Assessment of Landscape Characteristics on Spatial Distribution of Soil Moisture Index

by

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19192

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons.)
(Civil)

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Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering programme
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In partial fulfilment of the requirement for
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(CIVIL)

Approved by,

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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.

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(FAIZ HASHEMI BIN MD ADROS)

ABSTRACT

Water content of soil is what defines soil moisture, which is held in between the voids of the particles of soil and it plays an important role in the assessment of different components of water and energy balance. Soil moisture acts as the utmost source of water for purposes such as agriculture, and vegetation of natural plants, which influences a number of vital processes including the growth of plants, production in agriculture and a number of soil processes. The dynamics of soil moisture can be modified by a number of factors such as climate change, properties of soil, topography, and the characteristics of the landscape itself. In this study, the author is aiming to find the relationship between two main parameters, which are the distribution of soil moisture and how it is affected by the variation of landscape characteristics.

New approaches and techniques for monitoring and modelling of soil moisture data has been developed. For this research, the author utilized remotely sensed data by satellite imagery (Landsat-8), in order to capture and analyze the soil moisture distribution, in the site of Cameron Highlands. Accordingly, the landscape characteristics of the site were gathered as well, by utilizing the Digital Elevation Model (DEM). After all of the required data has been gathered, the analysis of the two main parameters was conducted using the Geographical Information System (GIS) software, in order to achieve the main aim of the study which is to assess on how the landscape characteristics affect the spatial distribution of soil moisture, at the site of Cameron Highlands.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Soil moisture governs the partitioning of the mass and energy fluxes between the land and atmosphere, thus playing a key role in the assessment of the different components of water and energy balance. To name a few, soil moisture is an important variable for flood and landslide modelling and prediction, drought assessment and forecasting, numerical weather prediction, etc. It is also water source for plants and, hence, its knowledge is required for irrigation management and agricultural studies (Brocca et al., 2017). The scientific community has well recognized the very important roles of soil moisture in earth science applications. Hence, new approaches and techniques for monitoring, modelling and using soil moisture data have been developed.

A landscape is part of the earth's surface. It consists of a variety of geographical features that describes the characteristic of an area. Landscapes are divided into two main categories, which are natural and human (Easton, 2013). Natural landscapes are mainly unaffected by human activities and typical to particular areas of the world. Human landscapes are defined by the land that have been created and modified by people and it is also referred to as cultural landscapes.

At the site of Cameron Highlands, in which the author conducted the study, it is located in Pahang, at the north- western corner of the state. It is one of the most popular hill resorts in the country. This highland still retains much of the charm as a lovely place to visit. Although massive development in the last decades has changed the landscape of the highlands. It still remains as a popular destination for those who wanting to escape the hot weather of the lowlands. Being the primary agricultural region of the nation, visitors will find an abundance of vegetable farms dotted all over Cameron Highlands. It is also known as the leading producer of various flowers and plants in Malaysia.

In terms of the landscape characteristics, Cameron Highlands consists of both natural and human landscapes. The natural landscape of the site can be seen with its mountains, rivers, and rich tropical rainforest. On the other hand, human landscape is evident through the development and urbanization of the area, mainly for human settlement and agricultural purposes, such as buildings, houses, roads and plantation farms.

Hence, in this assessment, the author would like to explore more on how the various landscape characteristics can affect the spatial distribution of soil moisture. As stated by Qiu et al. (2001), there are some studies that indicate the distribution of soil moisture is influenced by a few factors, such as land use, slope gradient, slope position and relative elevation. In the case of increasing-type of profile distribution, in which the soil moisture will increase when going deeper into the soil, it is mainly affected by the type of land use. The variability becomes more evident when topography is also in the equation (Qiu et al., 2001).

FIGURE 1.1 (1): Scenery of a tea plantation in Cameron Highlands

1.2 Problem Statement

Cameron Highlands is widely known for attraction for local and international tourists, mainly for its undisturbed natural landscapes and mountainous views. Besides, the location is also home to various agricultural plantations such as tea and strawberries. But, by recent rapid development in the study area, Cameron Highlands' landscape has been disturbed by such activities. Continued urbanization has resulted in disturbance of natural landscape characteristics of the site. When any natural landscape goes through this process of development, land surface characteristics such as vegetation cover or land use/land cover (LULC), are modified and altered (Khandelwal et al., 2016). This also affects several soil properties, especially in this case, affects the soil moisture content.

In estimating the soil moisture, size of the study area affects the whole process of estimating the soil parameter. Cameron Highlands which is relatively very large in size, processes involved in the estimation of soil moisture will be quite difficult as there is large area to be covered. Also, heterogeneity of land types and characteristics distributed across the study area hindered easy assessment. Furthermore, mountainous in nature of the area could introduce great errors when interpolation methods is employed for ground based soil moisture assessment. As a results, remote sensing techniques will be adequate for soil moisture assessment.

Apart from that, as Cameron Highlands is located in relatively higher elevation as compared to its surrounding areas, the area is prone to natural hazards and occurrences, such as soil erosion and landslide. In a study conducted by Ray et al., (2010), they stated that the increase of soil moisture will cause a decrease in the slope stability. When there is too much moisture in the soil, it will loosen up the interconnectivity strength of the soil particles, of which can lead to unwanted circumstances of landslide and soil erosion, threatening the safety of the people within the involved area. Hence, by collecting remotely sensed soil moisture data, it can provide updates of slope conditions, which will be necessary for hazard predictions.

1.3 Objectives and Scope of Study

In this assessment of landscape characteristics on spatial distribution of soil moisture, the following the specific objectives to achieve the aim of the study:

1. To evaluate various types of landscape characteristics in Cameron Highlands.
2. To determine the soil moisture content of the site area, through the utilization of remote sensing and Geographical Information System (GIS) techniques.
3. To assess effects of variation of landscape characteristics on spatial distribution of soil moisture.

Apart from that, in order for the author to achieve the objectives set as mentioned above, the author is bounded within the following scope of study:

1. The landscape characteristics that will be identified are within the site of Cameron Highlands only, excluding any other surrounding areas.
2. In gathering the data for the soil moisture, the only method that will be utilized is by remote sensing, without using any other methods available.
3. The relationship between the soil moisture distributions with respect to the landscape characteristics of the site, will only be analyzed with a Geographical Information System (GIS) software, ArcGIS.

CHAPTER 2

LITERATURE REVIEW

2.1 Preamble

For this assessment, the author would like to identify the effect of various landscape characteristics on the spatial distribution of soil moisture. As stated by Qiu et al. (2001), there are some studies that indicate the distribution of soil moisture is influenced by a few factors, such as land use, slope gradient, slope position and relative elevation, which can be classified as several characteristics of the landscape. Hence, the author have reviewed and gone through a number of past studies and researches, in order to get to know more on the details of the involved topic.

2.1.1 Role of Soil Moisture

The water content of soil is what defines soil moisture, which is held in between the voids of the particles of soil (Dobriyal, Qureshi, Badola, & Hussain, 2012). In the hydrological cycle, the soil moisture is one of the important parameter that modulate the land surface-atmosphere interactions, which affects the condition of weather and climate. Soil moisture acts as the utmost source of water for purposes such as agriculture, and vegetation of natural plants, which influences a number of vital processes including the growth of plants, production in agriculture and a number of soil processes. According to Escorihuela and Quintana-Seguí (2016), soil moisture act as a fundamental parameter in a number of tangible processes pertinent to agriculture, hydrology, meteorology, or climatology. From the findings of Jia et al. (2017), the dynamics of soil moisture can be modified by a number of factors such as climate change, properties of soil, topography, and the characteristics of the land use/land cover.

2.1.2 Remote Sensing Application for Soil Moisture Assessment

Soil moisture is a variable that is occasionally observed in situ, hence, the time evolution and the spatial structure of the soil moisture data is lackadaisical. Because of this restriction, method of remote sensing has been utilized to mitigate the problem faced (Escorihuela & Quintana-Seguí, 2016). As highlighted by Dobriyal et al. (2012), remote sensing techniques involve the usage of satellites, radar/microwaves, and active and passive sensors. Remote sensing allows for an alternative way of obtaining soil properties in a short period of time. For sensing soil moisture remotely, the whole electromagnetic spectrum is used, but only the microwave region is suitable to be utilized for quantitative measurements. According to Brocca, et al. (2017), remote sensing technique is the most suitable for a large scale measurement of soil moisture distribution. Even though the remote sensing method is complex but it is cost effective and not as tedious as field measurement. This is because other methods of estimation only provide measurement at a point, which represents only a small volume of soil. Even though the point measurement is more precise and accurate, the result that is obtained from it will be lacking in terms of its spatial representation. Applicability of remote sensing has been on increase due to the availability of low to moderate resolutions of satellite data.

At this moment, as stated by Brocca et al. (2017), there are several coarse resolution, satellite surface soil moisture products that are available, either in near real time (NRT) or few days after sensing, which are:

1. Soil Moisture Active and Passive (SMAP) mission (L-band radiometer), starting from April 2015 with approximately 36 km/2-day spatial/temporal resolution.
2. Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the Global Change Observation Mission forWater, GCOM-W, satellite (C- and X-band radiometers) starting from July 2012 with approximately 25 km/1-day spatial/temporal resolution.
3. Soil Moisture and Ocean Salinity (SMOS) mission product (L-band radiometer) starting from January 2010 with approximately 50 km/2-day spatial/temporal resolution.

4. Advanced SCATterometer (ASCAT) onboard Metop-A and Metop-B satellites (C-band scatterometer) starting from January 2007 with approximately 25 km/1-day spatial/temporal resolution.

The available satellite missions for remote sensing as listed above can be proved by Escorihuela & Quintana-Seguí, (2016), as their research in comparing the remote sensing datasets utilizes three of the soil misture products as above, which are AMSR, SMOS, and ASCAT. The AMSR, is multi channel passive microwave instrument which functions to measure the brightness temperatures at five frequencies. As demonstrated in their findings, the performance of AMSR soil moisture has shown to be good in a number of studies. For the SMOS, it is designed to observe soil moisture over the Earth’s landmasses and salinity of the oceans. Its products are observations which are multiangular, of the brightness temperature which are then used obtain the soil moisture and vegetation optical depth. Next, for the ASCAT, its main purpose was to allow measurements of sea surface wind vector, but as demonstrated by Escorihuela & Quintana-Seguí, (2016), the scatterometer is also capable of measuring large scale soil moisture. The product of soil moisture is captured from the backscattering coefficients of the radar, measured by the ASCAT through the method of change detection.

In order to validate whether the data obtained for the remotely sensed soil moisture is reliable and accurate for different types of landscape characteristics, Escorihuela & Quintana-Seguí, (2016) have utilized several remotely sensed soil moisture products and compared the data with a land surface modelling data, which simulated the soil moisture at the site. The data for the soil moisture from the remote sensing estimation method are obtained in land cover classes such as dry-lands, irrigated crops, forests and grass shrubs or natural vegetation. For the SMOS product, it has problems when the sensed area is close to the sea and if the area has a steep relief. But, when it is used for crops and natural landscape areas with a decent performance. Apart from that, for ASCAT, the data obtained has low correlation with the land simulated data when topography is the important feature of the area. In cultivated areas, data obtained from ASMR has better correlation when compared with the simulated soil moisture data, which is comparatively better than SMOS.

In another study, a new approach is suggested for estimating soil moisture content, capitilizing on the strengths of multispectral satellite imagery. A soil moisture index, the Perpendicular Soil Moisture Index (PSMI) is proposed, and it is evaluated using raw image digital count (DC) data, in the red, near-infrared, and thermal infrared spectral bands (Shafian & Maas, 2015). To test this approach, the authors had measured soil moisture in 18 agricultural fields in the semi-arid Texas High Plains for over two years period, and compared them to corresponding PSMI values determined from Landsat image data. In the end, the results showed that PSMI was having strong correlation with observed soil moisture. From there, it was further demonstrated that maps of PSMI developed from the Landsat imagery, could be constructed to show the relative spatial distribution of soil moisture across a specific region.

2.1.3 Soil Moisture in Various Landscapes

In North China, specifically in Loess Plateau, it is known that the area suffered mostly from erosion of soil. To mitigate the problem, campaign for afforestation has been greatly promoted by the government of China. Referring to images of remote sensing, the cover of vegetation in the region of Loess Plateau has hiked from 31.6% in 1999, to 59.6% in 2013 (Jia et al., 2017). But, the cause for more plantation of trees has initiated the scarcity of water supply. As afforestation is done in the area, the shortage of water has aggravated simultaneously, which led to formation of dry soil layers at some point of the area.

In another study of soil moisture in the same region of Loess Plateau, the idea of vegetation cover causing water shortage in the area is supported by Jia et al. (2013). According to them, slope in the area, which is called loessial slopes, has soil moisture profile which deteriorates by the effect of cultivation cover. In their study, they have taken four plots in the region which differs by vegetation type. From this, they have conducted a long term monitoring and identified the trend of the soil moisture distribution, across the assigned four plots of area. In conclusion, the trend of soil moisture distribution in the horizontal manner is quite similar, while the distribution of soil moisture along the vertical manner has some different trend, showing the changes of moisture content as the depth of soil differs.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The assessment of landscape characteristics on spatial distribution of soil moisture was carried out using the research methodology, as described below. Figure 3.1 is the representation of each step of the methodology, in order to achieve the aim and objectives of the study.

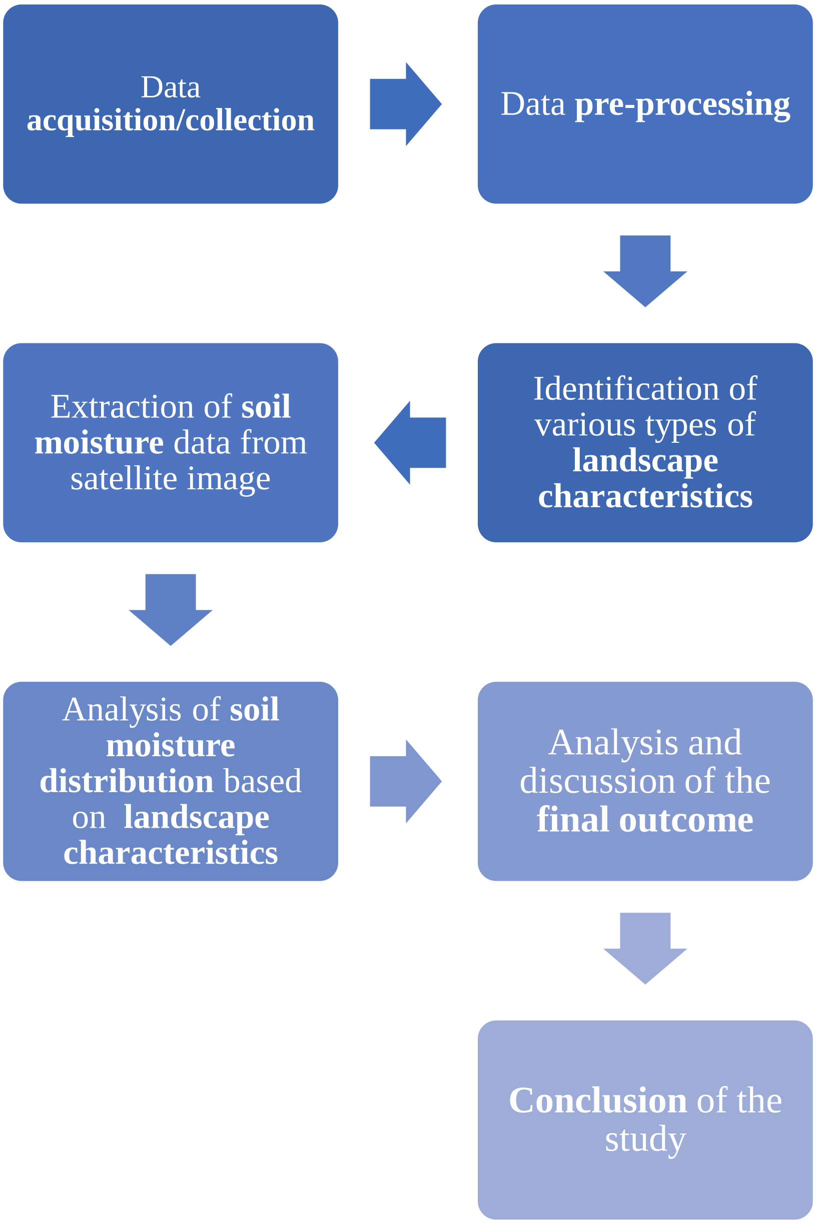

FIGURE 3.1 (1): Stages of research methodology

3.1.1 Data Acquisition/Collection

In order to begin the assessment, the author started with the process of getting all the required raw data. In this study, the data required are the Landsat images and the Digital Elevation Model (DEM) of the Cameron Highlands site.

