RELATION BETWEEN ANTECEDENT RAINFALL OR RAINFALL AMOUNT WITH THE OCCURANCE OF LANDSLIDE IN UNIVERSITI TEKNOLOGI PETRONAS

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CIVIL ENGINEERING
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Relation between Antecedent Rainfall or Rainfall Amount with the Occurrence of Landslide in Universiti Teknologi PETRONAS

By

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD ARIF BIN WAN MOHD DZULKIFLI

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Abstract

This study is presented to examine the relation between antecedent rainfall or rainfall amount with the occurrence of the landslide in Universiti Teknologi PETRONAS (UTP), Tronoh, Perak. The landslide had occurred near the Civil Engineering Block, Block 13, and caused a slight damage to that area. It was said that there were heavy rains for a few days before the event took place. Thus there is some possibility that the event might be caused by the rainfall. This study basically is to find out the effect of the rainfall (antecedent rainfall or rainfall amount) toward the occurrence of the landslide. The data of the rainfall for 2-year period had been obtained from the Hydrology and Water Resources of Department of Irrigation and Drainage Malaysia (DID) in order to perform this research. The data has been analyzed one by one and the result of the analysis shows the antecedent rainfall factor plays more important role than the triggering rainfall in this particular case.

TABLE OF CONTENTS

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background of study

Nowadays, landslide is a common incident happened in many Malaysia and most of the tropical area in the world. For last few months, there were several landslide cases were reported in media. The latest was the tragedy of massive landslide that happened at Taman Bukit Mewah and Taman Bukit Utama in Bukit Antarabangsa, Kuala Lumpur. The catastrophe had destroyed many houses and properties around that residential area as shown in Figure 1.1. It also had killed many innocent people who live there. It was said that the main factor of this catastrophe was due to the heavy rain.

Figure 1.1. Damages caused by landslide at Bukit Antarabangsa

The Bukit Antarabangsa landslide is actually the third to occur in the Klang Valley in a week. On Nov 30, 2008, two sisters, were killed in a landslide which hit their bungalow in Ulu Yam Perdana, Gombak. On Thursday, a landslide in Jalan Semantan caused part of the retaining wall of a car park situated between two buildings to collapse, burying six cars and damaging five other vehicles. These landslides are believed to have been caused by movement of underground water and a condition made worse by the heavy rainfall in recent weeks.

Actually there were more landslides had been occurred especially during the raining season. On Dec 11, 1993, one of three blocks of the 12-storey Highland Towers apartments collapsed killing 48 people.

This kind of tragedy can not afford to be happened again in the future because besides causing physical damages, it also can cause economic loss and this will give bad impression to the stability of national administration. Further action need to be taken and this has to be started with the investigation to find the major factor that leads to the landslide problem.

Basically, a landslide (or landslip) is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments. Although the action of gravity is the primary driving force for a landslide to occur, there are other contributing factors affecting the original slope stability. Normally, pre-conditional factors build up specific sub-surface conditions that make the area or slope prone to failure, whereas the actual landslide often requires a trigger before being released.

There are many factors that can contribute to the landslide events. Actually, landslides are caused when the stability of a slope changes from a stable to an unstable condition. A change in the stability of a slope can be caused by a number of factors, acting together or alone. These are some of possible causes that can lead to the landslide events;

Geological causes

- Weak materials
- Sensitive materials
- Weathered materials
- Sheared materials
- Jointed or fissured materials
- Adversely orientated discontinuities

- Permeability contrasts
- Material contrasts
- Rainfall and snow fall

Morphological causes

- Slope angle
- Uplift
- Rebound
- Fluvial erosion
- Wave erosion
- Glacial erosion
- Erosion of lateral margins
- Subterranean erosion
- Slope loading
- Vegetation change

Physical causes

- Intense rainfall
- Rapid snow melt
- Prolonged precipitation
- Rapid drawdown
- Earthquake
- Volcanic eruption
- Thawing
- Freeze-thaw
- Shrink-swell

- Ground water changes
- Soil pore water pressure
- Surface runoff
- Seismic activity

Human causes

- Excavation
- Loading
- Drawdown
- Land use change
- Water management
- Mining
- Quarrying
- Vibration
- Water leakage
- Deforestation

As mentioned before, most of the landslides tragedies in Malaysia were found occurred during the raining seasons. Thus there is high possibility that the main cause for the landslide is coming from the rainfall.

In this study, the rainfall (antecedent rainfall or rainfall amount) will be taken as the major factor to examine the cause for the landslide. It is hoped that it will help the authorities and all the related departments to come with some ideas in order to prevent this landslide problem or at least lessen its side effect.

1.2 Problem statement

Previously, a landslide had been occurred in Universiti Teknologi PETRONAS (UTP) at the hilly area near Block 13. As shown in Figure 1.2 – 1.4, the landslide was not really dreadful but yet it was still significant to engineering field as if there are no further action taken, this tragedy might be happened again and may be next time the impact will be greater.

Figure 1.2. Right view of Landslide.

Figure 1.3. Front view of Landslide.

Figure 1.4. Left view of Landslide.

There are many factors contribute to the landslide such as rainfall, initial water table location, geometry of the slope, and etc. It was said that a few days before the accident was happened, there was raining all day long. So, there was a possibility that the landslide was caused by that antecedent rainfall. A research will be conducted to find out is there any relation between the rainfall (antecedent rainfall or rainfall amount) with the slope stability that has made the landslide to be occurred.

1.3 Objective and scope of study

The objective of this study is to examine the relation between antecedent rainfall or rainfall amount with the occurrence of the landslide near the Block 13 in Universiti Teknologi PETRONAS (UTP). This study will cover the collection of rainfall data, data modeling and rainfall analysis.

This study only covers the effect of the rainfall to the landslide without considering any other soil properties factors.

Chapter 2: Literature Review

As been mention before, rainfall is one of the major factor that can cause landslide to take place. But it is still confusing on what kind of rainfall that can really cause this incident. Although the correlation between rainfall and landslides is widely recognized, there has been some debate as to the relative roles of antecedent rainfall and the triggering rainfall.

In the scope of landslide study, the antecedent rainfall is referred to the rainfall in the days right away preceding a landslide event. The triggering rainfall meanwhile is referred to the rainfall that falls at the time that the landslide occurs.

There are already some researches have been made to see and prove the effect of the antecedent rainfall on the slope stability. The researches show that the landslide might be occurred due the amount of the rainfall during the event, the antecedent rainfall or even including both of the factors.

Earlier, according to Brand (1984) through the researches made by him in Hong Kong, it is suggested that the antecedent rainfall was not a major factor to lead the landslide. Most of the landslides happened due to the short duration rainfall with a very high intensity. It was found that the 70mm/h of rainfall intensity would be enough to cause landslides in Hong Kong and a significant number of failures could be expected if the rainfall exceed 100mm/day. The limited influence of antecedent rainfall on landslides in Hong Kong was due to the high permeability of the local soils (Brand, 1992).

In Papua New Guinea, landslides might be happened if the rainfall intensity exceeds 70mm/h, as being suggested by Murray and Olsen (1988) and most of the major landslides occurred after 24 hour rainfall of 125mm. Major incidents would not be expected to occur until the rainfall reaches or exceeds the intensity of 100mm/day.

Pitts (1985) also concluded that the effect of the antecedent rainfall toward the slope stability in Singapore was not too much significant.

