ASSESSMENT THE IMPACT OF FOREST COVER CHANGE ON RAINFALL IN KELANTAN RIVER BASIN

by

MUHAMMAD AFIQ ALIF BIN KAMARULAKMAL

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THESIS DECLARATION

I hereby declare that the work embodied in this Report is the result of the original research and has not been submitted for a higher degrees to any universities or institutions.

……………………………………………..

Student

Name: Muhammad Afiq Alif Bin Kamarulakmal

DATE: 20/1/2021

I certify that the Report of this final year project entitled Assessment The Impact of Forest Cover Change on Rainfall In Kelantan River Basin by Muhammad Afiq Alif Bin Kamarulakmal, matric number E17A0018 has been examined and all correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Sustainable Science) with Honors Faculty of Earth Science, University Malaysia of Kelantan.

Approved by,

…………………………………………….

Supervisor

Name: Dr. Marieanne Christie Leong

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Assessment The Impact of Forest Cover Change on Rainfall In Kelantan River Basin

ABSTRACT

This study hypothesized that rainfall decreases with reduced Leaf Area Index (LAI) as the land use and land cover changes from 2010 to 2019. With reduction in vegetation, the evapotranspiration (ET) rate is expected to be lower, hence reducing the amount of water vapor in the atmosphere. The reduced amount of atmospheric water vapor creates a dry environment over the vegetation, which restricts the air from achieving saturation to form clouds, thus affecting rainfall. This study aims to study forest cover change on rainfall in Kelantan River Basin (KRB) based on the relationship between LAI, ET and rainfall between 2010 and 2019. The study utilized remotely-sensed ET (MYD16A2GF) and LAI (MYD15A2H) from NASA MODIS, and rainfall from the Global Precipitation Measurement Mission (GPM). Trend and time-series analyses were performed for all three variables and the relationship between ET, LAI and rainfall were determined using multiple linear regression. The results show that seasonal change in ET and LAI were mostly decreasing, while rainfall showed an increasing trend. Both ET and LAI were found to have a weak negative correlation with rainfall, indicating that they do not significantly influence rainfall in KRB between 2010 and 2019.

Menilai Impak Perubahan Liputan Hutan Terhadap Taburan Hujan Di Lembangan Sungai Kelantan

ABSTRAK

Hipotesis kajian ini adalah menujukkan hujan menurun dengan penurunan Indeks Kawasan Daun (LAI) apabila penggunaan tanah dan tutupan tanah berubah dari 2010 hingga 2019. Dengan pengurangan tumbuh-tumbuhan, kadar evapotranspirasi (ET) diharapkan lebih rendah, sehingga mengurangi jumlah air wap di atmosfera. Jumlah wap air atmosfera yang berkurang mewujudkan persekitaran kering di atas tumbuh-tumbuhan, yang menyekat udara daripada mencapai ketepuan untuk membentuk awan, sehingga mempengaruhi hujan. Kajian ini bertujuan untuk mengkaji perubahan litupan hutan pada taburan hujan di Lembangan Sungai Kelantan (KRB) berdasarkan hubungan antara LAI, ET dan taburan hujan antara tahun 2010 dan 2019. Kajian ini menggunakan ET (MYD16A2GF) dan LAI (MYD15A2H) dari jarak jauh iaitu MODIS NASA , dan taburan hujan dari Global Precipitation Measurement Mission (GPM). Analisis tren dan siri masa dilakukan untuk ketiga-tiga pemboleh ubah dan hubungan antara ET, LAI dan taburan hujan ditentukan menggunakan regresi linear berganda. Hasilnya menunjukkan bahawa perubahan musim di ET dan LAI sebagian besar menurun, sementara taburan hujan menunjukkan tren yang meningkat. Kedua-dua ET dan LAI ditemukan memiliki korelasi negatif yang lemah dengan taburan hujan, yang menunjukkan bahawa mereka tidak mempengaruhi hujan secara signifikan di KRB antara tahun 2010 dan 2019.