As per the methodology proposed for this project, first and foremost, the raw data that is required for the later proceedings is collected and acquired before going any further into the project. The raw data that is required for this assessment is consist of the satellite images of Landsat-8 and the Digital Elevation Model (DEM) for the site of Cameron Highlands. For the satellite images of Landsat-8, the data is easily accessible by the public through the website of United States Geological Survey (USGS). In this assessment, the distribution of the soil moisture index by the changes in the landscape characteristics of the site is monitored within two specific periods in the year of 2016, which are during the dry and wet season of the particular year. This is done to ensure that the data obtained is reliable for all climate condition or changes that occur throughout the year. In determining the specific time of which both of the seasons actually occur, rainfall data of Cameron Highlands which is obtained from the website of Jabatan Pengairan dan Saliran (JPS) is used as the reference. The month of which the highest rainfall intensity was recorded is chosen as the wet season while the month that observed the lowest rainfall is taken as the dry period of the year.

Daily totals Year 2016 site 4513033 GUNONG BRINCHANG at C. HIGHLANDS, PAHANG
Rain mm

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	13.0	0.0	0.0	4.0	0.0	0.0	?	0.0	13.0	0.0	?	14.0	
2	1.5	7.0	0.5	0.0	0.0	22.5	0.0	0.0	23.0	1.5	2.0	11.0	
3	0.0	?	0.0	0.0	0.0	8.0	0.0	0.0	18.0	3.0	53.0	1.0	
4	0.5	17.5	12.0	?	7.5	0.0	0.0	?	20.5	1.0	6.0	1.0	
5	0.0	9.0	0.0	?	8.5	3.5	0.0	?	0.5	7.0	2.0	?	
6	0.0	23.5	0.0	0.0	6.5	32.5	0.5	0.0	0.5	3.0	0.0	?	
7	0.0	12.5	0.0	0.0	17.0	?	5.0	0.0	1.0	10.5	5.0	0.0	
8	0.0	0.0	?	0.0	?	?	0.5	0.0	2.0	0.0	10.0	0.5	
9	0.0	0.0	?	0.0	?	0.0	21.0	32.5	?	22.0	7.0	53.0	
10	?	0.0	0.0	5.5	34.0	0.0	2.0	4.0	0.5	43.5	24.5	11.5	
11	?	3.5	0.0	0.5	12.5	6.5	0.5	11.0	0.0	?	5.0	4.0	
12	0.0	4.5	0.0	0.0	18.5	28.0	0.0	0.0	0.0	0.5	1.0	0.5	
13	11.0	32.0	0.0	0.0	13.5	0.0	0.0	1.5	0.0	1.0	1.0	0.0	
14	0.5	0.5	0.0	0.0	19.5	0.0	0.0	0.0	0.0	2.5	10.0	0.0	
15	3.0	1.0	0.0	3.0	21.5	0.5	25.0	0.0	0.5	13.5	0.0	0.0	
16	10.5	0.5	0.0	9.5	3.5	5.5	22.5	0.0	0.5	21.0	1.5	4.5	
17	9.0	0.0	0.0	1.5	13.5	4.5	26.0	2.5	0.0	0.5	16.0	0.5	
18	1.0	4.5	0.0	4.5	5.0	3.5	24.0	0.0	0.5	0.0	7.0	7.0	
19	0.0	3.0	0.0	0.0	12.0	14.5	0.5	2.5	1.5	0.0	77.5	9.5	
20	0.0	0.0	3.5	0.0	8.5	0.5	7.0	1.0	3.5	1.0	10.5	5.0	
21	0.0	0.0	0.5	9.5	2.0	0.0	25.5	0.0	3.5	9.0	0.0	16.5	
22	0.0	0.0	0.5	0.0	0.0	0.0	21.0	0.0	10.0	0.5	19.5	1.0	
23	0.0	0.0	8.0	0.5	0.0	0.0	2.0	8.5	0.0	10.0	7.0	2.0	
24	1.0	1.5	0.0	0.0	0.0	0.0	8.5	0.5	0.5	0.5	3.0	14.0	
25	6.5	0.0	0.0	0.5	4.0	0.0	2.5	20.5	0.0	1.0	2.0	61.0	
26	7.0	0.5	0.0	18.5	0.0	0.0	6.0	8.5	0.0	0.0	16.0	4.0	
27	7.0	1.5	0.5	17.5	0.0	0.0	0.5	0.0	23.0	28.5	3.5	2.0	
28	1.0	3.5	0.5	2.0	131.5	0.0	5.5	6.0	21.0	12.5	15.5	0.0	
29	0.5	1.0	0.0	0.0	5.5	0.0	1.5	1.0	18.5	13.0	7.0	0.0	
30	0.0		0.0	0.5	2.0	?	0.5	2.5	4.0	16.0	0.0	4.0	
31	0.0		11.5		0.5		0.0	17.5		?		?	
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot	73.0	127.0	37.5	77.5	347.0	130.0	208.0	120.0	166.0	222.5	312.5	227.5	2048.5
Max	13.0	32.0	12.0	18.5	131.5	32.5	26.0	32.5	23.0	43.5	77.5	61.0	131.5
NO>0.0	15	18	9	14	21	12	22	15	21	24	25	22	218

FIGURE 4.1 (1): Representative rainfall data of Cameron Highlands

According to the rainfall data provided as shown in Figure 4.1 (1), courtesy of JPS, the wet season in Cameron Highlands is determined to be in the month of May 2016. Meanwhile, on the contrary, the dry season of the site is observed to be occurring two months earlier, which is in the month of March 2016. From the USGS website, in every month, the satellite will be capturing images of the Earth with the frequency of two times. Hence, by having the options of two sets of satellite images in every month, the images which has better quality in terms of the clarity and cloud coverage is chosen to be the data of the assessment in order to reduce the errors which can be caused by the amount of clouds or haze covering the surface of the earth. Therefore, for the wet season of 2016, the satellite images to be used are taken on the 30th of May, as shown in Figure 4.1 (2). Meanwhile, for the dry season, the images taken on the 29th of March are to be used, as per Figure 4.1 (3).

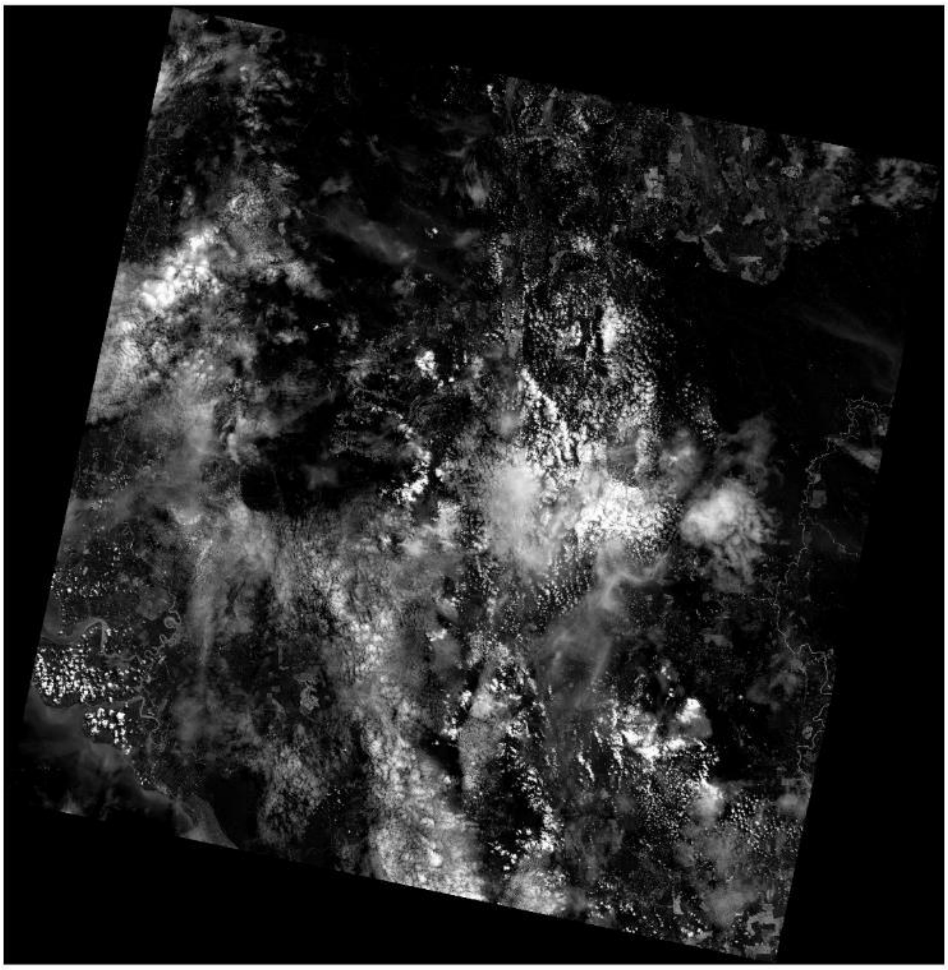

FIGURE 4.1 (2): Landsat 8 image taken on May 30th, 2016

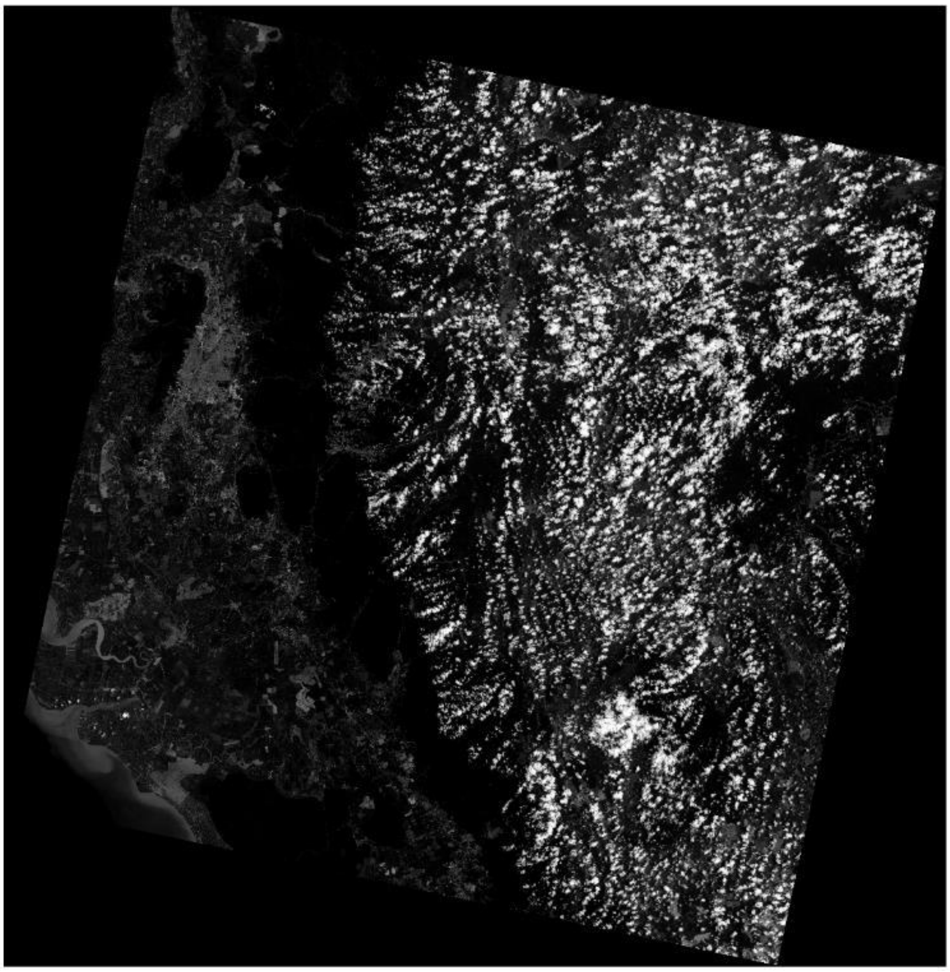

FIGURE 4.1 (3): Landsat 8 image taken on March 29th, 2016

On the other hand, for the raw DEM data of Cameron Highlands as shown in Figure 4.1 (4), it does not need any retrieval work as the data is already pre-purchased prior to this assessment. Even though DEM data is freely available across the web, the resolution and quality of the DEM might not be as good as those which can be purchased. For this project, the purchased DEM data of Cameron Highlands is of very high quality which is valued at 5m resolution, in order to allow for much better accuracy in the analysis processes, as well as yielding the best results at the end of the assessment.

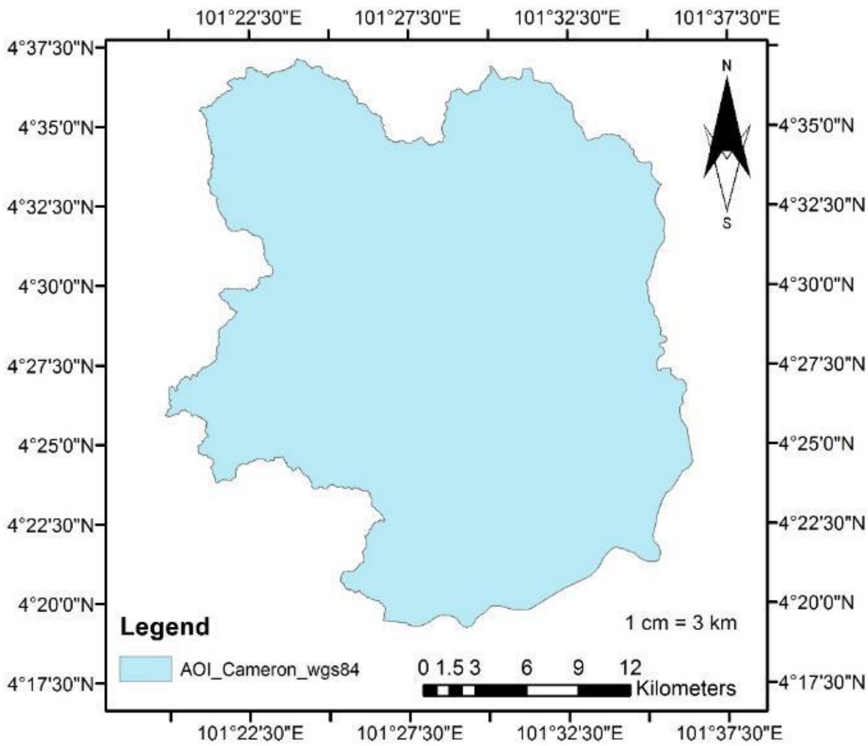

FIGURE 4.1 (4): Raw DEM data in ArcGIS

3.1.2 Data Pre-Processing

After obtaining both of the required raw data for the project, the next stage of the methodology, which is the pre-processing of the raw data is conducted. Specifically, for the satellite images of Landsat-8, the pre-processing step can be divided into three different parts, which are the atmospheric correction, extraction by mask, and radiometric correction. From the obtained satellite images of Landsat 8, they will contain the real time cloud cover or haze in the atmosphere of the Earth during the time of which the images are taken by the satellite. These covers in the atmosphere block the transmission of the satellite to the surface of the Earth which will cause errors in the end result when data is to be extracted from the images taken with the satellite. Instead of reflecting onto the Earth's surface, the transmission of waves from the satellite will be reflected by the cloud and haze covers, causing the data obtained to be unreliable in representing the real and actual properties of the Earth's surface.