However, Tan et al. (1987) re-examined Pitt's conclusions and suggested the otherwise; the antecedent rainfall could be significant in effecting the slope stability. Later, Chatterjea (1989) also came out with same conclusions. For the study case made by Wei et al. (1991) at Bukit Batok landslide in Singapore, it was found that the landslide occurred after a period of heavy rainfall but during the day of the landslide, there was no rainfall. This showed how the antecedent rainfall may affect the slope stability.

According to Rahardjo et al. (2001), the landslides that had occurred at Nanyang Technology University Campus in Singapore were due to the antecedent rainfall. From the investigation they made, it seemed that the antecedent rainfall during the five days before the event was significant in causing these landslides since other rainfall events of similar magnitude (but with less antecedent rainfall) did not cause landslides. In that study, any daily rainfall greater than 90mm must be followed by a 5-day antecedent rainfall exceeding 60mm first before it can initiate the landslides.

Unlike other researches, instead of using 5-day period, Lumb (1975) used a 15-day period to quantify antecedent rainfall for Hong Kong. It was still effective to prove the effect of the antecedent rainfall towards the slope stability. Later, the way he used was adopted by Tan et al for their study on the landslide in Singapore. However, Chartterjea (1989) suggested that such a long period might be inappropriate for the rainfall pattern in Singapore and he adopted a period of 5-days.

However, in the other research, also by Rahardjo et al. (2008), to identify the role of some controlling parameters (particularly the role of antecedent rainfall) in inducing instability of a homogenous soil slope, it is found that the significance of the antecedent rainfall depends on soil permeability. Yes, it is true that the effect of antecedent rainfall depends on soil permeability but for the investigation at area which have slightly same soil permeability; this parameter still can be considered as the main cause for the landslide.

By taking these journals as reference and main idea, a research will be done to identify the effect antecedent rainfall to the landslide that had happened at Universiti Teknologi PETRONAS (UTP) campus.

In engineering point of view, regardless the role of the soil permeability, the antecedent rainfall actually drives an increase in pore water pressures within the soil. This fluid pressure provides the block with buoyancy and later reducing the resistance to movement of the soil. It is happened when the slope fills with water. The fluid pressures then act down the slope as a result of groundwater flow to provide a hydraulic push and decrease the stability and further causing the landslide.

For examining the connection between antecedent rainfall or rainfall amount with the landslide occurrence, the rainfall data at the event area need first to be presented in graph. It is to ease the observation of the data.

The graph needs to be studied first and then identify the major storm events. If it is found that there is any daily rainfall that exceeds the rainfall record at day that the landslide was happened, but yet still produced no landslide, it means the landslide might be due to the antecedent rainfall. The accumulative rainfall for a certain period prior to a heavy-storm day also can be considered as the factor if the effect of antecedent rainfall can not be proven.

After the cause has been identified, further study on the soil properties also can be done to give more information about which types of soil might be affected to those factors.

Chapter 3: Methodology

Determination of the effect of the antecedent rainfall toward land slide is to be done. The researches will be made through the internet, books and reliable articles or journals to collect all available information concerning the topic on the effect of antecedent rainfall on the slope stability. The collections of technical details regarding various researches on the subject will be used to implement and accomplish this project within the timeframe given.

3.1 Project activities

This project will include the following activities:

3.1.1 Acquiring Rainfall Data

To do this investigation, a data of rainfall records at the landslide area, for 2 years period at least, is needed. The rainfall records from January 2007 through January 2009 will be studied to identify major storm event as the landslide is assumed to fail early in 2009. The rainfall data needs to be gathered from reliable source so that a convincing result can be produced. The data can be obtained from:

- Hydrology Department of Universiti Teknologi PETRONAS (UTP) Civil Engineering Department
- Department of Irrigation and Drainage Perak

However, those departments can only provide at most up to one week period of rainfall data. For longer period data requirement, it needs to be obtained from Hydrology and Water Resources of Department of Irrigation and Drainage Malaysia (DID).

The procedure of applying hydrological data from the DID is as follows;

1) The applicant is requested to fill in the appropriate application forms (Form DI.1 (see Appendix 1) or Form DI.2) which are available in the DID website, *http://h2o.water.gov.my*. It is recommended that applicant refers to DID station inventory in order to determine the stations and period of data availability required during the process of filling-up the form.

2) The applicant has to either fax the completed form to the given address or send it via E-mail.

3) The application usually will be approved in one week.

As there is no specific rain gauge station placed at the occurrence place, the rainfall data from the nearest rainfall stations are requested. There are seven rainfall stations located around Universiti Teknologi PETRONAS which are;

1) 4308092

2) 4409090

3) 4409091

4) 4409121

5) 4410120

6) 4410122

7) 4410123

There is possibility that there might be some data missing in the provided data from the DID. If this is happened, the estimation of the missing data needs to be calculated.

If it is given that the annual precipitation values, P_1, P_2, P_3, ..., P_m at neighbouring M stations 1, 2, 3, ..., M respectively, the missing annual precipitation P_x at a station X which is not included in the above M stations can be found by using some simple calculation.

If the normal annual precipitations at various stations are about 10% of the normal annual precipitation at station X, then arithmetic average procedure can be used to estimate the P_x.

$$P_x = \frac{1}{M}(P_1+P_2+\ldots+P_m)$$

If the normal precipitations vary significantly, then P_x is estimated by using *normal ratio method*, byweighing the precipitation at the various stations by the ratios of normal annual precipitations.

$$P_x = \frac{N_x}{M}[(P_1/N_1)+(P_2/N_2)+\ldots+(P_m/N_m)]$$

Beside the rainfall data, the date of the occurrence of the landslide also needs to be obtained. The date is very important in order to further this study. The detail can be obtained from the Property Management and Maintenance Department of Universiti Teknologi PETRONAS.

3.1.2 Modeling the Rainfall Records

After gathering the data from all those stations, the details will be modeled and presented by using hyetograph. According to K Subramanya, a hyetograph is a plot of the intensity of the rainfall against the time interval. It is usually represented as a bar chart. It is a very convenient way to show the characteristics of a storm.

Those data taken from the rain gauges actually only represent point sampling of the areal distribution of a storm. Thus, in order to convert the point rainfall values at the various stations into an average value over the catchment area, these three methods can be used;

1) Arithmetical-Mean Method
2) Theissen-Mean Method
3) Isohyetal Method

Arithmetical-Mean Method

This technique calculates areal precipitation using the arithmetic mean of all the point or areal measurements considered in the analysis. If P_1, P_2, …, P_i, …P_n are the rainfall values in a given period in N stations within a catchment, then way to calculate the value of the mean precipitation or the effective depth P_e over the catchment by the arithmetic-mean method is as follow;

1) Sum the precipitation (P) at each station (1 through n).

2) Divide the sum from (1) by the total number of stations (N). This will yield the effective depth of precipitation (P_e)

$$P_e = \frac{(P_1+P_2+\ldots+P_i+\ldots+P_n)}{N} = (1/N)\sum_{i=1}^{N} P_i$$

Theissen-Mean Method

This is another graphical technique which calculates station weights based on the relative areas of each measurement station in the Thiessen polygon network. The individual weights are multiplied by the station observation and the values are summed to obtain the areal average precipitation. The procedure of determining the weighing area is as follows;

1) Connect each station to each nearby station with a straight line. These lines cannot cross and should connect only the nearest stations. If done correctly, you will form several triangles.