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LIST OF ABBREVIATIONS

ET	Evapotranspiration
LAI	Leaf Area Index
LULCC	Land Use and Land Cover Change
MODIS	Moderate Resolution Imaging Spectroradiometer
GPM	Global Precipitation Measurement
AppEEARS	Application for Extracting and Exploring Analysis Ready Samples
KRB	Kelantan River Basin
CPF	Collaborative Partnership on Forests
FDPM	Forest Department Peninsular Malaysia
ENSO	El Niño and Southern Oscillation
NASA	National Aeronautics and Space Administration

CHAPTER 1

INTRODUCTION

1.1. Introduction

ET is a process of evaporation of water from leaves through plant transpiration during photosynthesis. It changes due to a multitude of factors such as climate, temperature, humidity and water source (Çalişkan et al.,2013). Evapotranspiration is an essential mechanism in the water cycle as it is responsible for 15% of the water vapour in the atmosphere. Without this water vapour supply, clouds could not develop, so rainfall will never occur. Once water vapour is emitted into the environment, all mechanisms are affected, meaning that they have been merged into one term to cover both bases. This applies to the needs for field irrigation and thus groundwater management, the introduction of new crops or farm planning to adapt to climate change (Hadi et al., 2019)

1.2. Background of the study

Forests shelter approximately three quarters of terrestrial species (Collaborative Partnership on Forests [CPF], 2008) and play a vital role in providing important ecological functions such as organic carbon growth, nitrogen cycles and water conservation. Globally, natural forest regions have faced deforestation threats and conversions to agriculture or industrial land for many centuries, and these threats remain until the present day. This has led to grave ecological implications. including habitat loss and disturbances to ecological functions such as water and nutrient cycling. A forest is a plot of land trees that harbours a plethora of vegetation and wildlife species. Not only are they important for ecological functions, they are also important in maintaining the earth's weather and climate. Most animal are in need of trees to function and live. Forests are very important and now are thriving in many parts of the world. They are an ecosystem that includes many plants and animals.

Tropical rainforests play a vital role in the functioning of the natural systems of the planet. Forests control local and global climates by collecting and producing rainfall and trading greenhouse gases, particularly carbon dioxide. Most importantly, they regulate rainfall through the process of evapotranspiration. For instance, the Amazon itself produces 50% to 80% of its own rainfall through evapotranspiration. It is a significant factor that defines the surface runoff and is thus important for the nature of the drainage and hydraulic system (Tukimat et al., 2012).

Therefore, rainforests have severe implications on the water budget. Once forests are cleared, evapotranspiration decreases due to lack of vegetation, resulting in reduced latent heat flux. In addition, the exposed ground increases albedo which in turn increases the surface sensible heat flux. The effects on the heat fluxes alter the atmospheric stability of the environment, further influencing the formation and development of clouds, and subsequently altering rainfall. Due to the important roles that forests play, particularly its role of evapotranspiration, it is necessary to quantify the effects of land use and land cover change on evapotranspiration, in order to better understand its effects on rainfall.

1.3. Problem Statement

Human beings have been exploiting the earth's surface for a number of purposes throughout their existence. The use of land surface involving the physical and biogeochemical component of land surface is commonly known as land use. The use of land often requires the alteration, either direct or indirect, of natural ecosystems and their effect on the ecology of the region hence the term land use and land cover change (LULCC) was coined (Pereira et al ., 2010). For example, the conversion of forests to cropland and pasture have risen significantly and this growth has given rise to renewed questions about the function of land use transition in causing changes in ecological diversity, soils and their productivity, air quality and water quality.

A large number of researches have explored the effects of LULCC on bio-geophysical and ecological functions (Mahmood et al., 2014), however, there are also other important aspects of LULCC impacts that are less studied, such as the intricate forest-atmosphere-water relationship. This is in part due to the fine-scale processes that occur in this relationship. Such fine-scale processes require high-precision equipment for quantitative analysis. Moreover, incorporating these processes in climate models are computationally expensive too. Nonetheless, there is a growing body of research in this fields and these studies have started to shed some light on the complex relationship between forest, atmosphere and water and how they impact the climate (Meyer, 2011). However, most of these studies are conducted at a regional or global scale, and most are concentrated in large continental areas such as the Amazon or Congo basin, which makes it less reliable for precision modelling at the local scale as well as in other environment such as the Maritime Continent, where Malaysia is located.

