312	0,176877	0,001562		
30	230,3224	163,3198	121,7169	101,948	92,52884	82,1151	74,01788		2,434104	7,794984	2,268438	0,759944	0,775548	0,856195	0,685853		
																38,54839	6,208735
PT3																	
	1	2	3	4	5	6	7										
2	129,4077	90,16749	74,07621	66,14089	61,1688	54,99444	52,03097		0,044795	0,517738	0,049962	0,00231	0,009663	0,007947	0,000241		
5	163,4481	115,8164	91,38581	79,55363	73,31452	65,62794	60,61526		0,348921	0,244041	0,400855	0,053013	0,023569	2,29E-05	0,019927		
10	189,4087	134,5643	103,8673	88,5136	81,06623	72,13213	65,53932		7,460603	3,08E-05	0,006152	0,963819	0,494862	0,057386	0,002398		
15	200,7705	142,6428	109,2393	92,18282	84,14726	74,62576	67,36308		6,181756	4,687177	5,168223	1,713268	0,695975	0,296965	0,012637		
30	232,1293	164,2744	137,2078	101,6342	92,028	80,95781	71,90216		2,060604	7,340547	0,009233	0,817611	0,874698	1,124702	1,187592		
																42,87924	6,548224
Metingen																	
	1	2	3	4	5	6	7										
2	127	97	76	65,75	60,4	54,33333	52,14286										
5	171	110,5	85,33333	77,5	72	65,66667	61,71429										
10	227	134,5	104,6667	97,75	87,4	74,16667	65,14286										
15	236	168,5	133	104,75	91,8	79,33333	68,28571										
30	254	199	138,3333	110,75	101	90,5	81,14286										

8.4. Excel sheets daily precipitation records

8.4.1. Daily precipitation measured at the YTU

Rijlabels	Som van Tipping bucket [mm]	Som van Disdrometer 1 [mm]	Som van Disdrometer 2 [mm]	Som van Tipping bucket of telemetric system [mm]
jun				
3-jun	6,4	3,8	6,9	7,0
4-jun	0,0	0,1	0,5	0,0
5-jun	7,2	5,2	18,4	6,9
6-jun	0,4	0,4	7,1	0,5
7-jun	11,6	8,5	16,3	10,7
8-jun	36,8	25,6	50,6	31,2
Eindtotaal	**62,4**	**43,7**	**99,8**	**56,3**

8.4.2. Daily precipitation measured at the ITC

Rijlabels	Som van Tipping bucket [mm]	Som van Disdrometer 1 [mm]	Som van Disdrometer 2 [mm]
mei			
18-mei	3,0	6,5	0,1
19-mei	2,0	5,7	0,6
20-mei	0,4	1,0	0,1
21-mei	42,2	35,3	12,6
22-mei	9,8	1,3	2,9
23-mei	116,8	134,0	31,3
24-mei	71,4	153,1	19,3
25-mei	0,2	1,7	1,2
26-mei	0,0	0,6	0,0
27-mei	7,0	13,8	1,6
28-mei	3,2	8,5	1,0
29-mei	8,2	15,3	1,8
30-mei	41,6	79,1	9,9
31-mei	13,0	30,9	3,6
jun			
1-jun	17,2	35,9	4,2
2-jun	9,4	22,7	2,7
3-jun	26,8	11,2	8,9
4-jun	0,4	0,6	0,1
5-jun	45,0	128,1	15,5
6-jun	5,4	13,2	1,7
7-jun	30,4	90,7	10,5
Eindtotaal	**453,4**	**789,3**	**129,6**

8.5. Excel sheet: Comparing the Social Weather App reports with the measured rain intensities

Date	Time	Location	Status	Measured intensity tiping bucket [mm/5min]	Measured intensity disdrometer 1 [mm/5min]	Measured intensity disdrometer 2 [mm/5min]
9-5-2016	14:03	Bago	No rain	0	0	0
9-5-2016	14:34	Bago	No rain	0	0	0
13-5-2016	12:47	Bago	No rain	0	0	0
15-5-2016	10:12	Bago	No rain	0	0	0
18-5-2016	15:36	Bago	Drizzle	0	0,1	0
18-5-2016	15:38	Bago	No rain	0	0,1	0
18-5-2016	15:40	Bago	No rain	0	0,1	0
18-5-2016	15:51	Bago	Light rain	0,6	1,8	0
18-5-2016	15:56	Bago	Light rain	2	4,1	0
19-5-2016	16:36	Bago	Drizzle	0	0,2	0
21-5-2016	12:28	Bago	Drizzle	0,4	0,4	0
21-5-2016	13:40	Bago	Heavy rain	1,8	4,1	0,1
23-5-2016	12:51	Bago	Moderate rain	0,4	0,4	0
23-5-2016	14:20	Bago	Heavy rain	4,6	0	1,6
23-5-2016	14:21	Bago	Heavy rain	8,4	0	1,9
1-6-2016	13:33	Bago	Light rain	0,4	1	0
3-6-2016	12:36	Yangon	Moderate rain	0,4	0,1	0,3
3-6-2016	12:39	Yangon	Light rain	0,2	0,1	0,2
3-6-2016	14:19	Yangon	No rain	0	0	0
7-6-2016	10:51	Yangon	Heavy rain	1,8	0,8	1,5
7-6-2016	11:13	Yangon	Drizzle	0	0	0
7-6-2016	11:16	Yangon	Moderate rain	0	0	0
8-6-2016	15:16	Yangon	Moderate rain	1,6	2,5	4,8

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