2) Each leg of the triangles formed in (1) is then bisected with a perpendicular line, thus forming polygons around each station. Draw over the lines defining the polygons with a RED pencil to avoid confusing them with other lines you have drawn.

3) Using an appropriate method calculate the land area (A) represented by each polygon (1 through n) and record this area for each station.

4) Also calculate the total area (A_t).

5) Calculate the effective depth of precipitation (P_e) by the following formula:

$$P_e = \frac{P_1(A_1)+P_2(A_2)+......+P_n(A_n)}{A_1+A_2+......+A_n} = \sum_{i=1}^{N} P_i \frac{A_i}{A_t}$$

Isohyetal Method

This is a graphical technique which involves drawing estimated lines of equal rainfall over an area based on point measurements. The magnitude and extent of the resultant rainfall areas of coverage are then considered versus the area in question in order to estimate the areal precipitation value. The procedure of determining the effective depth of precipitation is as follows;

1) The measured precipitation is recorded next to each station.

2) Using these values, neatly construct (n) isohyetals lines (contour interval = 2").

3) Calculate the area (A) between adjacent isohyetal lines (1-2,2-3,...,(n-1)-n).

4) Also calculate the total area (A_t).

5) Calculate the effective depth of precipitation (P_e) by the following formula:

$$P_e = \frac{C_{1\text{-}2}(A_{1\text{-}2}) + C_{2\text{-}3}(A_{2\text{-}3}) + \ldots + C_{(n-1)\text{-}n}(A_{(n-1)\text{-}n})}{A_t}$$

where C = depth of precipitation represented by adjacent isohyetal lines (1-2,2-3,..., (n-1)-n)

3.1.3 Analyzing Data

The data in the hyetograph will then be observed and analyzed in details one by one. From the observation made, the result will show exactly either the antecedent rainfall really causes the failure of the slope or not.

Let say if it is found that there is any daily rainfall that exceeds the rainfall record at day that the landslide was happened, but yet still produced no landslide, it means there was possibility that the landslide was occurred due to the antecedent rainfall. The accumulative rainfall for a certain period prior to a heavy-storm day also can be considered as the factor if the effect of antecedent rainfall can not be proven.

3.2 Gantt Chart and Key Milestone

Table 3.1: Milestone for the First Semester of 2-Semester Final Year Project

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Selection of Project Topic	■	■														
	- Research on Topic																
	- Confirmation of Topic Selection																
2	Preliminary Research Work		■	■	■	■											
	- Literature review																
	- Identifying methods used																
3	Submission of Preliminary and Progress Report						●										
4	Project Work					■	■	■	■	■	■	■	■				
	- Acquiring Data																
6	Seminar of FYP 1								●								
7	Project work continue								■	■	■	■	■	■			
	- Acquiring Data																
8	Submission of Interim Report Final Draft														●		
9	Oral Presentation															●	
10	Submission of Interim Report																●

● Suggested milestone

■ Process

Table 3.2: Milestone for the Second Semester of 2-Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue	■	■	■	■	■	■	■							
	- Modeling Data														
2	Seminar (compulsory)				■		■								
3	Submission of Progress Report 1							●							
4	Project work continue								■	■	■	■			
	- Analyzing Data														
5	Poster Exhibition											●			
6	Submission of Dissertation (soft bound)												●		
7	Oral Presentation													●	
8	Submission of Project Dissertation (Hard Bound)														●

● Suggested milestone

■ Process

Chapter 4: Results and Discussion

From out of 7 the rainfall stations placed near the Universiti Teknologi PETRONAS (UTP), only 5 of them have the required details (daily rainfall data for 2007-2009) which are;

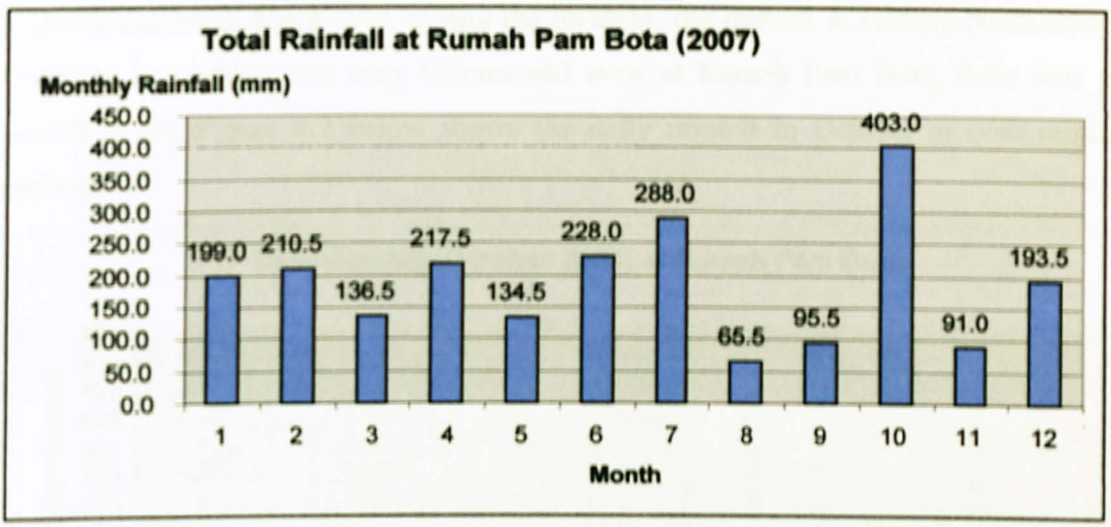
- *4309092 – Rumah Pam Bota*
- 4311001 – Pejabat Daerah Kampar
- 4409091 – Rumah Pam Kubang Haji
- *4409121 – Ladang Nalla*
- 4511111 – Politeknik Ungku Omar

And from these 5 stations, only the data from 2 stations have been picked to proceed with the project which are 4309092 and 4409121 as the location of the stations are the nearest one to the UTP. The daily rainfall data from those two stations are shown in the appendix section (Appendix 2).

As the landslide was occurred on 23rd October 2007 (according to Property Management and Maintenance Department of UTP), only data from year 2007 was taken into consideration to be studied and analyzed in order to identify the major storm events at the landslide spot as the result that produced by later data (2008 and 2009) will give no relative effect to this research.

After transferring all the rainfall data from Rumah Pam Bota and Ladang Nalla into proper table, the data then was analyzed in detail. The more specific data (such as daily rainfall data, monthly rainfall data, accumulative of 11-days rainfall data and so on) were calculated one by one and each results were plotted in hyetograph or bar chart. This is to ease the data analyzing process.

From the observation, it was found that the maximum monthly rainfall through out the year, at Rumah Pam Bota, was 403.0 mm in October while at Ladang Nalla was 350.0mm, also in October. From this fact, it can be assumed that the rainfall can be rated as one of the major factor for this landslide. The monthly rainfall records for 2007 at both stations are shown in Figure 4.1.