To the advantage of understanding of the researcher, the study of forest change and rainfall at a localised scale in Malaysia was only conducted on the island of Borneo (Takahashi et al., 2017). There has yet been any research undertaken for Peninsular Malaysia. Therefore, this study be the first to evaluate the forest-atmosphere-water relationship for Peninsular Malaysia. The study focuses on basin-scale research and the Kelantan River Basin is chosen as the study area. In this study, the forest-atmosphere-water relationship was investigated in terms of leaf area index (LAI), evapotranspiration (ET) and rainfall, in accordance to the objectives states in Section 1.3.

1.4. Objectives

1. To evaluate the change in forest covers in terms of leaf area index (LAI) from 2010 to 2019 in Kelantan River Basin
2. To measure the change in evapotranspiration (ET) and rainfall over Kelantan River Basin between 2010 and 2019.
3. To determine the relationship between LAI, ET and rainfall amount between 2010 and 2019 in Kelantan River Basin.

1.5. Scope of Study

In this study, it is hypothesised that rainfall decreases with reduced Leaf area index (LAI) as the land use and land cover changes from 2010 to 2019. This is because with reduced vegetation, the evapotranspiration rate is expected to be lower, hence reducing the amount of water vapour in the atmosphere. The reduced amount of atmospheric water vapour creates a dry environment over the vegetation, which restricts the air from achieving saturation to form clouds, thus affecting rainfall. This research focuses on Kelantan River Basin that is located in the north-eastern state in Peninsular Malaysia, that is Kelantan. The study utilises satellite data retrieved from Moderate Resolution Imaging Spectroradiometer (MODIS) and Global Precipitation Measurement mission (GPM) , but the processing of these data does not include bias correction and validation with ground data, and are thus considered as limitations of this study.

1.6. Significance of Study

This research would enable the understanding on the impact of forest cover change on the water cycle in The Kelantan River Basin. This will also open up opportunities for the growth and re-evaluation of the existing district physical structure in order to strengthen planning approaches for economic development and sustainability strategies.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

For centuries human has explored the forest as the primary source of living. Forests occupied 4 billion hectares or around 30% of the world's land area by nature in 2006 (Chang, 2006). There are the primary terrestrial species of the world and are spread across the globe. They may be categorized in various forms and with varying degrees of precision such as tree number, tree height, land usage, legal status and ecological role (Mori et al., 2016). The global estimate of the number of trees is 3 trillion, of which 1.4 trillion are in the tropics or subtropics, 0.6 trillion in the temperate regions and 0.7 trillion in the coniferous boreal forests (Pan et al., 2013).

In the tropics between 0 to 28 degrees north and south of the equator, the tropical tress are mainly of closed-canopy trees. The tropical forests are located in rainy areas, upon which the term rainforests was coined. The rainforests receive more than 200 cm of rainfall each year, either seasonally or year-round. The temperatures are consistently strong, between 20°C and 35°C (Olson et al., 2001). The high rainfall and temperatures in the rainforests translate into high humidity all year round. These forests are present in Asia, Australia, Africa, South America, Central America, Mexico and other Pacific Islands. Rainforest plants are very distinct from the temperate forest plants. In the rainforest, trees grow to a gigantic scale, assisted by solid, strut-like buttresses at the base of the trunk, helping to stabilize them in shallow forest soils. Massive creepers are twining along the trunks of the trees. A mature tropical lowland forest is made up of many layers. The top layer of vegetation consists of dispersed tall trees rising over a closed canopy layer created by the crowns of other plants. The canopy is the most fascinating aspect of the rainforest; this is where much of the flowering and fruiting of the plants takes place, attracting a number of amazing species. Under the canopy is the third sheet, made up of smaller trees whose crowns do not touch. Under this is a layer of woody and herbaceous shrubs. Finally, there's the field layer, which receives limited sunshine.

Further up the latitudes, the types of forests found are the boreal/taiga and temperate forests. The boreal forest comprises coniferous woodland belt that circumnavigates the northern hemisphere, passing across North America, Europe and Asia (Alexander et al., 2012). Boreal forests are important for carbon storage, with many coniferous and broad leaf forests in sub-polar regions increasing in vast subterranean carbon stores in the form of peat. Forests. On the other hand, temperate forests are a combination of deciduous, broad-leaved and evergreen coniferous plants (Gilliam, 2007). They span in regions such as East North America, North East Asia, and Western and Eastern Europe. They are more basic in form than the tropical forests, which host a limited number of tree species compared to that in the tropical forests. Temperate trees have been decimated over the years, but they are still growing in many regions and successfully developing carbon stores.