The pre-processing stage in removing these covers from the satellite images is called as the atmospheric correction. This correction measure allows the cloud and haze covers to be masked from the images and when the analysis is done for the extraction of data from the images, the masked part will be left out of consideration as they do not represent the real properties of the Earth's surface. A Geographical Information System (GIS) software called Geomatica is utilized for this atmospheric correction as it is equipped with an automated function called 'ATCOR', which accepts the input of satellite images and the function then applies masks to the visible cloud and haze cover that is appearing in the image, as per Figure 4.2 (1). The results of the atmospheric correction through Geomatica can be illustrated in Figure 4.2 (2), which is before the correction was made, and in Figure 4.2 (3) of which showing the results after the correction is done onto the satellite image. This specific procedure for atmospheric correction is applied onto the multispectral bands of the Landsat 8 images, which are namely:

- Red (RED - Band 4)
- Near-infrared (NIR - Band 5)

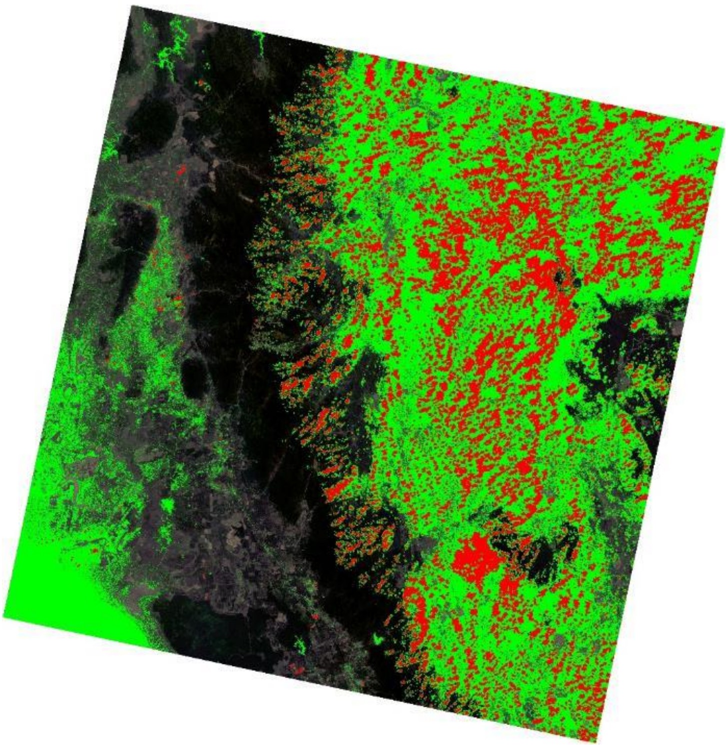

FIGURE 4.2 (1): Masking of haze (green) and clouds (red) through ATCOR function

FIGURE 4.2 (2): Landsat 8 image which is not yet corrected

FIGURE 4.2 (3): Corrected image of Landsat 8

When the atmosphere covers has been masked from the images, the next step is to correct the image according to only the required area of assessment which is the site of Cameron Highlands. Since the images captured by the satellite are in tiles measuring at 170km (north to south) by 183km (east to west) in size, the site of Cameron Highlands will only be a small part of a Landsat 8 image tile. Hence, extraction by mask is done in order to select the area from the whole tile of the satellite image which only represent the site of Cameron Highlands. With the utilization of another GIS software namely the ArcGIS, with the raw data of the site's DEM, it is used as a mask to be superimposed into the satellite image and mask out Cameron Highlands from the large tile of the image, as shown in Figure 4.2 (4). This is to omit every part of the land outside of Cameron Highlands, which are captured in the image, as the scope of this assessment is bounded only for the district of Cameron Highlands, which is as illustrated in Figure 4.2 (5). Since both of the DEM and the Landsat 8 images are using the same coordinate system, which is the WGS 84, a very widely used coordinate system for global positioning system (GPS) purposes, the extraction by mask process is much easier to be done. By superimposing one layer on top of the other, they automatically aligned themselves correctly as per their position in the real world.

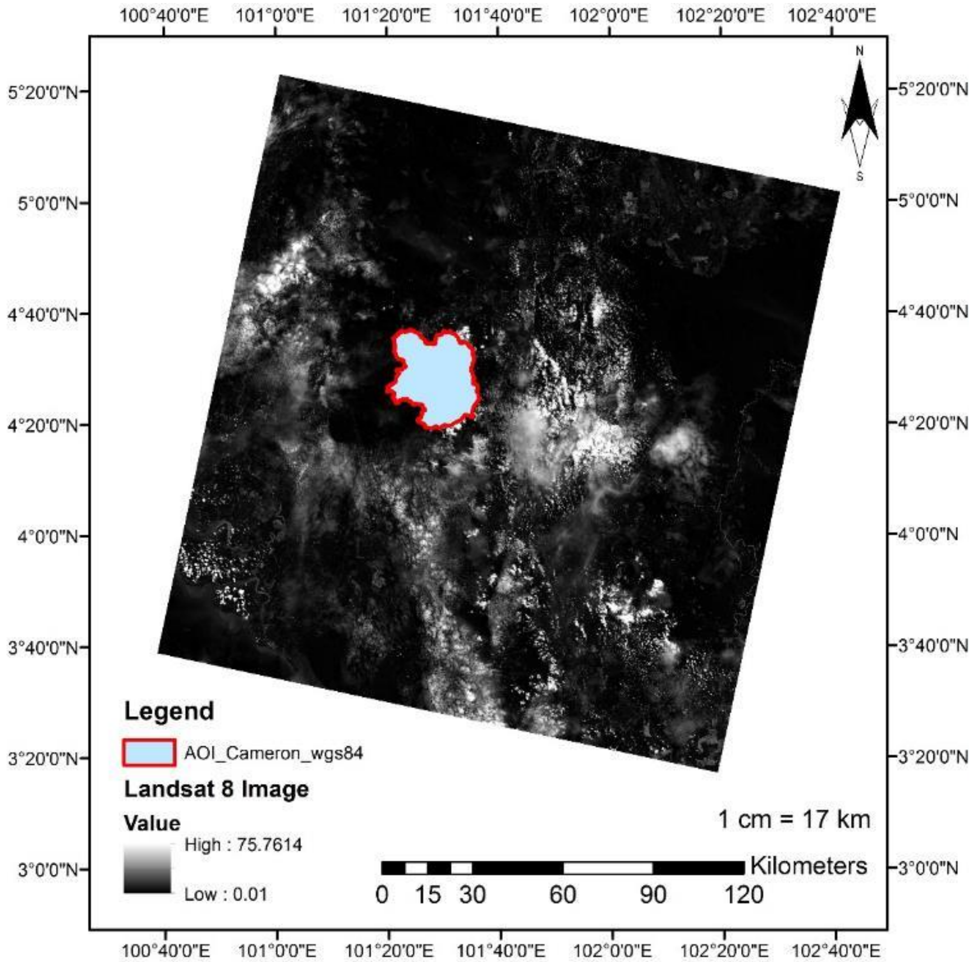

FIGURE 4.2 (4): Initial image prior to extract by mask

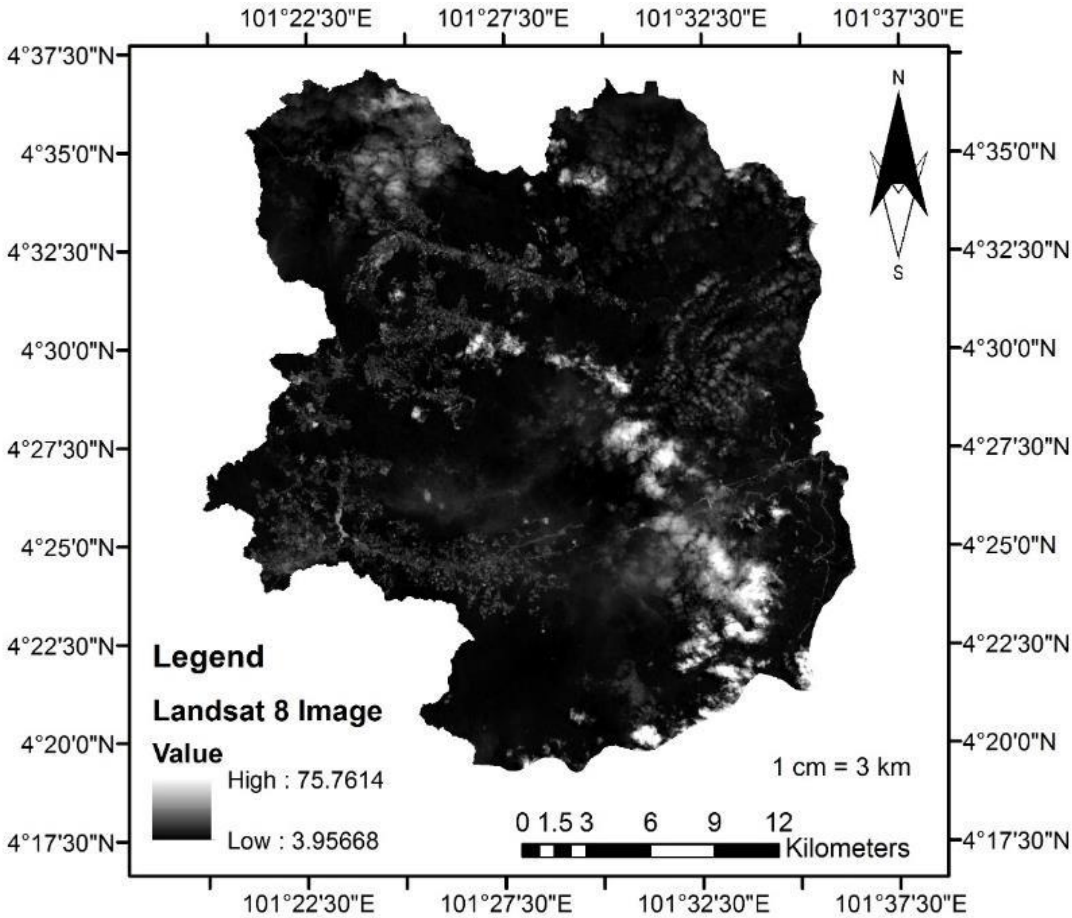

FIGURE 4.2 (5): Final image after extracting by mask

Furthermore, before the data is ready for further analysis works, radiometric correction is needed to be done for the thermal bands of the Landsat 8,which are namely:

- Thermal infrared 1 (TIRS – Band 10)
- Thermal infrared 2 (TIRS – Band 11)

Since the sensor of the satellite records the intensity of the electromagnetic radiation of the Earth's surface as digital number (DN). The DNs must be converted into radiance, which is a more realistic unit in order to prepare the data for further analysis. For this assessment, the raw digital numbers are converted into top of atmosphere (TOA) radiance by using the following equation:

$$L_\lambda = M_L \times Q_{cal} + A_L$$

where: $L_\lambda = Top\ of\ Atmosphere\ spectral\ radiance\ [W/(m^2\ sr\ \mu m)]$

$M_L = Band\ specifc\ multiplicative\ rescaling\ factor$

$Q_{cal} = Satellite\ image$

$A_L = Band\ specific\ additive\ rescaling\ factor$

From the metadata of the satellite images, the rescaling factors are already provided for the author's usage, which can be referred to in Table 4.2 (1) below:

TABLE 4.2 (1): Rescaling factor used for DN to TOA radiance conversion

Rescaling Factor	Band 10	Band 11
$\boldsymbol{M_L}$	0.0003342	0.0003342
$\boldsymbol{A_L}$	0.1	0.1

The results from the process of converting the DN into TOA radiance are as follows:

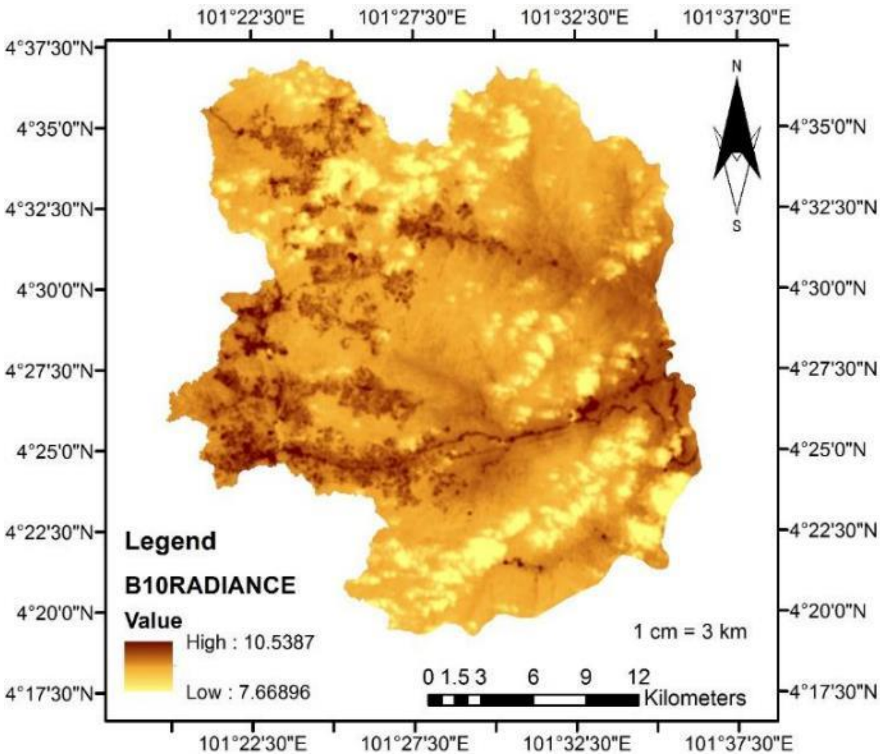

FIGURE 4.2 (6): Band 10 radiance for dry season

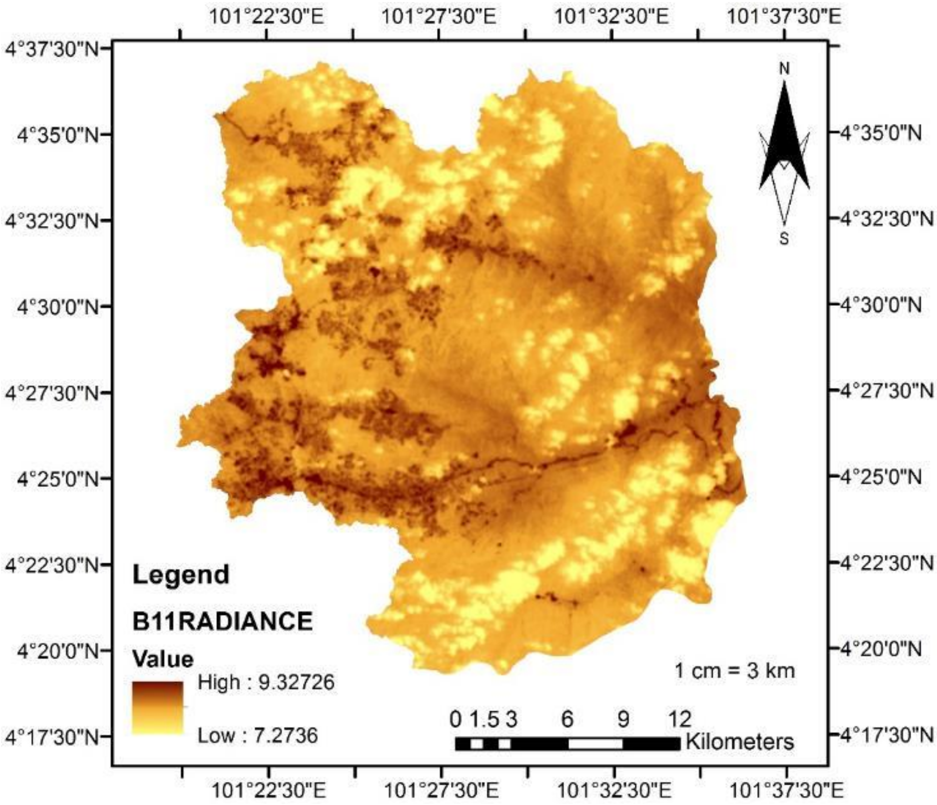

FIGURE 4.2 (7): Band 11 radiance for dry season

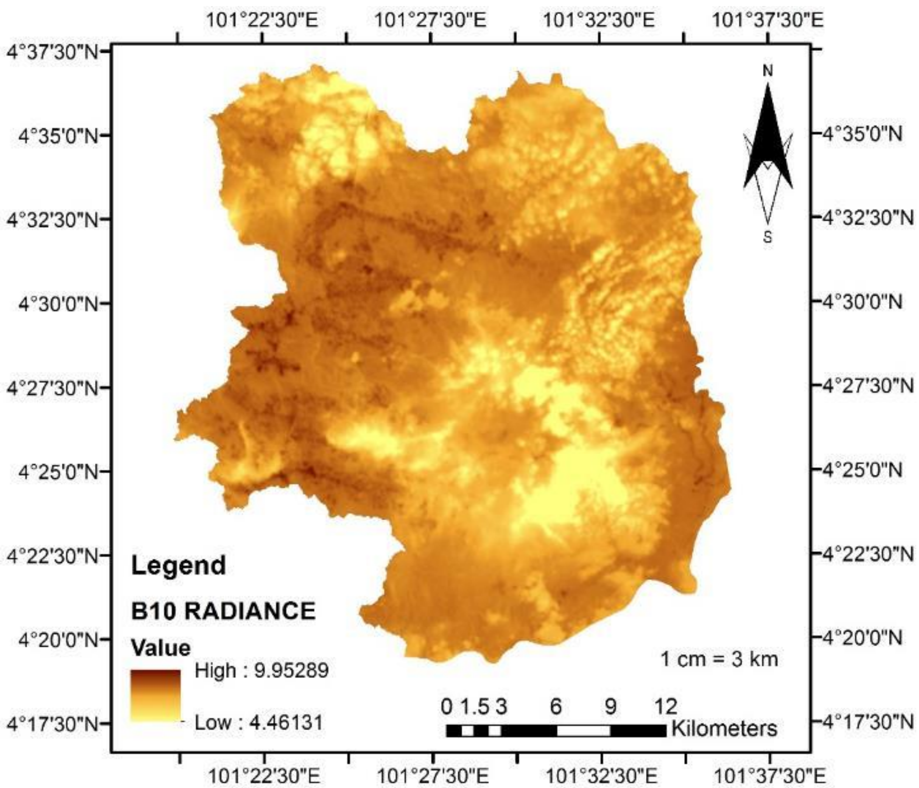

FIGURE 4.2 (8): Band 10 radiance for wet season

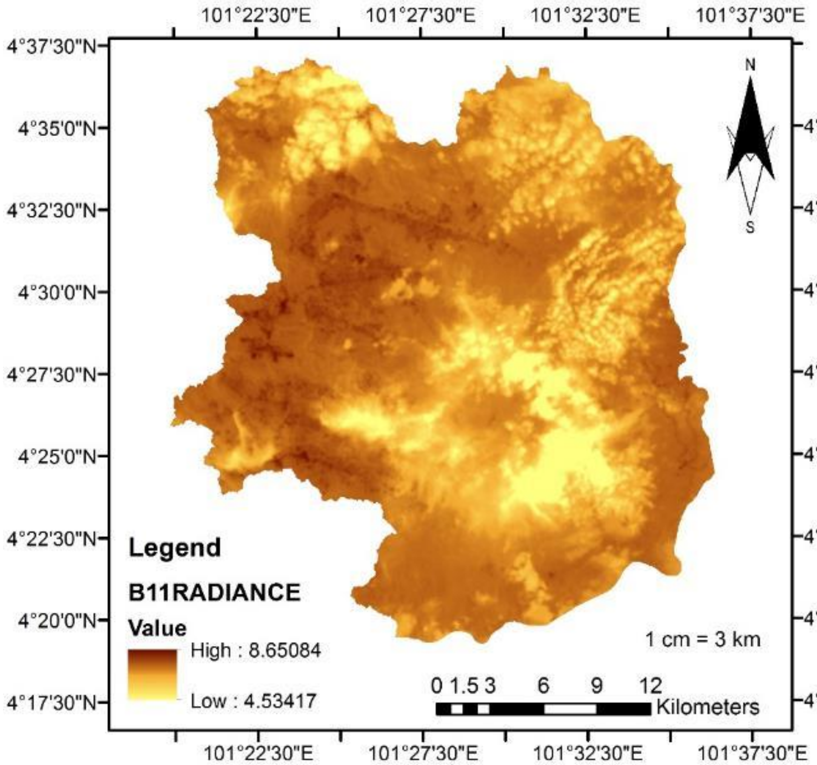

FIGURE 4.2 (9): Band 11 radiance for wet season

Through the corrections which has been conducted for the raw data, the processing stage can now proceed. As of the last correction, which is the radiometric correction, each pixel of the satellite image of the Landsat 8 is now represented in the units of TOA radiance. From this parameter, the temperature at satellite brightness can be calculated for all the data of both wet and dry season images, using the following equation:

$$T_b = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} - 273.15$$

where: $T_b = At\ satellite\ brightness\ temperature$ (degree Celsius)

$K_1 and\ K_2 = Thermal\ conversion\ constant\ for\ thermal\ bands$

$L_\lambda = Top\ of\ Atmosphere\ spectral\ radiance\ [W/(m^2\ sr\ \mu m)]$

The values for K_1 & K_2 can be taken from the metadata of the Landsat 8 image package, which are as Table 4.3 (1) below:

TABLE 4.3 (1): Thermal constants contained in the Landsat 8 metadata

Thermal Constant	Band 10	Band 11
K_1	774.8853	480.8883
K_2	1321.0789	1201.1442

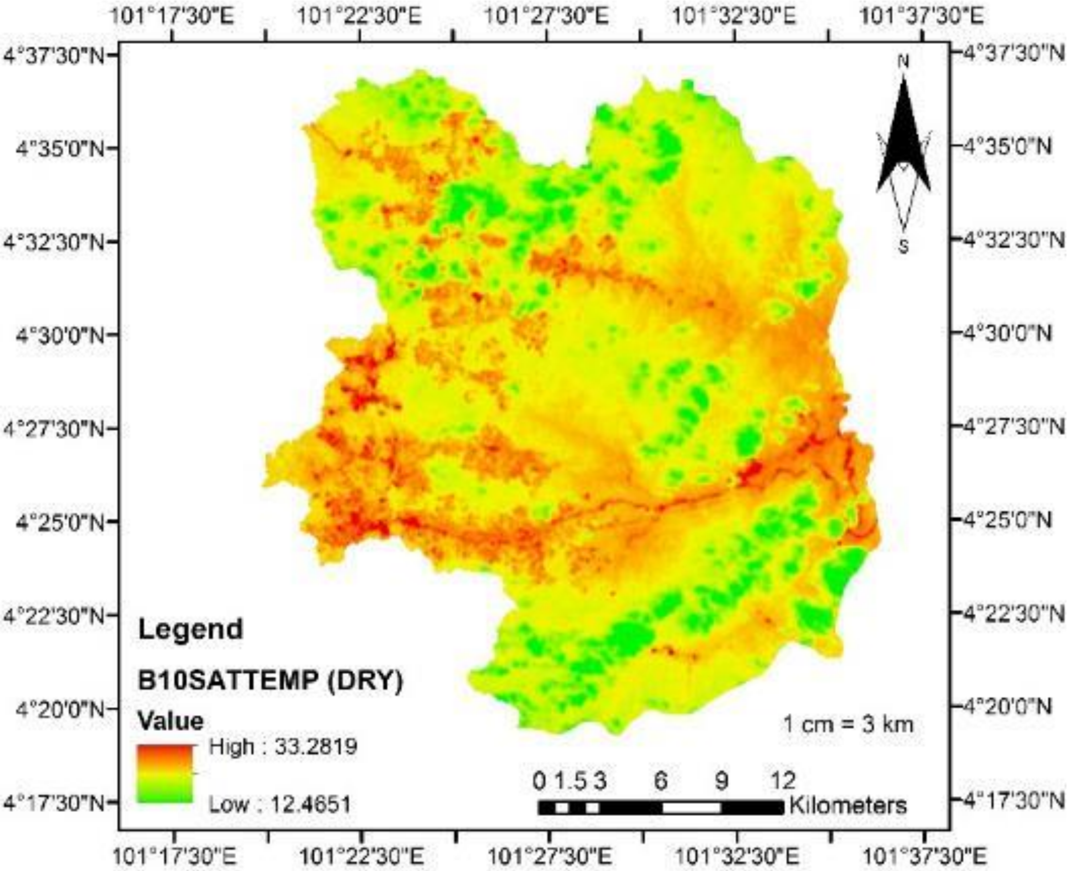

FIGURE 4.3 (1): Band 10 temperature at satellite brightness for dry season

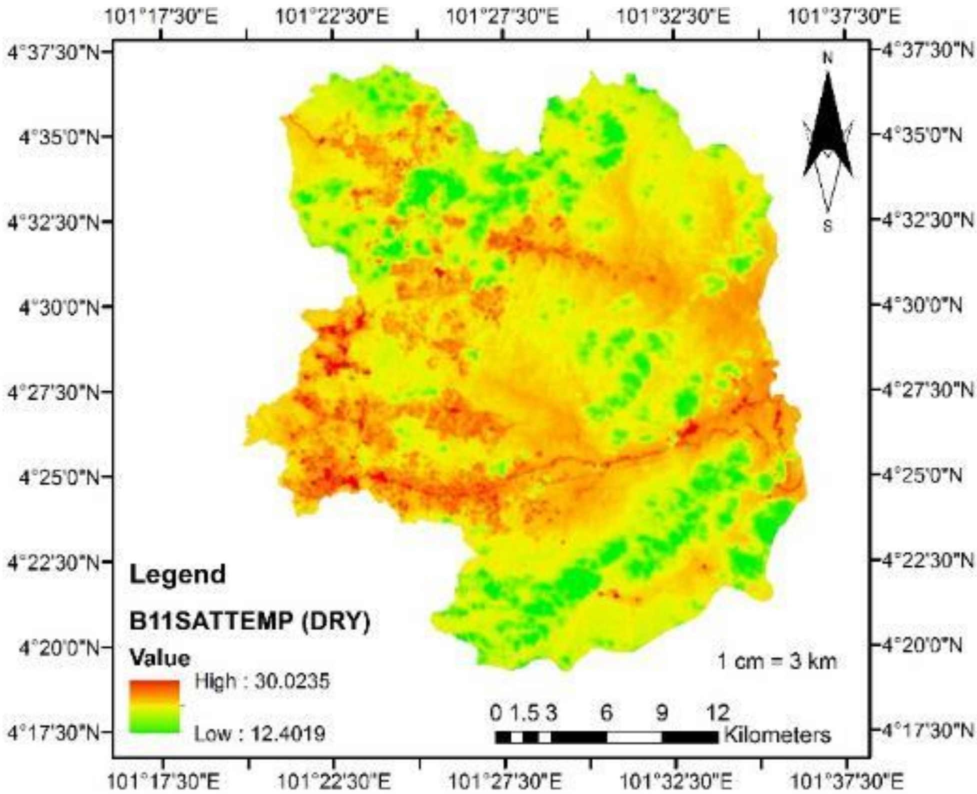

FIGURE 4.3 (2): Band 11 temperature at satellite brightness for dry season

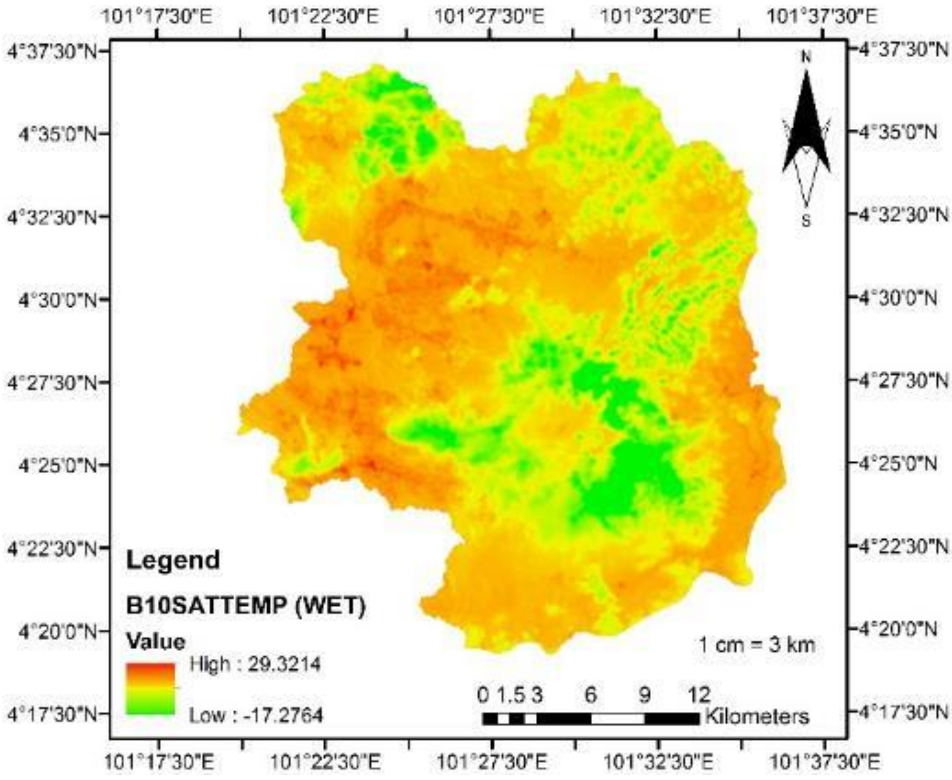

FIGURE 4.3 (3): Band 10 temperature at satellite brightness for wet season

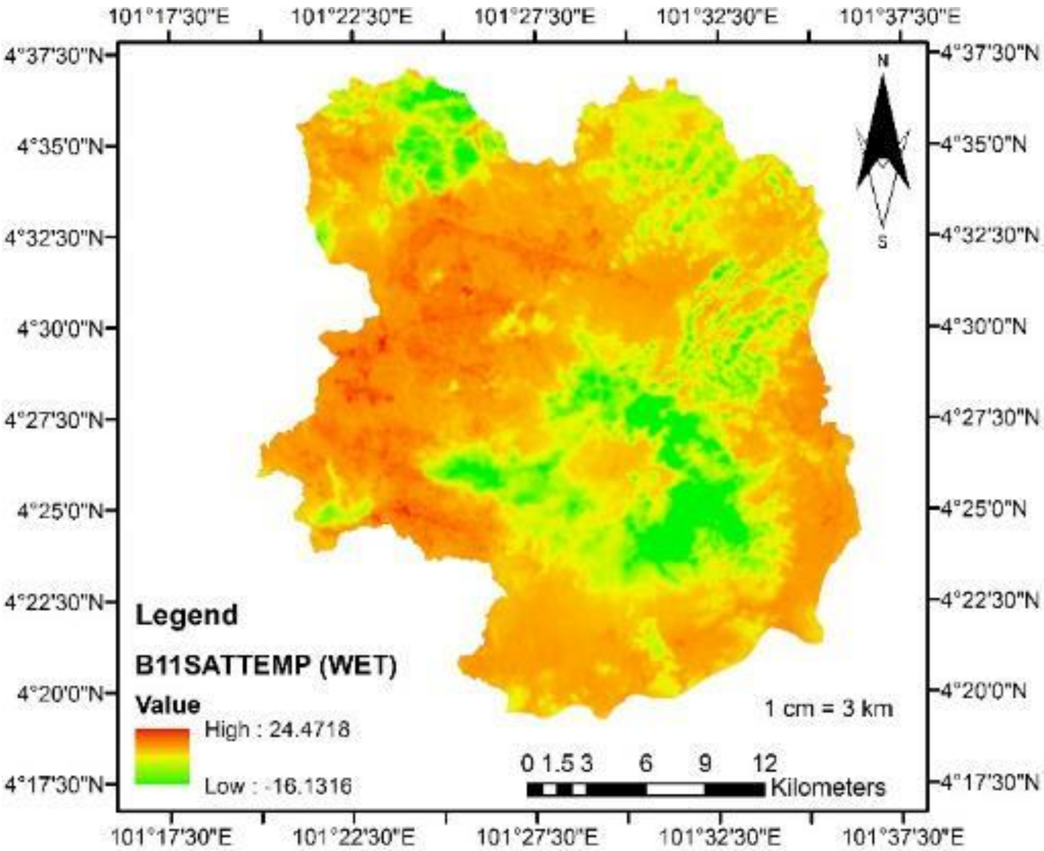

FIGURE 4.3 (4): Band 11 temperature at satellite brightness for wet season

From the dry and wet seasons' Band 10 and Band 11 temperatures at satellite brightness, the result is then combined through the function of cell statistics in ArcGIS, in order to compute the mean for both sets of data.

Next, it is required to determine the normalized difference vegetation index (NDVI) of the area in order to assess the distribution of live green vegetation within the site of Cameron Highlands. The NDVI for Landsat 8 images is calculated as the ratio between the values of red and near-infrared bands, as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

where: $NIR = Band\ 5\ of\ Landsat\ 8$

$RED = Band\ 4\ of\ Landsat\ 8$

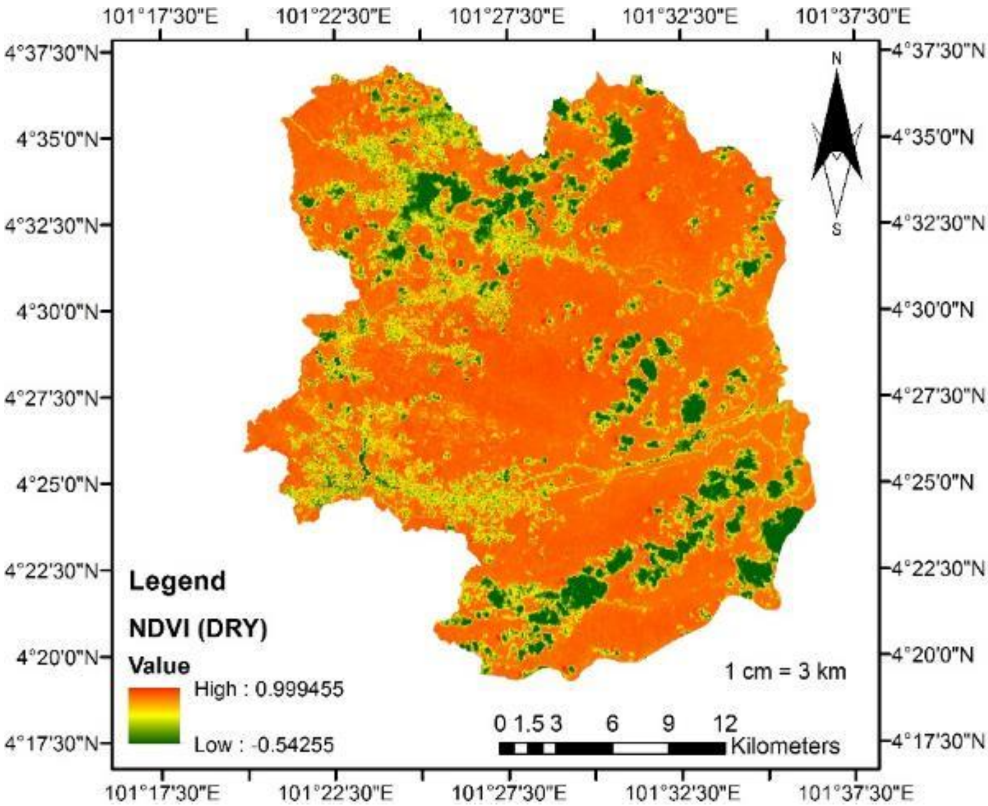

FIGURE 4.3 (5): NDVI for the dry season image

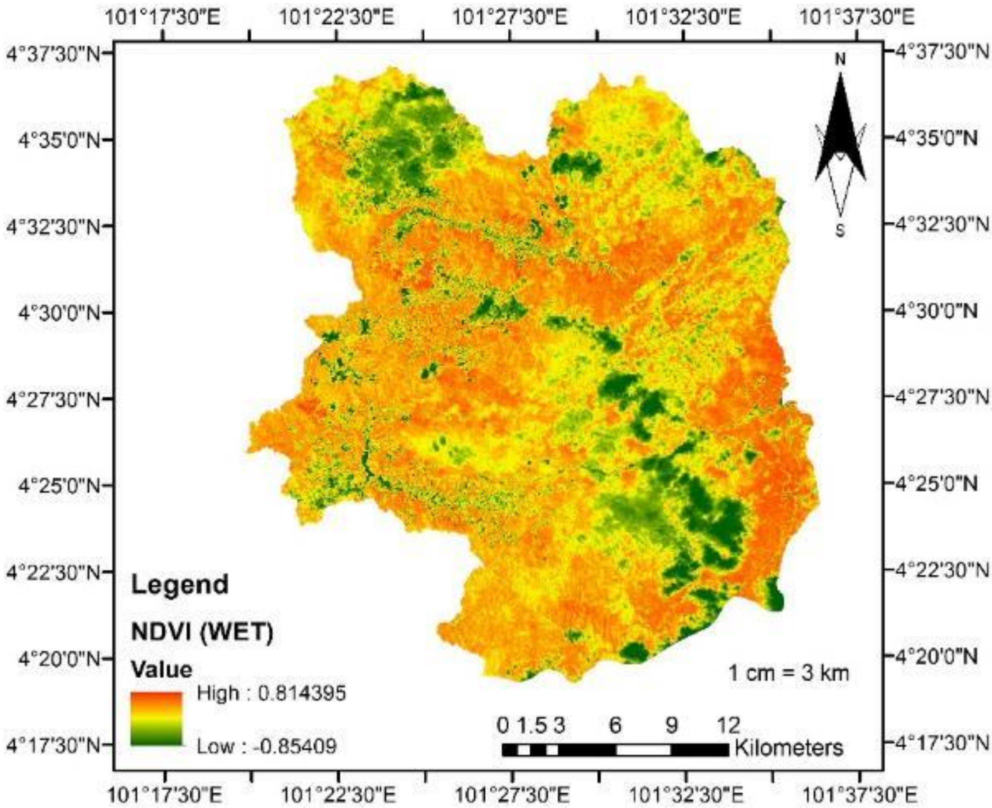

FIGURE 4.3 (6): NDVI for the wet season image

With the result of NDVI, the proportion of vegetation for the site can be computed with the usage of the following formula:

$$P_v = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2$$

where: $P_v = Proportion\ of\ vegetation$

$NDVI = Normalized\ Difference\ Vegetation\ Index$

$NDVI_{min}$ & $NDVI_{max} = Minimum\ and\ maximum\ values\ of\ NDVI$

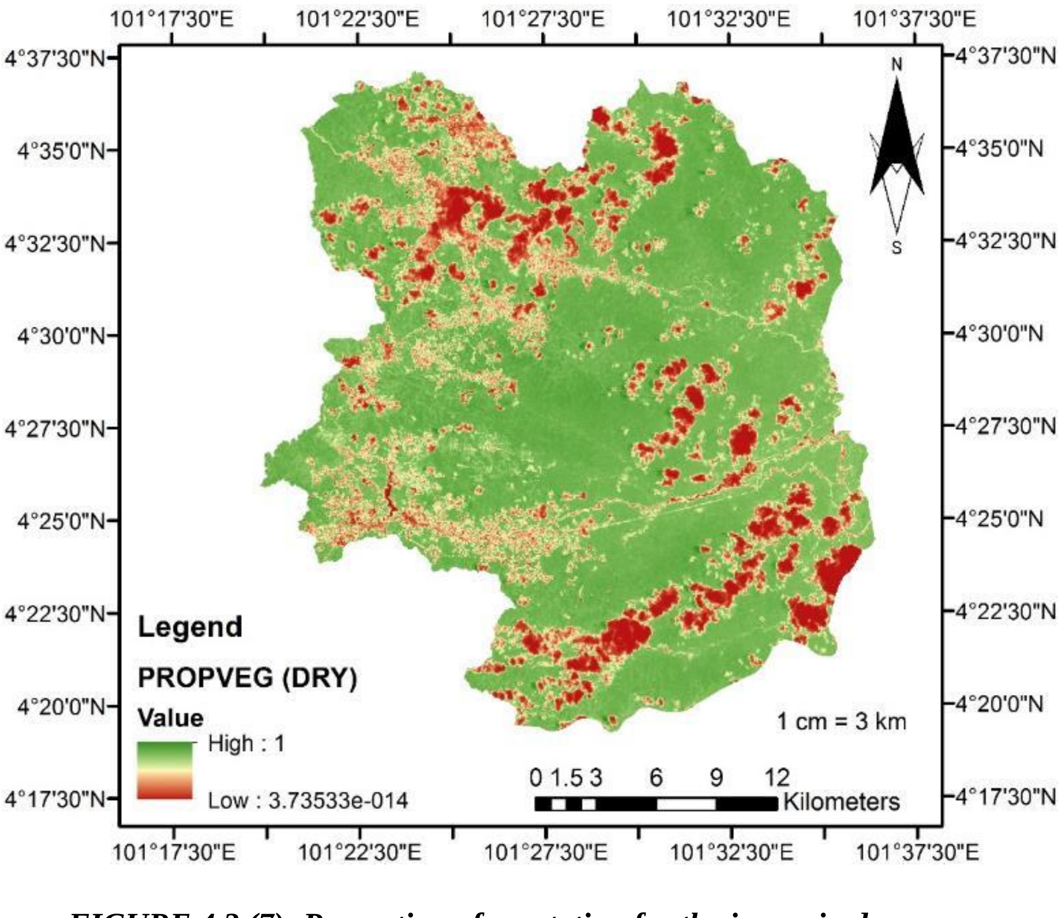

FIGURE 4.3 (7): Proportion of vegetation for the image in dry season

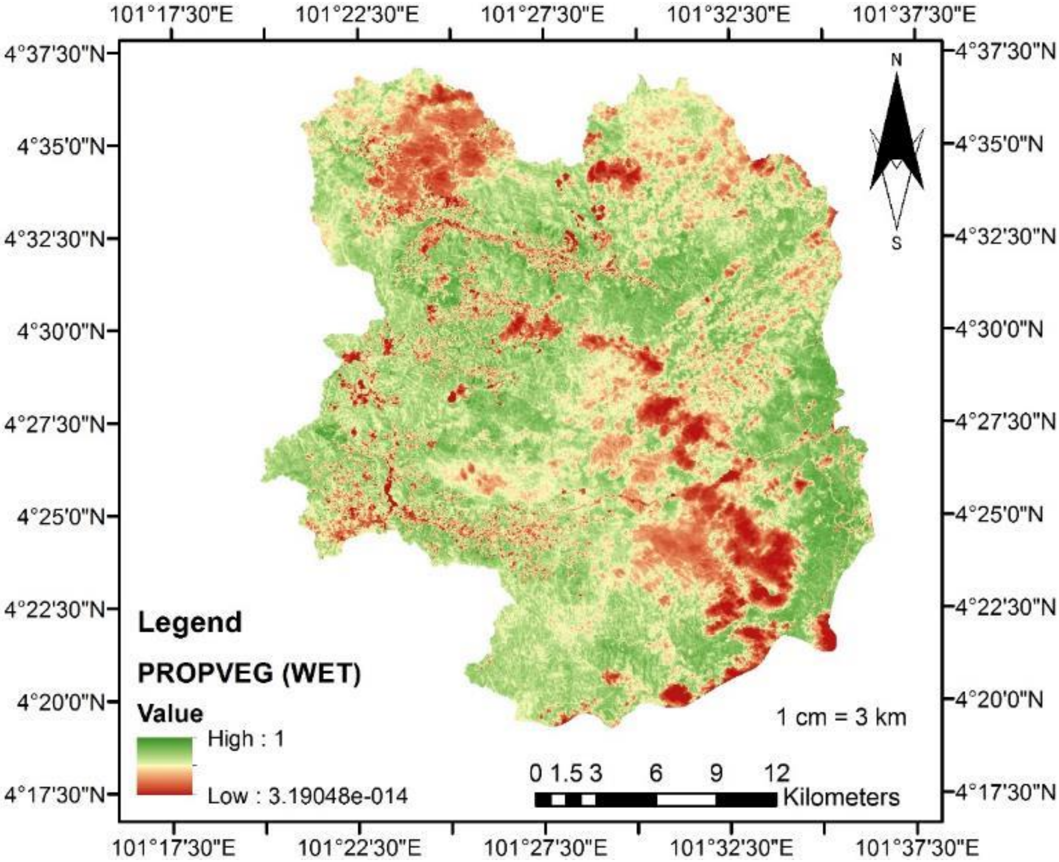

FIGURE 4.3 (8): Proportion of vegetation for the image in wet season

Prior to the determination of land surface temperature (LST), the emissivity of the land surface must be computed beforehand. The emissivity is determined as follows:

$$\varepsilon = 0.004\ P_v + 0.986$$

where: $\varepsilon = Emissivity$

$P_v = Proprtion\ of\ vegetation$

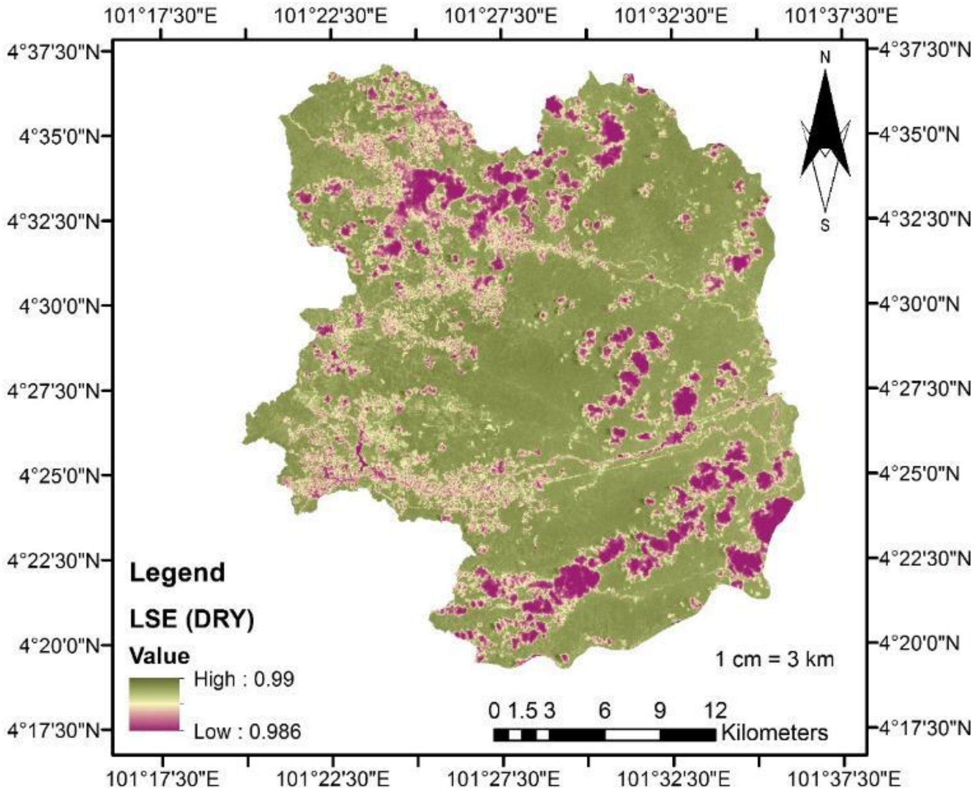

FIGURE 4.3 (9): Emissivity of land surface in dry season

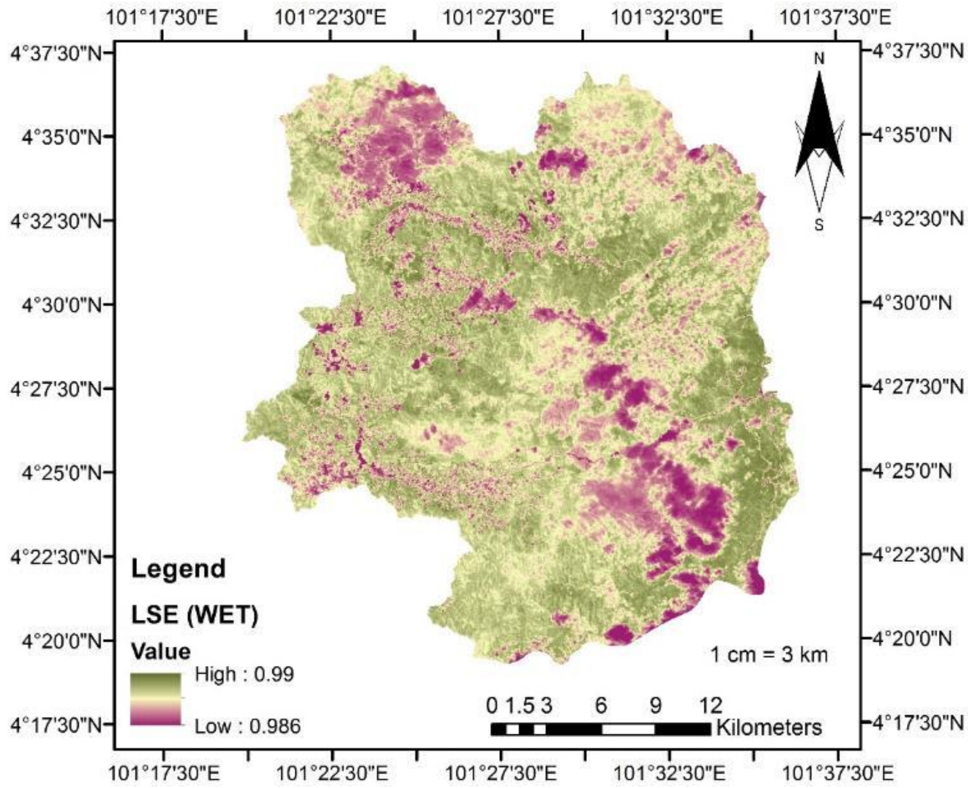

FIGURE 4.3 (10): Emissivity of land surface in wet season

When all the required data is computed, the LST distribution for the site of Cameron Highlands can be determined with the following formula:

$$LST = \frac{T_b}{1 + \left(\frac{\lambda \times T_b}{\rho}\right) \times \ln \varepsilon}$$

where: $LST = Land\ surface\ temperature\ (degree\ Celsius)$

$T_b = Mean\ of\ bands'temperature\ at\ satellite\ brightness$

$\lambda = Central\ band\ wavelength\ of\ emitted\ radiance\ (10.8)$

$\rho = 14380$

$\varepsilon = Emissivity$

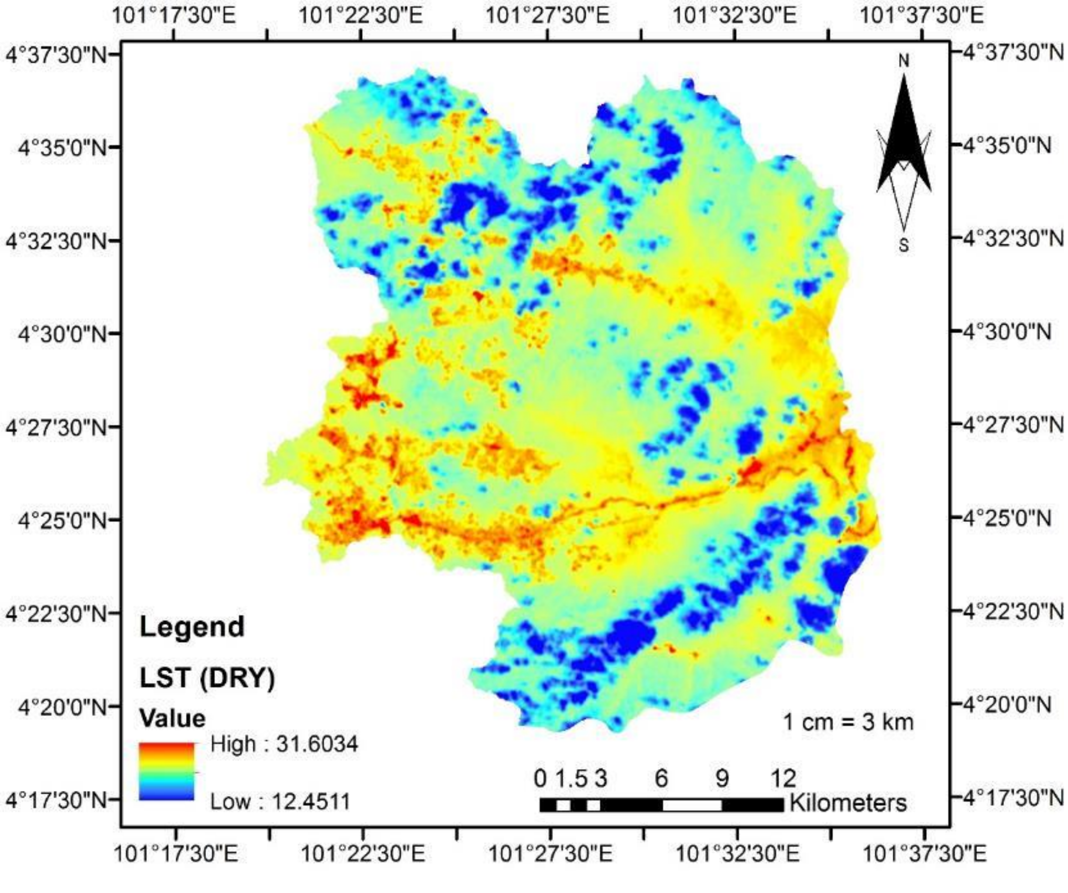

FIGURE 4.3 (11): LST distribution during the dry season

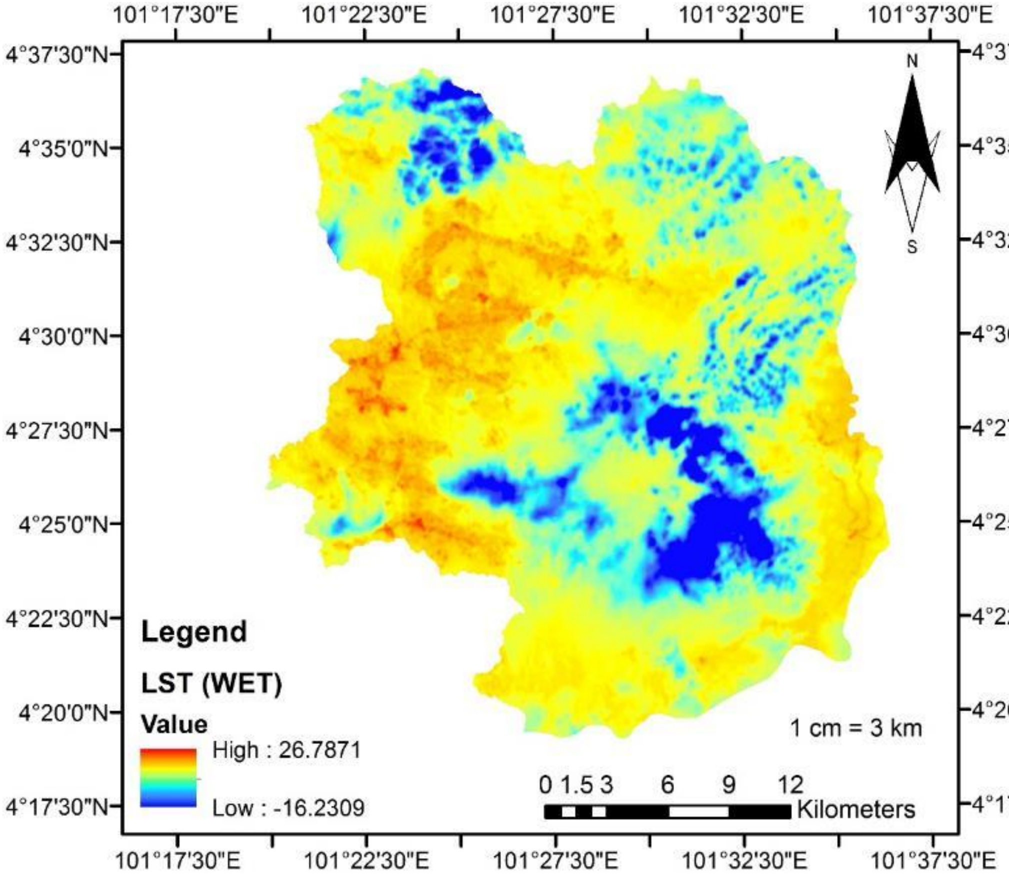

FIGURE 4.3 (12): LST distribution during the wet season

3.1.3 Identification of Various Types of Landscape Characteristics

Done with one of the two main parameters for this assessment, the DEM is now processed in order to acquire all the required landscape characteristics within the area of Cameron Highlands. For this project, there are three main landscape characteristics considered, which are the elevation, slope, and the slope aspect. Elevation simply shows on how high or low the land is located with relative to the datum, which usually taken as the Mean Sea Level (MSL). The slope values are self-explanatory as they reflect on how steep or how gentle the slopes that are available at the site. For the last one, which is the slope aspect, is the one which indicates the orientation of a specific slope, and they can be in eight different directions; north, northeast, east, southeast, south, southwest, west, and northwest.

From the raw DEM data, the listed three landscape characteristics can be obtained through some processing work. ArcGIS has a lot of ready-to-use tools which are utilized for this assessment. Firstly, the elevation itself in already contained within the DEM as shown in Figure 4.5 (1). Hence, in extracting the elevation, there are not extra processing needed. However, for obtaining the slope, the slope function within the spatial analyst tool is used. By inputting the DEM through the slope function, the result obtained is as shown in Figure 4.5 (2).

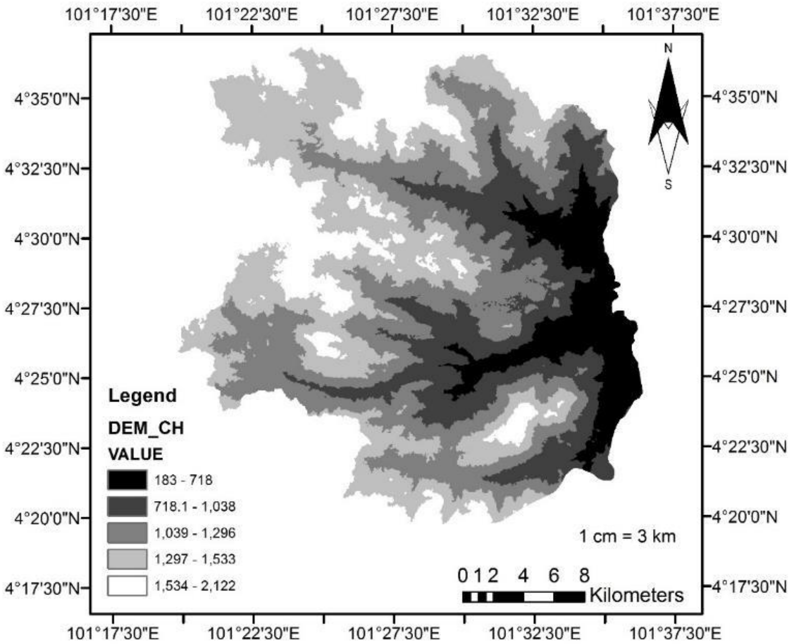

FIGURE 4.5 (1): Elevation classes in Cameron Highlands

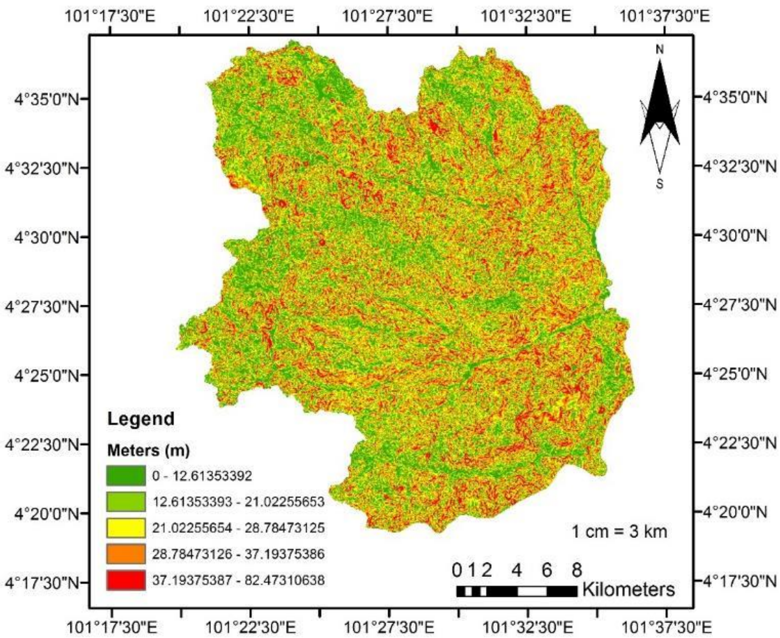

FIGURE 4.5 (2): Slope values across the site of Cameron Highlands

The same goes for determining the aspect of the slopes. ArcGIS has a function of aspect in the spatial analyst tool which is used to obtain the orientation of the slopes obtained. The result is shown in Figure 4.5 (3) below.