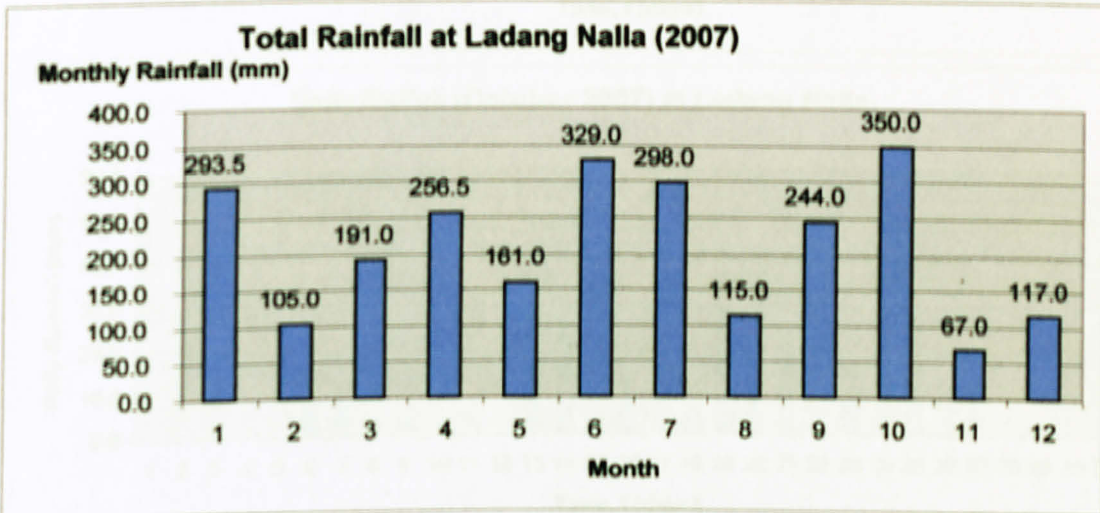


Figure 4.1. Monthly rainfall in 2007 at (a) Rumah Pam Bota (b) Ladang Nalla

During the period before the event took place which was on 23rd October, there were several days in which the daily rainfall exceeded 70mm; 4 days at Rumah Pam Bota, these were 83.5mm on 21st January, 113.0mm on 14th June, 103.0mm on 26th July and 79.0mm on 22nd October, while at Ladang Nalla, it got 2 days, 79.0mm on 15th January and 71.0mm on 23rd July.

Those rainfalls were sufficient to cause a landslide on those days but there was no landslide occurred. More over, during the incident, the rainfall at Ladang Nalla station was very low which was only 9.0mm and even at Rumah Pam Bota, there was no rainfall at all. Figure 4.2 below shows the daily rainfall in October at both rainfall stations.

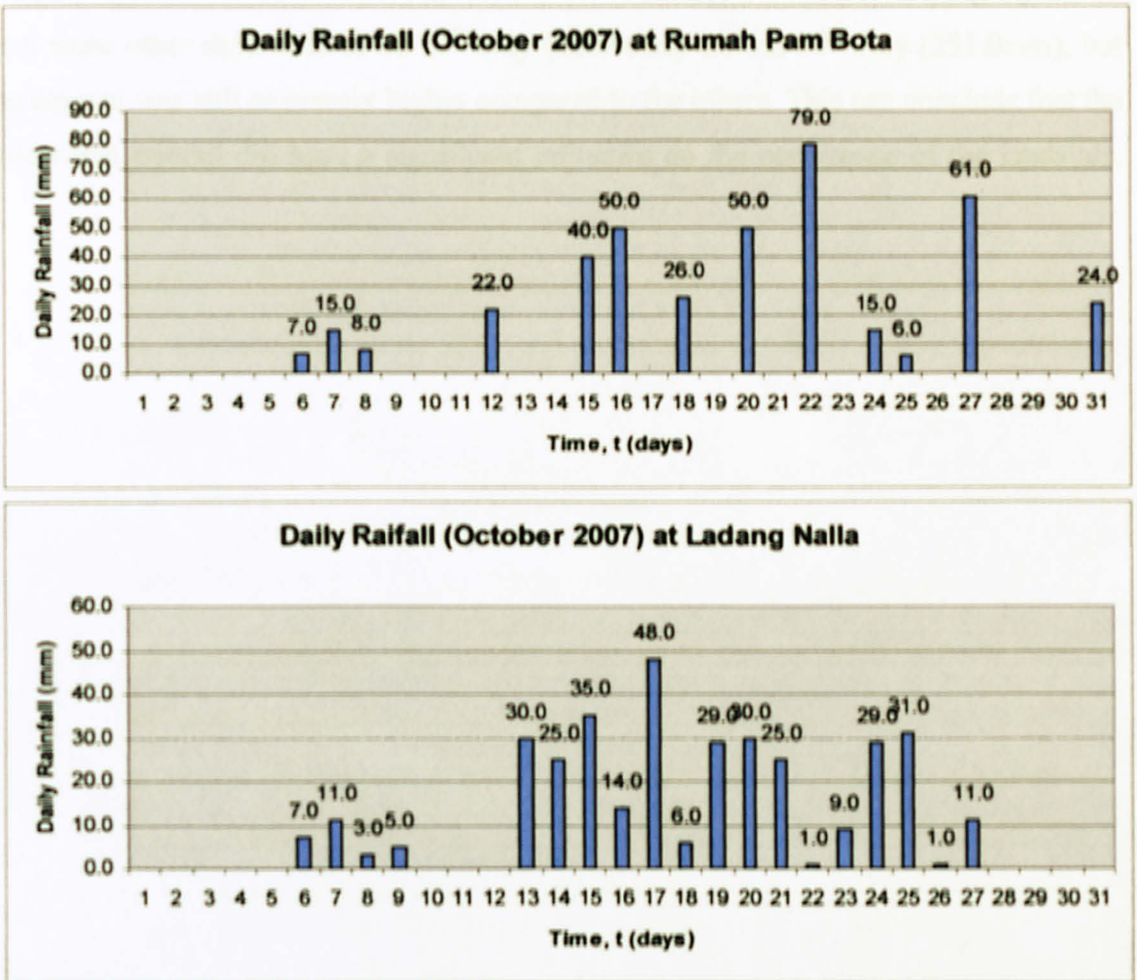


Figure 4.2. Daily rainfall data in October 2007 for (a) Rumah Pam Bota (b) Ladang Nalla

From the observation, it can be concluded that the landslide was not cause by the triggering rainfall. The landslide must be somehow due to the antecedent rainfall.

A data of accumulative rainfall had been made to find out the relation of the antecedent rainfall on the landslide and in this study case, the accumulation was taken up to 11 days. Figure 4.3 and 4.4 show the cumulative rainfall at Rumah Pam Bota and Ladang Nalla in three months which had highest monthly rainfall record through out the year which are June, July and October.

From the Figure 7, it clearly showed that 23rd October had the highest cumulative antecedent rainfall, 267.0mm, compared to the other days before that. At Ladang Nalla, even the cumulative antecedent rainfall on 23rd October, 243.0mm, was slightly lesser than some other days such as on 29th July (260.0mm) and on 30th July (251.0mm), but the amount was still extremely higher compared to the others. This can conclude that the antecedent rainfall did have a significant influence on the occurrence of the landslide.