2.2. The roles of forest

Human have become very reliant on forests as we rely on forests to survive, from the air we breathe to the wood we use. In addition to providing habitats for wildlife and human livelihoods, forests also provide habitat protection, reduce soil erosion and mitigate climate change. Despite our reliance on trees, we have also push them to the brink of clearance and extinction. Forests provide home for millions of species and sustain a broad variety of organisms. About 90% of all animals on the world live in the forest. Animals such as lizards, frogs, rats, crocodiles, alligators, beetles, bats, butterflies and monkeys, and other wild animals such as lions and leopards, all live in woodland or in rivers and streams in protected regions. As a consequence, these species shape their food chains in the forests by communicating with each other in their respective physical conditions that create an ecosystem. Good habitats are important to the well-being of animal species. In comparison, millions of aboriginal people already reside in the forests and thrive on forest resources to survive.

Forests have a significant part to play in the climate. The most well-known roles of forests is in purifying atmospheric air. Throughout the day, trees and plants consume carbon dioxide for photosynthesis and emit oxygen. As such, they help to purify the air we breathe, in addition to reducing the volume of carbon dioxide and other greenhouse gasses in the atmosphere responsible for global warming. Also, forests often act as climate stabilizers, because trees and plants control ambient temperatures by evapotranspiration and environmental breeze. In urban environments, for example, the existence of trees may reduce the reliance on air conditioners. Broad forests control area temperatures by capturing the radiant heat of the sun and encouraging rainfall as well as the cool atmosphere as an consequence of evapotranspiration.

In addition, forests control the natural process of water evaporation and condensation and precipitation as rain. Forests render that possible by collecting and redistributing rainwater relatively evenly throughout the whole metropolitan region, often referred to as the water economy. Forests often collect large quantities of water from the precipitation and transfer it into the aquifers, replenishing the groundwater sources. As such, forests are also known to act as catchment, irrigation or drainage zones, because nearly all water comes only from land-based sources and rivers, reservoirs and streams in forest areas. The water in streams and rivers are shielded from drying because of the forest shades. The Amazon rainforest, for example, has one of the largest watersheds and river networks in the country. Many other protected areas across the globe often act as significant drainage areas.

2.3. The relationship between forest and rain

Forests play an enormous function in controlling the distribution of atmospheric moisture and weather cycles over land. Firstly, forests modulate the distribution of atmospheric moisture and water cycle through evapotranspiration, that is, the evaporation of water in plant leaves and transpiration of water from soil. Forest contributes to local moisture by transpiration (the mechanism through which plants emit water from their leaves) and therefore contributes to local rainfall. On average, at least 40% of rainfall over land originates from ET, with elevated contributions in certain areas such as the Rio de Plata River drainage in South America due to its large area coverage of forest (Van der Ent et al., 2010). Transpiration leads to a disproportionate share of terrestrial ET (Jasechko et al., 2013)., thus generating a portion of the vapour required for rainfall. 50 – 80 % of central and western Amazon humidity persists throughout the water cycle of the environment (Nobre et al ., 2009). In the water cycle, water vapour from ET is evaporated into the atmosphere, creating clouds through condensation of water vapour. The condensed water in the cloud eventually grow into rain drops that fall back to the plants and soul, repeating the cycle again. When the trees are cleared, less moisture is evaporated into the atmosphere, limiting cloud formation and development and subsequently breaking the chain of water cycling back onto the earth's vegetation and soil. If this occurs for a long period of time, the affected regions may be subjected to drought (Voldoire and Royer, 2004).