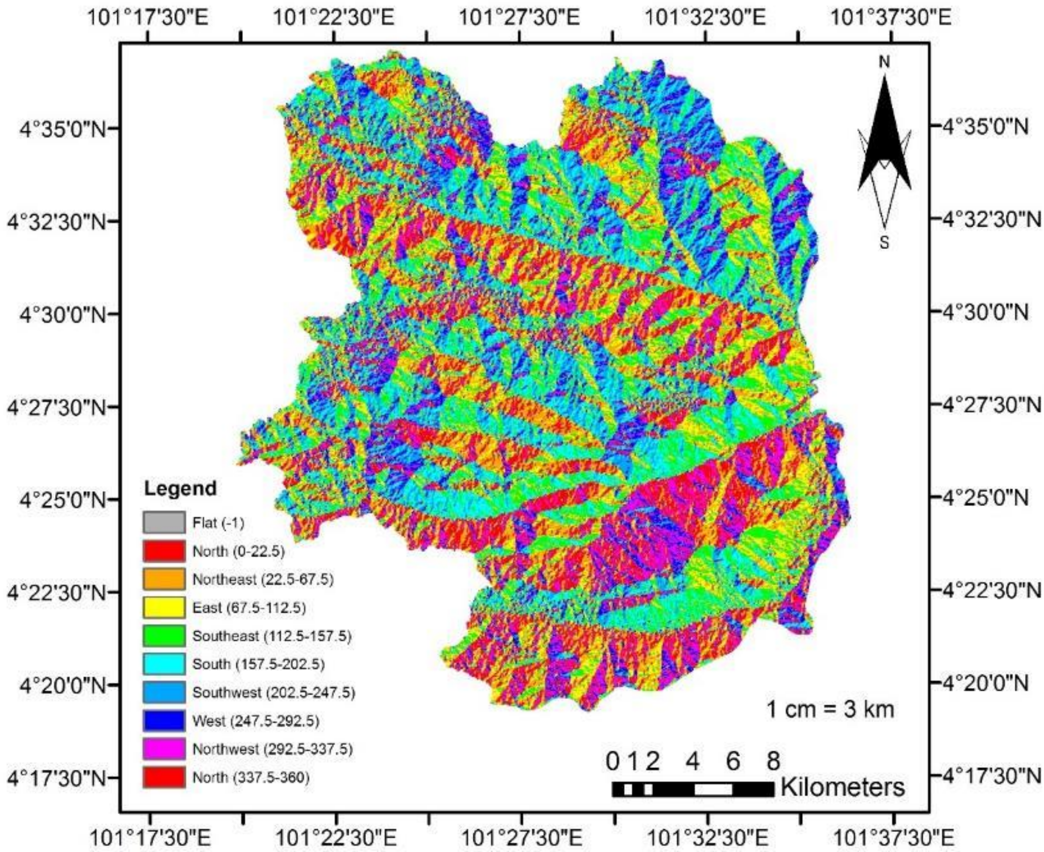

FIGURE 4.5 (3): Orientation of the slopes

3.1.4 Extraction of Soil Moisture Data from Satellite Image

Having the LST is the main parameter required in order to derive the soil moisture index (SMI) for the site of Cameron Highlands. When the LST is computed, the data is then be plotted against the NDVI as a two-dimensional space diagram, as in Figure 4.4 (1) below. From the plot of data, the author extracted two linear equations, in the form of '$y = mx + c$', which are the dry edge (LSTmax) and the wet edge (LSTmin).

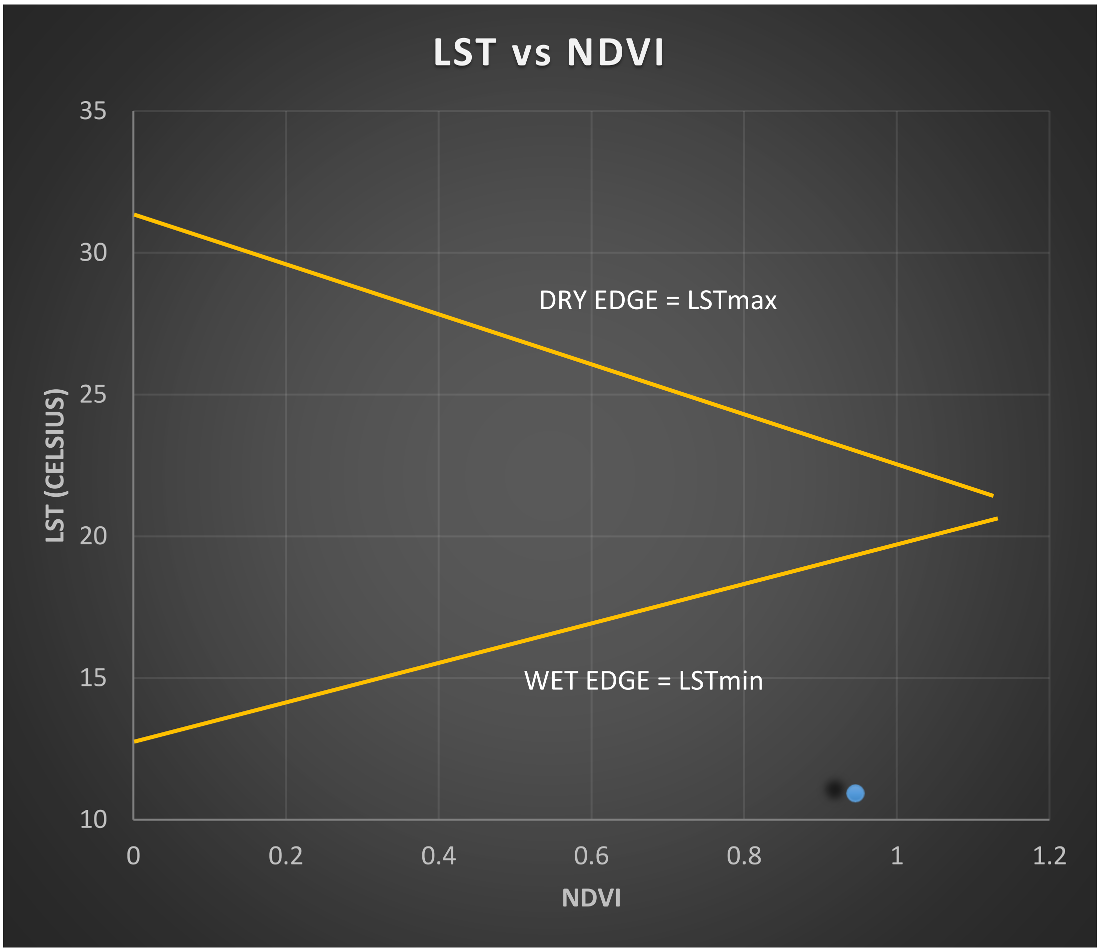

FIGURE 4.4 (1): LST is plotted against NDVI

For both dry and wet edge, the linear equations obtained are:

$$Dry\ edge, y = -9.84076x + 31.6$$

$$Wet\ edge, y = 6.284328x + 12.8$$

When both of the equations are computed, the LSTmax and LSTmin can be derived from them. Taking the lowest NDVI as the x-value in the dry edge equation will result in the LSTmax while taking the lowest NDVI as the x-value in the wet edge equation will result in the LSTmin. The values yielded for LSTmax and LSTmin are as below:

$$LST_{max} = 29.68\ ^{\circ}C$$

$$LST_{min} = 13.94\ ^{\circ}C$$

These values of LSTmax and LSTmin can then be plugged in into another equation in order to get the final SMI value. The equation is as per below:

$$SMI = \frac{LST_{max} - LST_i}{LST_{max} - LST_{min}}$$

where: $SMI = Soil\ moisture\ index$

$LST_{max}\ \&\ LST_{min} = Dry\ edge\ \&\ wet\ edge\ respectively$

$LST_i = Value\ of\ LST\ at\ a\ particular\ point$

For this assessment, in order to determine the spatial distribution of SMI, a total number of 650 points are specified from the bounded area of Cameron Highlands, and from these points, their particular SMI value are computed. All of the points are specified as in Figure 4.4 (2) below.

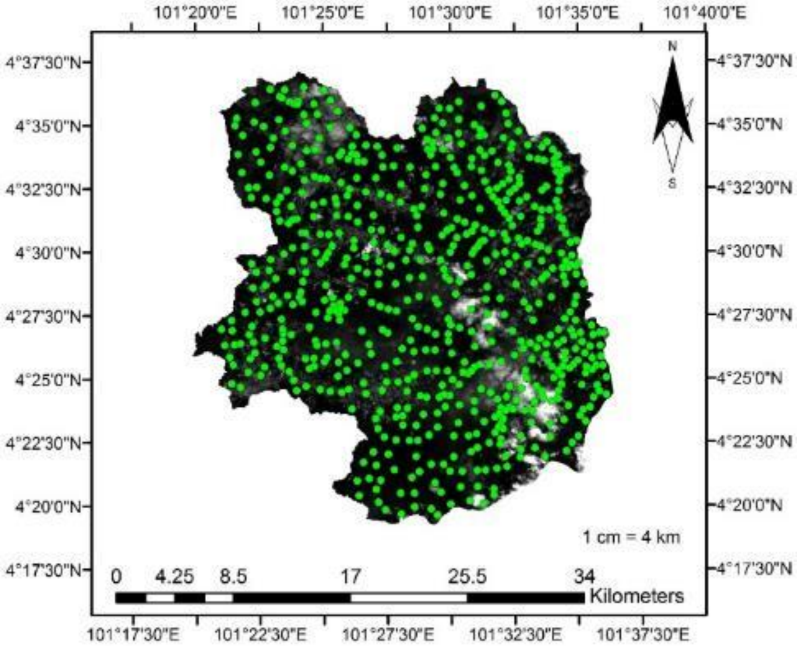

FIGURE 4.4 (2): Manually specified points to represent the whole area

Using the raster calculator function in ArcGIS and the equation determining the SMI, the respective values for the soil moisture are obtained for all the 650 points assigned throughout the map of Cameron Highlands.

3.1.5 Analysis of Soil Moisture Distribution Based on its Landscape Characteristics

When the validation of landscape characteristics and the soil moisture data of the Cameron Highlands watershed is completed, these two data was then analyzed simultaneously through the usage of a Geographical Information System (GIS) software. The software that is used by the author is the ArcGIS software.

3.1.6 Analysis and Discussion of the Final Outcome

This stage of the methodology involved the results gained after the analysis of the relationship, between the landscape characteristics of the site, with its soil moisture distribution.

3.1.7 Conclusion of the Study

Conclusion of the findings from the analysis and results obtained from the assessment is given here. Then, some recommendations are made for future studies.

3.2 Sources of Data Collection

For this study, the raw data required are the Landsat images and the Digital Elevation Model (DEM) of the Cameron Highlands site. They are obtained from reliable sources as stated below:

1. Jabatan Ukur dan Pemetaan Malaysia (JUPEM)
2. Malaysian Remote Sensing Agency
3. United States Geological Survey (USGS)

3.3 Key Milestones

TABLE 3.3 (1): Key milestone of the research

Key Milestone	Forecast Finish Date	Actual Finish Date
Selection of Project Topic	Week 1 (FYP 1)	Week 1 (FYP 1)
Objectives Identifying	Week 2 (FYP 1)	Week 2 (FYP 1)
Literature Reviewing	Week 6 (FYP 1)	Week 6 (FYP 1)
Data Acquisition/Collection and Data Pre-Processing	Week 12 (FYP 1)	Week 12 (FYP 1)
Identification of Various Types of Landscape Characteristics and Extraction of Soil Moisture Data from Satellite Image	Week 2 (FYP 2)	Week 2 (FYP 2)
Analysis of Soil Moisture Distribution Based on its Landscape Characteristics	Week 6 (FYP 2)	Week 6 (FYP 2)
Analysis and Discussion of the Final Outcome	Week 9 (FYP 2)	Week 10 (FYP 2)
Conclusion of the Study	Week 10 (FYP 2)	Week 11 (FYP 2)

3.4 Gantt Chart

TABLE 3.4 (1): Gantt chart for FYP 1

Project Flow	**Weeks**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Project Title Assignation														
Objectives Identifying														
Literature Reviewing														
Extended Proposal Submission														
Proposal Defense														
Data Acquisition/Collection and Data Pre-Processing														
Interim Report Draft Submission														
Interim Report Submission														

TABLE 3.4 (2): Gantt chart for FYP 2

Project Flow	**Weeks**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Identification of Various Types of Landscape Characteristics and Extraction of Soil Moisture Data from Satellite Image														
Analysis of Soil Moisture Distribution Based on its Landscape Characteristics														
Progress Report Submission														
Analysis and Discussion of the Final Outcome														
Conclusion of the Study														
Pre-SEDEX														
Final Report Draft Submission														
Project Dissertation Submission (Soft Bound)														
Technical Paper Submission														
Viva														
Project Dissertation Submission (Hard Bound)														

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis of Landscape Characteristic on SMI Distribution

After obtaining all the landscape characteristics required and the distribution of SMI values, these two parameters are then merged together in order to see the relationship in between them. This is done by using the earlier designated 650 points throughout Cameron Highlands and obtain all the required information which are the SMI, elevation, slope, and the slope aspect, at the specified points. In ArcGIS, the function of extract multi value to points under the spatial analyst tools is used. By executing this function, the input raster would be the SMI, elevation, slope and slope aspect. The output would be the 650 points, which is then filled with the required data as per the Table 4.6 (1).