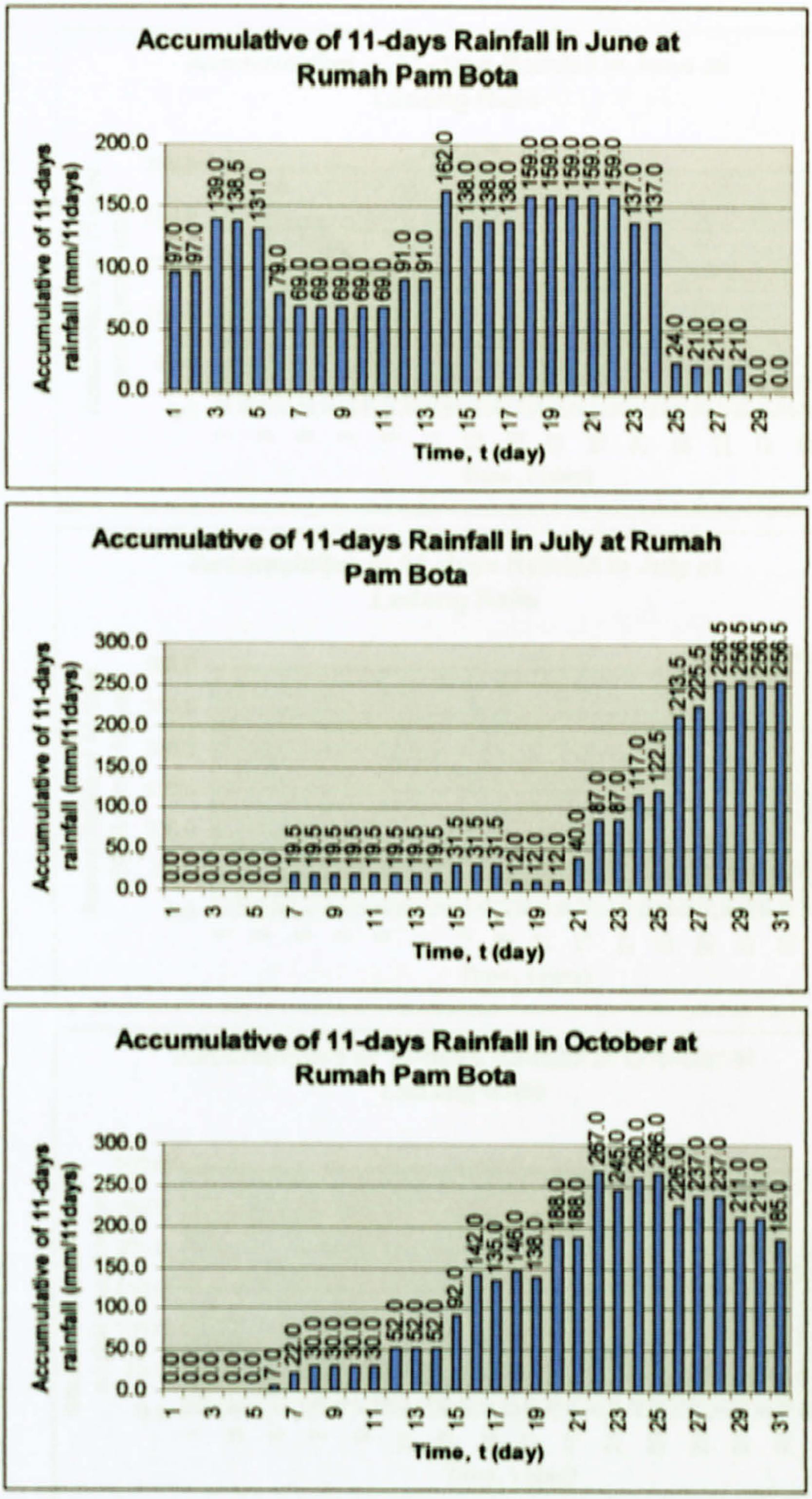


Figure 4.3. Accumulative of 11-days rainfall for the month of (a) June 2007 (b) July 2007 (c) October 2007 at Rumah Pam Bota.

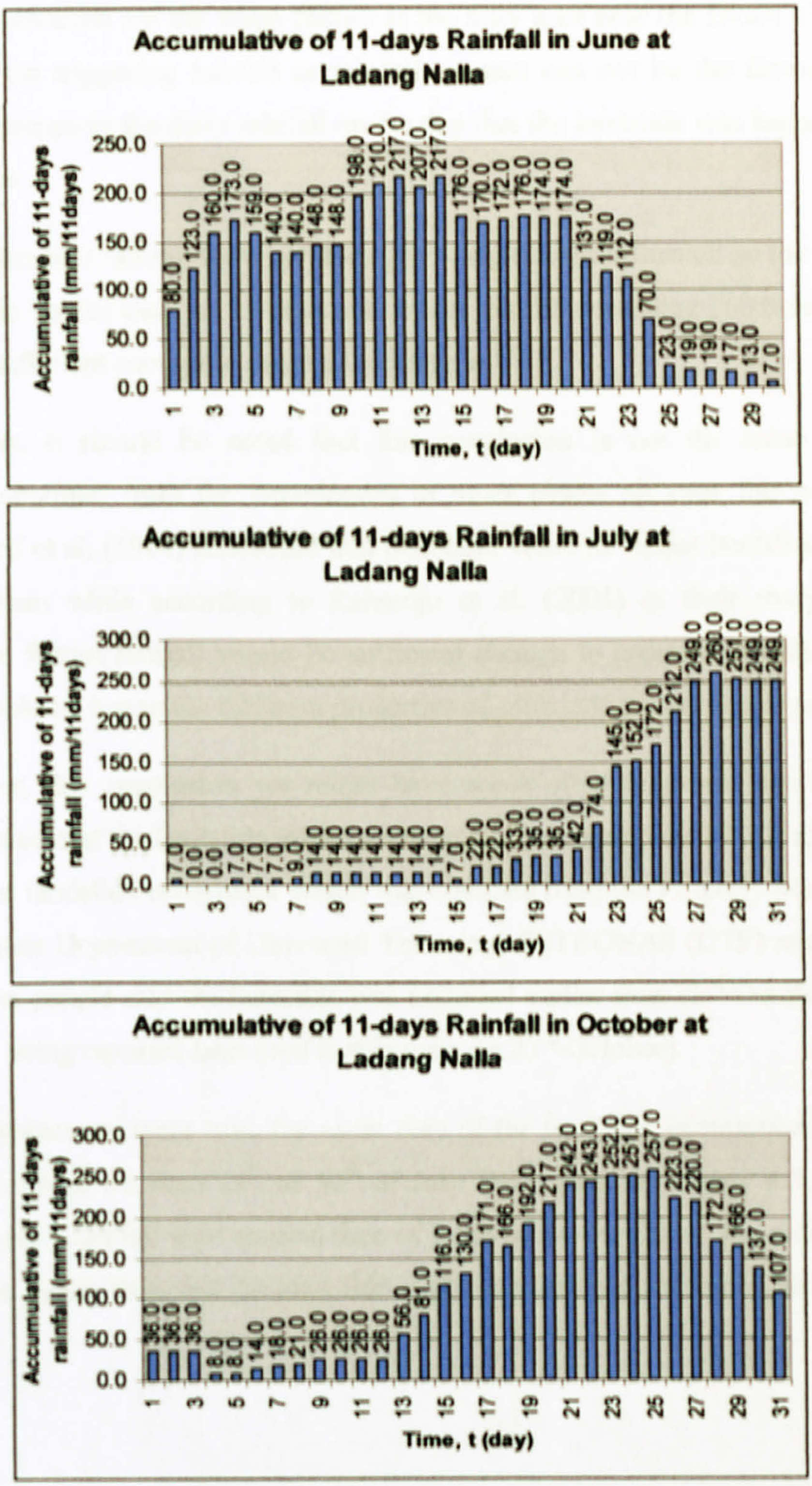


Figure 4.4. Accumulative of 11-days rainfall for the month of (a) June 2007 (b) July 2007 (c) October 2007 at Ladang Nalla.