Secondly, forests modulate a significant part of the transfer of moisture. Makarieva and Gorshkov (2017) introduced the biotic pump hypothesis. The hypothesis indicates that the air passage that carries moisture to continental interiors is powered and sustained by broad, dense areas of forest originating from the coasts. At all scales, upwind, extra-basin influences are the biggest contributor to ambient rainfall to downwind, in-basin precipitation. Upwind terrestrial ET, mostly supported by forest cover, may have a substantial effect on the supply of catchment water within and around the catchment area. Consequently, all or most of the catchments are inevitably related (Ellison et al., 2017).

Thirdly, forests control local and global temperatures and hence the distribution of wind (Hesslerová et al., 2013). At the local level, woods will stay much cooler throughout the day due to the shade and hence the role of evaporation and transpiration in the reduction of excessive heat. Forests may therefore be of special significance to the so-called "wind pipes" in greater areas. Condensation on plant surfaces, particularly thick, epiphytic lichens and moss populations, offers adequate moisture for tree growth, ET, drainage, regeneration of groundwater, and eventually runoff (Pepin et al.,2010). High altitude forest depletion has drastic, detrimental effects for the supply of water. If these trees are eliminated, the ambient moisture contained in the clouds can be transferred to certain areas. This may reflect a major risk to the nearby downstream deployment. Low altitude woods, however, still play a positive role in subsurface conservation, flood control and improved drainage at local locations (Bruijnzeel,2004), and runoff in earth regions is greatly and positively impacted by catchment water holding ability (Zhou et al.,2015). However, in this research will focus how rainfall can be affected by forest change due to land use and land cover changes.

2.4. Deforestation in Malaysia and its effect on rainfall

The atmosphere in tropical has typical daily temperatures varying from 26 °C to 28 °C. During November to March and May to September there are two monsoon cycles that are North-East Monsoon and South-West Monsoon. Rainfall is abundant with a maximum of 2,000 mm to 4,000 mm each year (Anon, 1996). The clouds cut out a significant amount of clear sunshine in the afternoon and evening. Malaysia gets approximately 6 hours of clear sunshine per day. The Malaysian rainforests are well known with richness in biodiversity and is considered as one of the world's mega-diversity countries and ranked 12th in the world on the Global Biodiversity Index (Ministry of Natural Resources and Environment [NRE], 2011).

However, the natural rainforests of Malaysia have undergone a drastic transformation since the pre-colonial times. In 1511, the European conquest of Malaya, with the capture of Malacca by the Portuguese had seen a high international demand for herbs, gum Arabic, gutta percha and what was later termed 'minor forest goods' , leading to massive harvesting of forest resources. During the colonial period at the end of the 19th century, timber became the prime industry. Logged timber was used exclusively for production in construction, building of railway lines and for tin mining and smelting (Ang, 1994). Concurrently, there was an unparalleled demand for gutta percha, a latex-like exuDATE from the gutta taba or Taban trees. Such material was used for the isolation of sea cables used in pre-wireless era. It culminated in severe deforestation of the Taban trees as they were converted into rubber plantations, as well as for paddy cultivation to meet the demand for food supply at that time. At the same time or sooner, tin mining had also been a major industry (Chan, 1990) and vast tracts of lowland forest concessions were created, whereby lowland forests were felled for tin mining. Such regions were left open with almost no vegetation after mining. Around the beginning of the 1970s, oil palms were brought into commercial cultivation, and once again large regions of lowland forests were cultivated for this crop. Malaysia's ground area was once nearly completely populated by trees. Forests also occupy about 59.5% of the overall surface area in 2001 (Forest Department Peninsular Malaysia [FDPM], 2001). Nevertheless, deforestation continue and remain a big concern as lands and forestry resources are needed for future development.

Throughout the 20 years from 1983 to 2003, there was a loss of nearly 4.9 million hectares of land cover throughout Malaysia (Forestry Department Peninsular Malaysia [FDPM], 2013). This is almost four times the scale of Singapore with a total of 250,000 hectares of land is destroyed annually. Aside from degradation, the existing forests face challenges from intensive forestry, illicit harvesting, and encroachment. As a consequence of deforestation, forests releases less atmospheric moisture, thereby affecting the production of rainfall, leading to a decrease in rainfall amount. This may render the local environment becoming drier. Excessive deforestation around the Malaysian capital Kuala Lumpur, along with the dry conditions produced by El Niño, have caused tight water rationing in 1998 and for the first time the city had to import water (Fung, Huang, & Koo, 2020). With a drier environment, the probability for clouds to form is lowered due to the increased atmospheric stability. Even when clouds form, their development will be limited, including the formation of raindrops, hence reducing the amount of rainfall and subsequently reducing the availability of surface water in cities throughout Malaysia. Finally, the increased temperature that arise from both deforestation and El Niño could devastate temperate agriculture such as tea, potatoes, berries, cut flowers and ornamental plants. Studies have indicated that rising temperatures in Cameron Highlands and Genting Highlands are due to major woodland clearance (Razali et al., 2018). If this pattern remains, the consequences of a warming environment will be severe and widespread.