TABLE 4.6 (1): Attribute table of representative 35 points taken out of the 650 points

FID	DEM_CH	NDVI__DRY_	LST__DRY_	NDVI__WET_	LST__WET_	Slope_DEM_	Aspect_DEM	SMI_Wet	SMI_Dry
0	1656	0.741976	18.2726	0.54686	9.01218	13.9819	45	0.854591	0.724894
1	1734	0.917867	19.1262	0.422924	15.0859	25.2966	237.529	0.523602	0.670647
2	1482	0.882945	18.8866	0.638809	5.02845	8.33267	8.1301	1.07169	0.685874
3	1453	0.893617	20.3472	0.183579	-1.71166	8.18756	210.256	1.43899	0.593051
4	1830	0.88872	18.668	0.491492	9.03778	37.052	243.083	0.853196	0.699766
5	1747	0.909682	19.034	0.518243	10.5796	28.7864	226.528	0.769174	0.676506
6	1788	0.879386	18.8627	0.469914	10.7492	27.8382	244.44	0.759932	0.687393
7	1835	0.854708	18.3668	0.357554	15.7013	38.5995	44.4744	0.490065	0.718908
8	1739	0.666784	17.1563	0.173134	4.83944	42.0576	41.7428	1.08199	0.795836
9	1561	0.910915	20.7418	0.40349	7.56557	11.0341	169.287	0.933425	0.567974
10	1462	0.688181	20.9309	0.243358	1.36716	23.7675	318.814	1.27121	0.555957
11	1370	0.87022	20.9881	0.479614	11.6425	9.64043	232.431	0.711251	0.552321
12	1902	0.879776	19.0357	0.530019	14.846	23.8753	208.664	0.536675	0.676398
13	1899	0.429779	15.702	0.288413	13.978	27.2004	40.9144	0.583977	0.888258
14	1846	0.241104	15.0267	0.261576	14.692	11.8297	351.469	0.545068	0.931174
15	1417	0.282208	16.3241	0.278642	7.16408	2.96434	36.8699	0.955304	0.848723
16	1251	0.139036	15.0429	0.513505	13.8167	14.063	150.255	0.592767	0.930145
17	1439	0.328097	17.3188	0.531888	13.8517	10.7882	222.797	0.59086	0.785509
18	1348	0.870393	19.6884	0.415468	13.0732	3.95218	192.995	0.633285	0.634919
19	1426	0.428516	21.5893	0.230874	14.9644	18.7396	192.339	0.530223	0.514115
20	1646	0.566768	17.7135	0.517116	13.9864	27.8132	238.65	0.58352	0.760426
21	1411	0.819047	21.7808	0.481243	9.73684	19.2935	240.781	0.815101	0.501945
22	1570	0.909063	20.3785	0.284808	2.84932	20.9213	188.569	1.19044	0.591062
23	1435	0.796625	23.7911	0.446418	19.5215	18.1341	198.435	0.281882	0.374188
24	1310	0.742234	20.2521	0.645438	18.2826	16.298	22.9321	0.349397	0.599095
25	1401	0.927392	22.0311	0.613737	18.5834	13.0389	206.565	0.333004	0.486038
26	1486	0.859362	21.6926	0.317225	16.9808	27.7034	264.908	0.420339	0.50755
27	1288	0.868052	21.4641	0.519875	15.7622	24.7781	86.7845	0.486747	0.522071
28	1209	0.934334	18.8403	0.496863	11.6821	8.54545	178.025	0.709093	0.688816
29	1521	0.694078	22.7817	0.244674	3.54218	4.14653	0	1.15268	0.438336
30	1474	0.495438	18.8445	0.572444	9.12567	29.7359	247.62	0.848406	0.688549
31	1437	0.906087	21.9983	0.472462	16.8956	14.5495	61.3895	0.424982	0.488122
32	1455	0.675621	23.0874	0.391466	20.0314	11.9067	245.323	0.254095	0.418909
33	1194	0.040215	14.0994	0.444958	9.18673	6.74741	293.199	0.845079	0.990105
34	1452	0.403974	23.989	0.391241	11.8702	4.68078	71.565	0.698842	0.361611
35	1149	0.832393	20.7235	0.504732	11.3431	26.8756	97.6333	0.727567	0.569137

When everything is set and done, the SMI data is averaged base on each classes division of elevation, slopes and slope aspects. The relationship between the SMI and the landscape characteristics is illustrated as per Figure 4.6 (1), Figure 4.6 (2), Figure 4.6 (3).

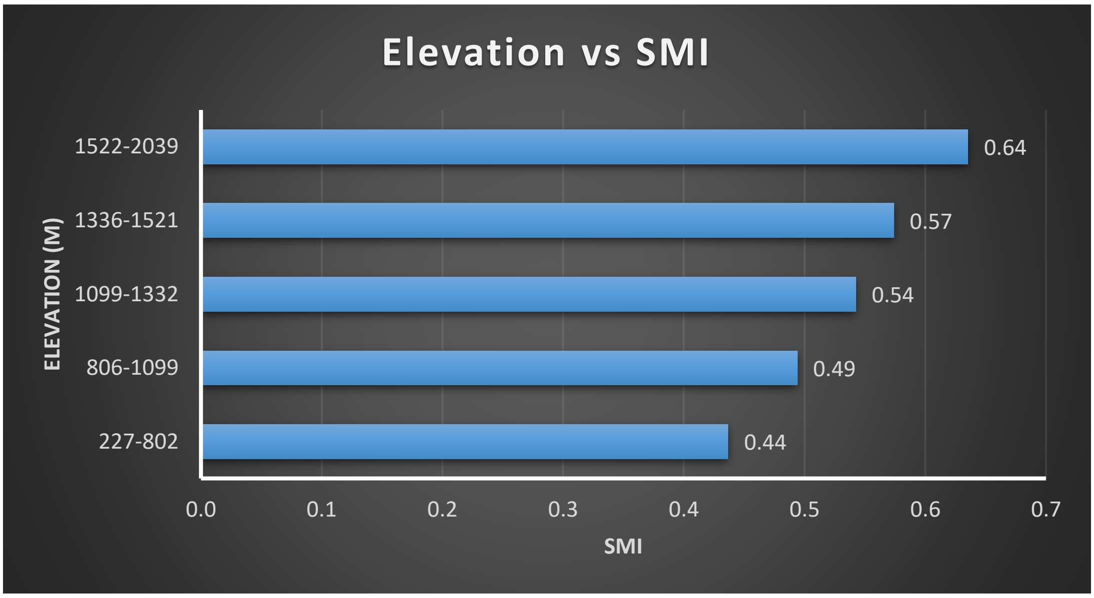

FIGURE 4.6 (1): Graph of elevation against SMI

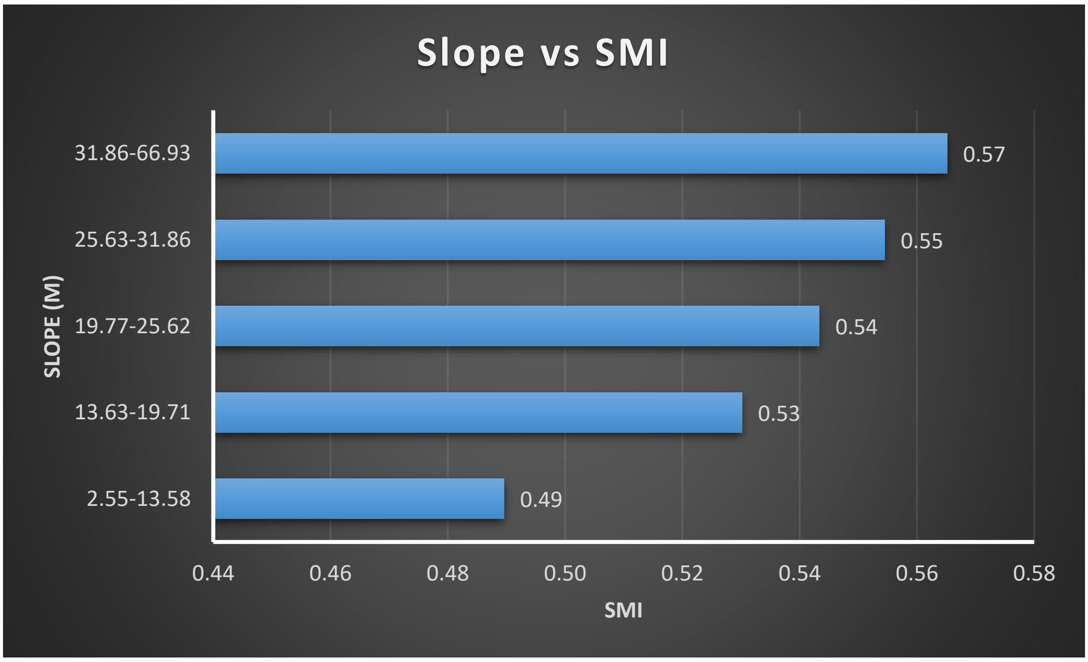

FIGURE 4.6 (2): Graph of slope against SMI

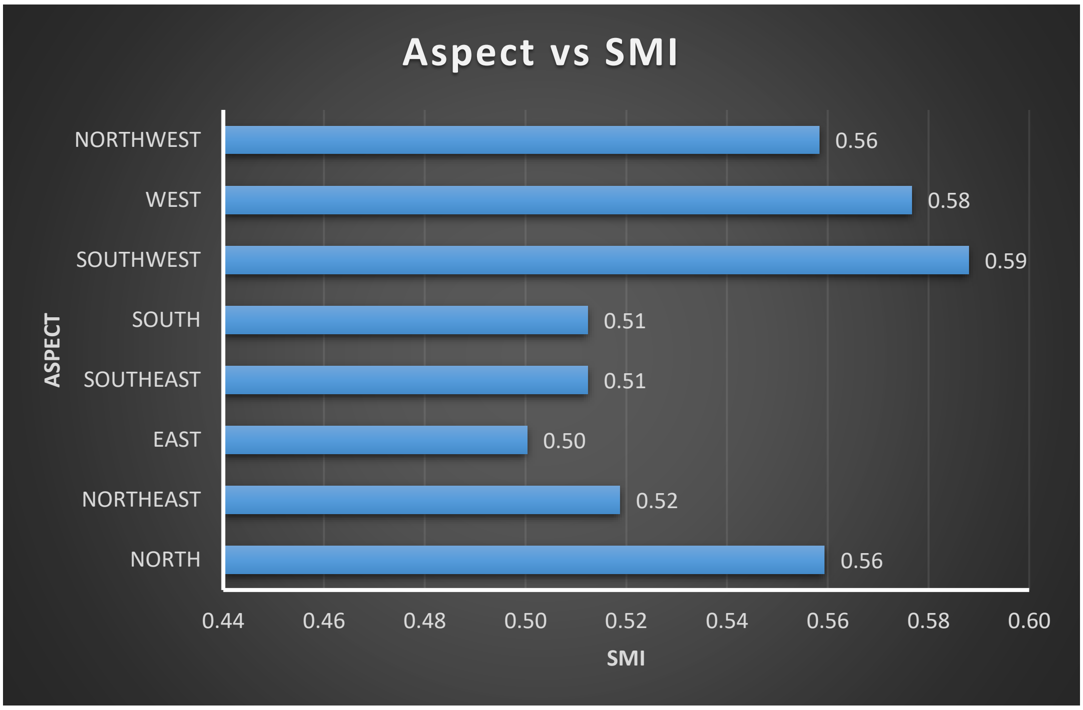

FIGURE 4.6 (3): Graph of aspect against SMI

4.2 Discussion of Results

From the results above, it can be proved that the variation of landscape characteristics at the site of Cameron Highlands affects the distribution of soil moisture. As per the figures illustrated above, the higher the elevation class, the higher the average SMI value. On top of that, when the slopes are high, it also showed a directly proportional relation, resulting in a higher SMI value. Last but not least, in terms of the slope aspect, the slopes which are oriented towards the southwest and west directions recorded the highest value of average SMI.

Higher elevation classes tend to record higher average SMI value due to its closeness to natural precipitation. When there is rain, these elevated areas are considered the catchment area as the rain reaches them first. Besides, the temperature in these elevated areas are lower as compared to others. This causes the process of evaporation to slow down as one of the parameters that catalyzes the speed of evaporation is the temperature. Hence, the soil moisture that is held in between the particles will last longer as compared to the areas with lower elevation classes, causing a higher reading in the average SMI value. Same goes for the slopes where the increase in the slope steepness causes the increase in the reading of average SMI. Steep slope allows for better soil moisture retention as it hinders the water from flowing deep into the soil. Unlike slopes which are gentler in general, the water content will not be retained at the same position in between the soil particles and they will flow deeper into the soil profile, causing the lowering of SMI reading. For the slope aspect, the main reason that dictates the final reading of the SMI is mainly due to hill shade effect that acts upon the slope. If the orientation of the slope causing it to be more exposed to the sunlight rays, it will promote the drying of the soil moisture content, making the final reading of SMI to be less as compared to the areas which orientation does not have much exposure to sunlight. As proven in the results, the orientation which has more hillshade effect and recorded a higher SMI are those which are directed to the southwest and west.

On top of that, the results which are obtained as per the above, are from the processing and analysis of data from the dry season only. For the wet season, it is founded that some of the resulting LST was obtained in the range of negative values, which is definitely not plausible for certain temperature to be recorded at a tropical area like Cameron Highlands. This error in the analysis can be explained by the amount and thickness of the cloud and haze cover which shrouded most of the area captured by the satellite. When electromagnetic waves are being transmitted from the satellite, it was reflected back by the haze and cloud cover, instead of reaching to the surface of the earth. When this happens, the data that was reflected back to the satellite will not be a representative of the Earth’s surface properties, leading to significant errors in the resulting LST.

From the author’s perspective, as the results are obtained and the relationship in between the two main parameters of landscape characteristics and soil moisture index are deduced, the areas which can be considered as hot spots, with higher reading of soil moisture indexes can be identified and known very successfully. By knowing these hot spots, future development or projects within the area of Cameron Highlands can be carefully planned to the maximum safety, for the people. Soil moisture is one of the main factors that governs the soil strength as they fill in the voids in between the particles of the soil. The higher the soil moisture, the lesser the interconnectivity strength and bond in between the soil particles, causing the strength to be lowered. Hence, if there is any new development that involves these hot spots, extra precaution and protection measures should be taken in the design process of the whole project in order to prevent any soil related failures and hazards as stated in the problem statement from the previous section. Since urbanization is also going rapidly in the site of Cameron Highlands, constant monitoring of soil moisture is very important in order to check for its spatial distribution, with respect to the landscape characteristics changes, which can reduce the soil strength and slope stability at any point in the site area, which is involved for any new development.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the proposed research methodology and the set objectives, this assessment study pertains to the identification of the relationship between two types of data, which are the variation of landscape characteristics and how it affects the distribution of soil moisture index. The study involves the site of Cameron Highlands, in which most of the landscapes varies from each other, mostly mountainous areas with some flat lands as well. Throughout the assessment, the data for the study has successfully being pre-processed and processed in order to obtain the soil moisture index as well as classifying the landscape characteristics of the whole area of Cameron Highlands.

The data collection and analysis that are conducted for this study are by the utilization of remote sensing and GIS techniques. Remote sensing involves the usage of satellite products or images, in order to get the data of Cameron Highlands without necessarily to be physically present at the site itself. This method is used in order to get both raw data of soil moisture and landscape characteristics of the site. When everything is set, GIS is used in order to get the final results through various analyses, deducing the relationship in between the two parameters and how they relate to each other.

All in all, the results obtained by relating the two main parameters in this assessment has been yielded successfully. The method of using remote sensing and GIS techniques has certainly been proven to be capable in computing the SMI as well as evaluating the landscape characteristics. The final output can be used in order to carefully plan for a better future development of the site accordingly to the soil condition, with respect to the distribution of soil moisture as well as the landscape characteristics.

5.2 Recommendations

For this particular study, the end results obtained after all of the necessary analysis has been done, can be more accurate and have higher reliability by doing some alterations to the research, methodology wise. For the study to have better results, the data collection of both parameters, soil moisture and landscape characteristics, can be done in various ways instead of using only one method, which is the remote sensing for soil moisture index and DEM for landscape characteristics. By collecting the data in many ways, it will ensure that the study will be carried out and analyzed using the most accurate or the most representative data of the site.

On top of that, as set and planned in the preparation stage of the study, the key milestone and the Gantt chart has been outlined earlier before the research even begin. It is recommended that all the deadline set for the activities that has been planned for the study should be met, if not being done earlier before it. This is to ensure that the work flow of all the activities that is conducted for the study can go as smooth as possible, easing the work for the researcher himself. When an activity is delayed or done after the deadline set, it will mess up the pre-planned flow, which can cause haste and rush into the work activities. Because of that, the results obtained from analyses will not be as good as those obtained from an ideal project flow.

Moreover, exclusively for the soil moisture data, if there is ample time period that allows a field survey by ground-truthing to be done in order to validate the data captured from the satellite imagery, it will be making the research much more meaningful as the results can be checked with representative real life data from the site itself. However, this particular activity will consume a lot of time as it is very tedious and the researcher is needed to go to the site and collect the data at various points of the site. If the field survey were to be done, the time period provided in order to complete the project will be needed an extension as it requires a lot of time and effort in order to complete the task.

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