This observation for the slope failure at the hilly area near the Block 13 in UTP suggests that the triggering rainfall or rainfall amount can not be the factor for this landslide occurrence as the daily rainfall on the day that the landslide was happened was totally very low.

The antecedent rainfall however does give a significant influence on the initiation of the landslide. In this case, an 11-days antecedent rainfall exceeding 260.0mm appears to have been sufficient enough to cause a landslide in UTP.

However, it should be noted that this conclusion is not the same as other observations obtained from the experiences in other places all over the world. For example, Brand et al. (1984) concluded that threshold value for major landslide in Hong Kong as 100mm while according to Rahardjo et al. (2001) in their study case in Singapore, the 90mm rainfall would be sufficient enough to create a landslide. These differences could be due to the different properties of soils in those particular areas.

However, this conclusion yet might have some other argument can be made. Some people said that the landslide might not be actually occurred on 23rd October 2007. The date of the landslide occurrence which was obtained from the Property Management and Maintenance Department of Universiti Teknologi PETRONAS (UTP) might not be accurate. Some people said the landslide was occurred earlier than 23rd October and the problem only being reported later (and in this case, on 23rd October).

If the statements were true, the exact date of the landslide occurrence should be laid on some where between 27th to 30th of July 2007. Base on Figure 4.5, most the highest antecedent rainfall with elapsed time of 1-day to 11-day fell on those dates. Thus there are some possibilities that the landslide might be actually occurred on those date.

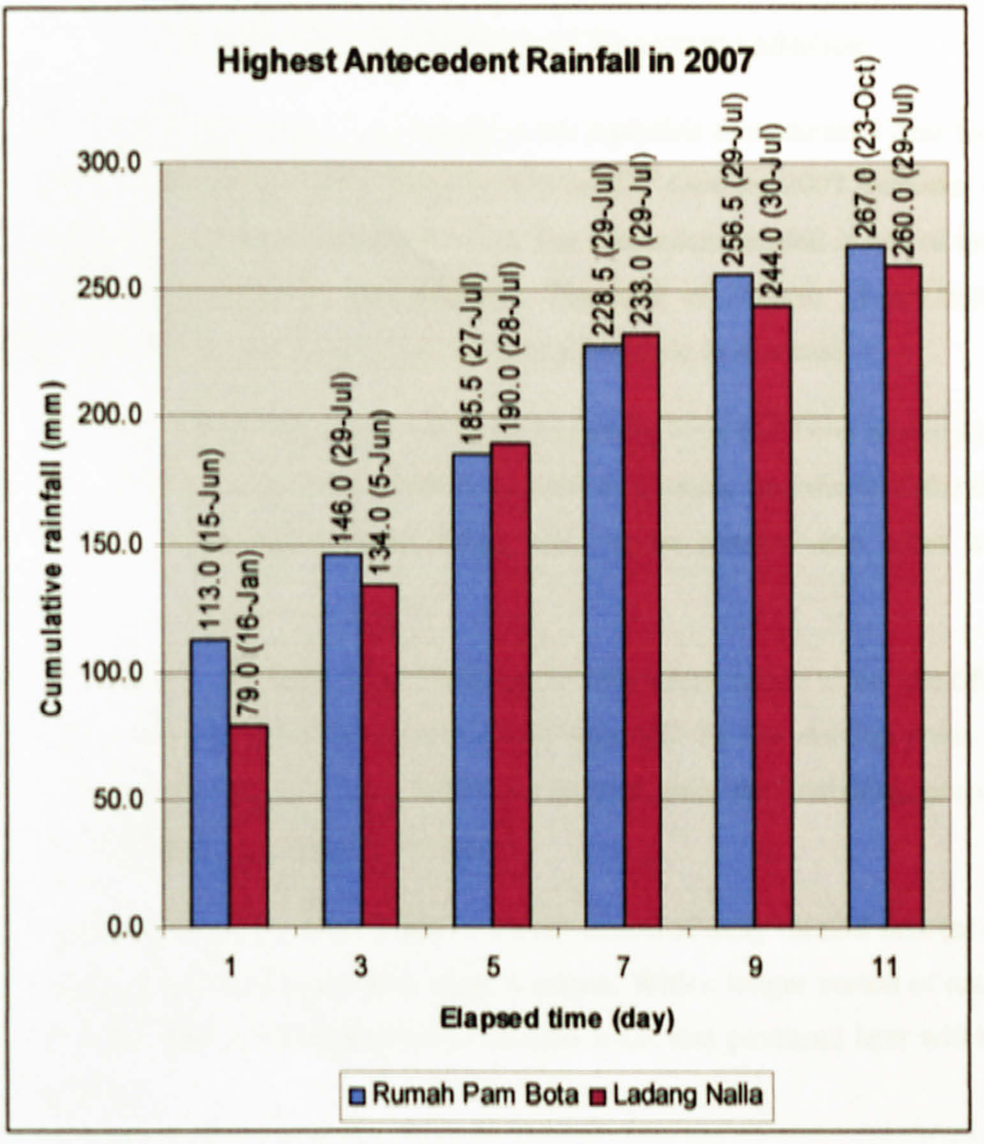


Figure 4.5. The highest antecedent rainfall with elapsed time of 1-day, 3-day, 5-day, 7-day, 9-day and 11-day at Rumah Pam Bota and Ladang Nalla through out of 2007.

Chapter 5: Conclusion and Recommendation

In the end of this study, the research on the landslide that occurred near the Block 13 in Universiti Teknologi PETRONAS (UTP) on 23rd October 2007 indicates that the landslide was initiated by antecedent rainfall. The antecedent rainfall is one of important factors for the occurrence of the landslide. The total of 260mm 11-day antecedent rainfall appears to have been sufficient to cause a landslide in this case.

However, in this study, there are some important keys had been missing or taken for granted which had leaded the result to be not too accurate. In order to make this kind of research more successful, those things need to be stressed and taken into full attention;

- Exact date of the landslide occurrence – This detail needs to be identified first before proceeding to other steps. This date will be the starting point to start analyzing the rainfall data. Without a certain date, the analyzing process will become harder and more complicated.

- Period of exanimate rainfall data – 2-year period of daily rainfall data (at least) is required to make the research more accurate. With a longer period of data, more analyzed data can be compared so that the result that produced later will be more reliable.

- Rainfall data type – The hourly rainfall data is the most preferable in order to conduct this kind of research. With the hourly data, the accuracy of the result will be higher.