2.5. The responses of rainfall to deforestation

Land use and land cover change, in particular deforestation, have major effects on urban and remote ecosystems. For example, deforestation will explicitly alter the partitioning of heat fluxes and the water supply, contributing to change in precipitation (Mahmood et al.,2014) Tropical rainforests have lower albedos, wider leaf and stem areas for evapotranspiration, and higher heights than other plant types. Consequently, transforming rainforest to barren earth or grassland has three main impacts on land surface conditions: (1) a drop in evapotranspiration, (2) an rise in surface albedo and (3) a decrease in surface roughness. The results of tropical deforestation are heavily dependent on the spatial dimensions of deforestation, the regional ecosystems, and the mean temperatures of deforestation. Such large-scale deforestation studies typically indicate a cooler and drier atmosphere geographically over the deforested areas (Lawrence and Vandecar, 2015). The warming effect is induced by a significant decline in the surface latent heat flux, which overwhelms a smaller drop in net surface radiation, whereas the drying effect is triggered by a decline in transpiration, which can lead to a predicted decline in precipitation (Katul et al., 2012). Lawrence and Vandecar (2014) outlined the challenges in forecasting climate change induced by tropical deforestation on a continental and local scale; for example, precipitation may be decreased or increased in conjunction with the size and condition of deforestation. In relation to pasture or cropland, tropical forest plants sustain a high degree of evapotranspiration throughout the dry season, which is a significant source of ambient moisture that is returned back to rainfall regionally and subtropical.

Previous studies have concluded that there is a pronounced diurnal cycle of convection and precipitation highly affected by geographical characteristics, such as the thermal contrast between continents, oceans and mountain valley circulations, and modulated by monsoon wind in the tropical atmosphere (Kanamori et al., 2013). Deforestation often influences the dynamics of air circulation by changing the physical properties of the ground surface, the carbon cycle and the energy budget. Many research have attempted at studying the forest-hydrological cycle relationship, however, most research are conducted in a global scale with coarse resolution, thus limiting the fine scale processes required to understand the intricate forest-hydrological cycle relationship. Furthermore, such studies are very limited in Southeast Asia. Therefore, this study intends to bridge the gap by conducting a basin-scale research in Peninsular Malaysia, with a focus on the Kelantan River Basin.

CHAPTER 3

MATERIAL AND METHOD

3.1. Study Area

The Kelantan River Basin (KRB) is situated within the north-eastern Peninsular Malaysia between 4° – 6° N and 101° – 103° E (to Figure 3.1) .The KRB covers an area proximately 12,000 km^2 , which is cover 85% of the Kelantan State. The basin is dominated by forests (76%), followed by rubber plantation (11%), oil palm plantation (11%) and other land-uses (2%) in 2008. The elevations within the KRB range from 8 to 2174 m , with mountain ranges in the western and south-western regions of the basin. The KRB has a tropical climate, with abundant rainfall throughout the year, range from 2000 to 4000 mm/year (Tan et al., 2016). The basin receives heavy rainfall during the northeast monsoon (NEM) between November and January, and a drier condition during the southwest monsoon (SWM) between May and August.