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Appendices

	DOKUMEN KUALITI	NO. KELUARAN : 3
BAHAGIAN HIDROLOGI DAN SUMBER AIR		NO. PINDAAN : 0
	BORANG PEMBEKALAN DATA HIDROLOGI OLEH JABATAN PENGAIRAN DAN SALIRAN UNTUK PROJEK KERAJAAN / PENYELIDIKAN	TARIKH KUATKUASA : 01.04.08
BHSA-DK-DI.1		MUKA SURAT : 1 drpd. 1

FORM DI.1

1. **NAMA PEMOHON** (*Name of Applicant*) : MOHD ARIF B WAN MOHD DZULKIFLI
2. **No. Kad Pengenalan** (*I.C No.*) : 890203-03-5341
3. **JAWATAN RASMI** (*Official Designation*) : STUDENT
4. **ALAMAT RASMI** (*Official Address*) : LOT 716, KAMPUNG DAYA SETIA, PANTAI CAHAYA BULAN, 15350, KOTA BHARU, KELANTAN.
5. **NO. TELEFON DAN E-MEL** (*Telephone No. and E-mail Address*) : 019-9551240 / ritzy_pisces007@yahoo.com
6. **NAMA PROJEK** (*Name of Project*) : Effect of Antecedent Rainfall on Slope Stability
7. **LOKASI PROJEK** (*Location of Project*) : Universiti Teknologi PETRONAS (UTP), Tronoh, Perak.
8. **BUTIRAN DATA YG DI PERLUKAN** (*Details of Data Required*) :

Jenis dan Unit Data yg. Diperlukan/*Type and Units of Data Required*	No. Stesen atau Nama Stesen/*Station No. or Name of Station*	Tempoh Data yang diperlukan/*Period of Data Required*	Kegunaan Data/ *Proposed Use Of Data*
Daily rainfall data	Closest to UTP	1st January 2007 – 28th February 2009	Final Year Project

In the event of the above hydrological data being supplied by the Department of Irrigation and Drainage, I/we agree to comply with the following conditions:

(a) *that the data shall not be utilized for other project or study unless fresh application has been made to the D.I.D.*

(b) *that acknowledgement for the use of the data obtained from the D.I.D. will be suitably made in any report, paper or publication in which such data have been quoted or utilized and a copy of such report , paper on publication be extended to D.I.D. free of charge, on ……………*

(c) *that all application and receipt of any data must be through the Data Information Unit, Hydrology and Water Resources Division.*

(d) *that the data shall be ready for collection within one week from the date of application. In the event that such an arrangement cannot be met, the applicant will be notified through telephone or E-mail for a new date of collection.*

(e) *that the applicant shall collect the data within three months from the date of application. The applicant shall then be requested to make a fresh application there after.*

……………………………… (*Date of Application*)

……………………………… (*Signature of Applicant*)

Appendix 1: Form DI.1 (Application form for acquiring hydrological data for the use of government project, research or academic)

Appendix 2.1. Table of Daily Rainfall Data at Rumah Pam Bota for 2007

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	22.5	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.5	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	42.0	0.0	0.0	3.5	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	27.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0
7	18.0	0.0	0.0	0.0	0.0	0.0	19.5	0.0	15.0	15.0	11.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0
9	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	2.5	0.0	0.0	10.5
10	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	8.0	0.0	32.0	0.0	22.0	0.0	0.0	0.0	22.0	0.0	20.0
13	20.0	54.5	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	14.5	0.0	0.0	0.0	17.0	113.0	0.0	0.0	0.0	0.0	44.5	0.0
15	0.0	22.0	0.0	0.0	4.5	3.0	12.0	0.0	0.0	40.0	0.0	0.0
16	0.0	20.0	0.0	9.0	0.0	0.0	0.0	10.5	35.0	50.0	0.0	0.0
17	0.0	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	25.0	10.0	0.0	0.0	21.0	0.0	1.5	0.0	26.0	0.0	112.0
19	34.0	15.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	50.0	17.0	30.0
21	83.5	28.5	25.0	0.0	0.0	0.0	28.0	35.5	0.0	0.0	0.0	20.0
22	0.0	8.5	0.0	20.0	0.0	0.0	47.0	0.0	0.0	79.0	5.0	0.0
23	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	10.5	0.0	31.0	27.5	0.0	30.0	0.0	0.0	15.0	6.5	0.0
25	0.0	8.0	0.0	0.0	7.5	0.0	5.5	0.0	0.0	6.0	0.0	0.0
26	9.0	0.0	0.0	21.0	52.0	0.0	103.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	7.5	10.0	0.0	12.0	0.0	0.0	61.0	0.0	0.0
28	0.0	0.0	0.0	25.5	0.0	0.0	31.0	0.0	0.0	0.0	0.0	0.0
29	0.0		14.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0		40.0	8.5	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0
31	0.0		11.0		0.0		0.0	0.0		24.0		0.0
Total	199.0	210.5	136.5	217.5	134.5	228.0	288.0	65.5	95.5	403.0	91.0	193.5

Appendix 2.2. Table of Daily Rainfall Data at Rumah Pam Bota for 2008

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	25.0	0.0	0.0	0.0
2	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0
3	0.0	0.0	27.0	21.0	0.0	35.0	50.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	50.0	4.0	0.0	0.0
5	7.0	0.0	35.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5
6	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0
7	70.5	0.0	26.0	16.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0
8	81.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	25.5	5.5	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0
10	37.5	0.0	39.0	18.0	0.0	8.0	0.0	0.0	52.0	90.0	38.0	10.0
11	0.0	0.0	36.0	0.0	0.0	0.0	0.0	0.0	3.0	35.5	0.0	12.5
12	0.0	0.0	110.0	100.0	0.0	0.0	0.0	20.5	0.0	0.0	60.0	14.5
13	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	25.0	23.0	10.0
14	0.0	0.0	25.0	43.0	0.0	0.0	100.0	0.0	5.0	4.0	0.0	50.5
15	8.5	0.0	0.0	0.0	0.0	0.0	17.0	0.0	0.0	30.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	53.0	0.0
17	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	0.0
18	0.0	0.0	0.5	11.0	0.0	0.0	0.0	153.0	0.0	9.0	0.0	0.0
19	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0	41.0	0.0
20	0.0	0.0	6.0	0.0	0.0	0.0	37.0	6.5	0.0	42.0	0.0	0.0
21	0.0	0.0	0.0	7.5	0.0	0.0	41.0	18.0	0.0	47.5	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	75.0	0.0	16.0	0.0	9.5	43.0	8.0	4.5	0.0	0.0
24	0.0	55.0	17.5	0.0	0.0	0.0	7.0	13.0	0.0	3.0	28.0	50.0
25	0.0	0.0	40.5	0.0	0.0	0.0	0.0	14.0	0.0	0.0	25.0	0.0
26	0.0	0.0	0.0	0.0	12.0	0.0	0.0	32.5	4.5	0.0	59.5	0.0
27	79.0	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	20.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
29	0.0	0.0	0.0	0.0	0.0	52.0	0.0	5.0	0.0	0.0	0.0	43.0
30	0.0		0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0		45.5		0.0		0.0	12.0		0.0		0.0
Total	303.5	110.0	487.0	268.0	53.0	119.5	261.5	317.5	173.0	385.0	338.5	221.0

Appendix 2.3. Table of Daily Rainfall Data at Rumah Pam Bota for 2009

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	17.0										
2	0.0	0.0										
3	0.0	0.0										
4	0.0	0.0										
5	12.0	0.0										
6	0.0	0.0										
7	0.0	0.0										
8	13.0	0.0										
9	0.0	0.0										
10	0.0	0.0										
11	0.0	0.0										
12	0.0	0.0										
13	0.0	0.0										
14	39.0	0.0										
15	0.0	0.0										
16	0.0	0.0										
17	21.0	7.0										
18	0.0	0.0										
19	0.0	0.0										
20	0.0	20.0										
21	0.0	0.0										
22	15.0	15.0										
23	0.0	0.0										
24	0.0	12.5										
25	13.0	7.0										
26	0.0	5.0										
27	0.0	0.0										
28	0.0	21.0										
29	0.0											
30	0.0											
31	0.0											
Total	113.0	104.5										

Appendix 3.1. Table of Daily Rainfall Data at Ladang Nalla for 2007

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	46.0	43.0	0.0	0.0	0.0	0.0	48.0	0.0	0.0	6.0
2	0.0	0.0	0.0	0.0	0.0	52.0	0.0	0.0	56.0	0.0	10.0	0.0
3	0.0	0.0	0.0	0.0	0.0	37.0	0.0	0.0	4.0	0.0	0.0	0.0
4	0.0	0.0	0.0	8.0	0.0	45.0	7.0	0.0	1.0	0.0	0.0	0.0
5	0.0	0.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	3.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0
7	20.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	19.0	11.0	3.0	10.0
8	2.0	0.0	0.0	0.0	0.0	8.0	5.0	0.0	3.0	3.0	6.0	4.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.0	0.0	0.0
10	9.0	0.0	0.0	0.0	14.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
11	18.5	0.0	0.0	1.0	5.0	12.0	0.0	0.0	0.0	0.0	5.0	14.0
12	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	16.0
13	2.0	8.0	6.0	34.0	18.0	42.0	0.0	0.0	37.0	30.0	6.0	10.0
14	0.0	47.0	12.0	30.0	23.0	47.0	0.0	0.0	13.0	25.0	0.0	14.0
15	79.0	0.0	6.0	0.0	5.0	4.0	0.0	0.0	0.0	35.0	3.0	0.0
16	0.0	0.0	1.0	15.0	0.0	0.0	15.0	14.0	25.0	14.0	0.0	0.0
17	0.0	0.0	33.0	0.0	0.0	2.0	0.0	49.0	0.0	48.0	0.0	5.0
18	6.0	0.0	0.0	0.0	0.0	4.0	13.0	0.0	0.0	6.0	20.0	0.0
19	12.0	0.0	4.0	0.0	0.0	6.0	7.0	0.0	0.0	29.0	10.0	3.0
20	16.0	24.0	6.0	10.5	16.0	0.0	0.0	5.0	0.0	30.0	1.0	0.0
21	61.0	0.0	3.0	7.0	0.0	7.0	7.0	7.0	0.0	25.0	0.0	29.0
22	23.0	0.0	6.0	7.0	9.0	0.0	32.0	14.0	0.0	1.0	0.0	0.0
23	0.0	10.0	2.0	10.0	0.0	0.0	71.0	0.0	28.0	9.0	0.0	0.0
24	29.0	3.0	0.0	4.0	32.0	0.0	7.0	25.0	0.0	29.0	0.0	0.0
25	13.0	1.0	0.0	5.0	20.0	0.0	20.0	0.0	1.0	31.0	0.0	6.0
26	0.0	0.0	1.0	13.0	19.0	0.0	40.0	1.0	7.0	1.0	0.0	0.0
27	3.0	0.0	0.0	68.0	0.0	0.0	52.0	0.0	0.0	11.0	0.0	0.0
28	0.0	12.0	0.0	1.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0
29	0.0		28.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
30	0.0		13.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0
31	0.0		23.0		0.0		0.0	0.0		0.0		0.0
Total	293.5	105.0	191.0	256.5	161.0	329.0	298.0	115.0	244.0	350.0	67.0	117.0

Appendix 3.2. Table of Daily Rainfall Data at Ladang Nalla for 2008

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	4.0	30.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	0.0
2	0.0	0.0	10.0	16.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
3	0.0	15.0	2.0	21.0	0.0	3.0	0.0	0.0	112.0	0.0	0.0	0.0
4	0.0	2.0	21.0	12.0	0.0	25.0	40.0	0.0	3.0	0.0	0.0	0.0
5	0.0	4.0	0.0	8.0	0.0	5.0	0.0	12.0	0.0	19.0	0.0	14.0
6	0.0	18.0	45.0	30.0	0.0	10.0	0.0	0.0	23.0	0.0	0.0	6.0
7	58.0	0.0	3.0	6.0	0.0	10.0	0.0	0.0	0.0	7.0	0.0	2.0
8	15.0	0.0	3.0	0.0	0.0	0.0	2.0	0.0	0.0	56.0	0.0	33.0
9	40.0	0.0	22.0	0.0	0.0	14.0	6.0	2.0	6.0	16.0	11.0	0.0
10	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0
11	0.0	0.0	3.0	16.0	0.0	8.0	18.0	0.0	33.0	21.0	0.0	0.0
12	0.0	0.0	43.0	13.0	0.0	0.0	33.0	0.0	1.0	45.0	0.0	0.0
13	0.0	0.0	56.0	17.0	0.0	0.0	58.0	0.0	0.0	0.0	18.0	5.0
14	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	30.0	0.0
15	0.0	10.0	0.0	7.0	0.0	0.0	13.0	0.0	0.0	11.0	7.0	30.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0	32.0	9.0
17	0.0	25.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	25.0
18	5.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	78.0	0.0
19	5.0	4.0	19.0	0.0	19.0	3.0	0.0	0.0	0.0	6.0	0.0	8.0
20	3.0	0.0	16.0	7.0	0.0	2.0	0.0	135.0	0.0	19.0	34.0	0.0
21	2.0	0.0	0.0	20.0	0.0	0.0	26.0	3.0	0.0	21.0	0.0	0.0
22	0.0	0.0	35.0	0.0	1.0	0.0	1.0	20.0	0.0	15.0	37.0	0.0
23	0.0	0.0	28.0	7.0	0.0	4.0	0.0	0.0	0.0	3.0	15.0	0.0
24	0.0	0.0	30.0	0.0	28.0	2.0	51.0	21.0	0.0	3.0	5.0	0.0
25	48.0	0.0	14.0	4.0	4.0	0.0	9.0	30.0	0.0	4.0	6.0	0.0
26	0.0	0.0	37.0	0.0	1.0	0.0	0.0	3.0	0.0	0.0	3.0	0.0
27	0.0	0.0	41.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0
28	20.0	72.0	0.0	0.0	0.0	0.0	0.0	58.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0
30	5.0		3.0	0.0	0.0	10.0	0.0	0.0	15.0	4.0	0.0	3.0
31	0.0		4.0		22.0		0.0	20.0		0.0		8.0
Total	201.0	160.0	443.0	218.0	75.0	96.0	273.0	319.0	193.0	342.0	276.0	162.0

Appendix 3.2. Table of Daily Rainfall Data at Ladang Nalla for 2008

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5.0	0.0										
2	2.0	6.0										
3	15.0	0.0										
4	0.0	0.0										
5	3.0	16.0										
6	0.0	36.0										
7	0.0	5.0										
8	0.0	0.0										
9	23.0	0.0										
10	0.0	0.0										
11	0.0	0.0										
12	0.0	15.0										
13	0.0	0.0										
14	10.0	0.0										
15	22.0	0.0										
16	0.0	0.0										
17	0.0	10.0										
18	42.0	0.0										
19	2.0	15.0										
20	0.0	0.0										
21	0.0	0.0										
22	22.0	20.0										
23	0.0	0.0										
24	0.0	35.0										
25	4.0	35.0										
26	0.0	2.0										
27	5.0	5.0										
28	5.0	2.0										
29	0.0											
30	0.0											
31	8.0											
Total	168.0	202.0										