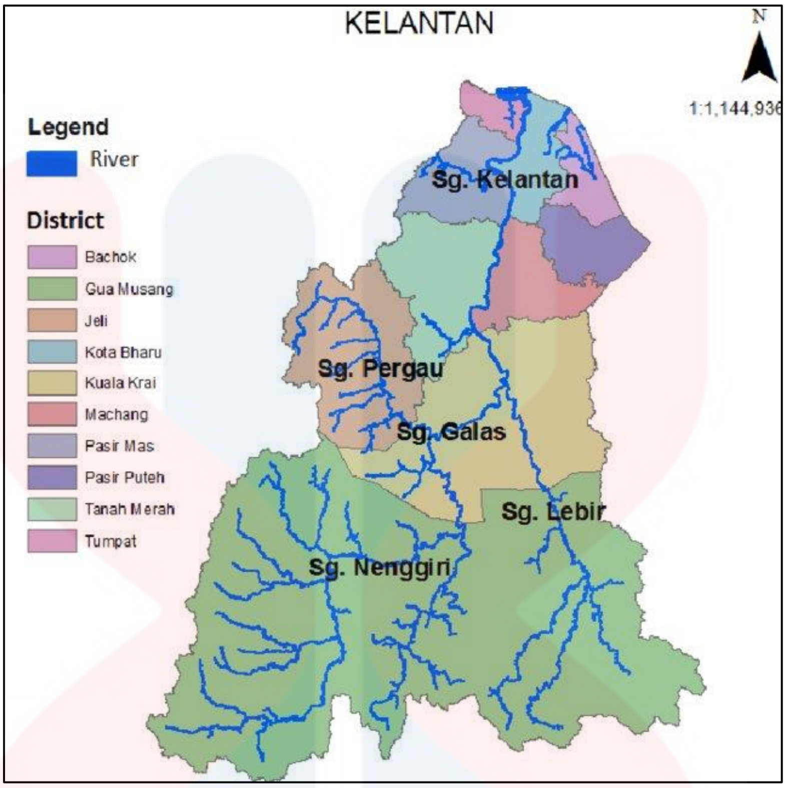

Figure 3.1: Kelantan River Basin (Source: Adnan et al., 2014)

3.2. Research Tool

In this study, the data have been extracted from Application for Extracting and Exploring Analysis Ready Samples (AρρEEARS) USGS website at https://lpdaacsvc.cr.usgs.gov/appeears/ for ET (MYD16A2GF) and LAI (MYD15A2H). Rainfall is extracted from Global Precipitation Measurement Mission (GPM).

3.3. Secondary Data

The study utilised secondary data in the form of satellite-based data. The main variables that has be explored in this study are rainfall that extracted from the Global Precipitation Measurement (GPM) mission an international network of satellites that provide next-generation global observations of rain and snow., evapotranspiration (ET) from the MYD16A2GF Version 6 Evapotranspiration/Latent

Heat Flux (ET/LE) product of a year-end gap-filled 8-day composite dataset produced at 500 meter (m) pixel resolution., and the leaf area index (LAI) from the MYD15A2H Version 6 Moderate Resolution Imaging Spectroradiometer (MODIS) combined Leaf area index (LAI) and Fraction of Photosynthetically Active Radiation (FPAR) product of an 8-day composite dataset with 500 meter (m) pixel size., for the years between 2010 and 2019. However, in year 2019 recorded the least amount of rainfall because the data collected for rainfall was only available up to eight months.

The evapotranspiration data serves as a measure of how much water vapour is released into the atmosphere from the vegetation, which we represent using the LAI. From there, we investigated the relationship between ET, LAI and rainfall. The data of ET have to be averaging by multiply for scale factor of 0.1 $kg/m^2/year$ to get an annual for 8 day data and it the same for LAI data also.

3.4. Statistical Analysis

Three variables are identified for this study, where the response variable Y is the amount of rainfall, which is assumed to be a function of two predictor variables i.e.; X_1= LAI and X_2= ET. These two predictor variables influence the rainfall amount as they are altered by LULCC, which then may influence in the water cycle in Kelantan river basin area. The Mann-Kendall trend analysis was performed to determine the time-series trends of ET, LAI and rainfall. Pearson correlation coefficient between each individual variable were obtained to determine the correlation before proceeding to multiple linear regression analysis that determine the influence of correlation of either ET or LAI with rainfall.

CHAPTER 4

RESULT AND DISCUSSION

4.1. Introduction

This chapter presents the results for ET, LAI and rainfall obtained from satellite data between 2010 and 2019, as mentioned in Chapter 3. The data is analysis to find the relationship between rainfall and ET, LAI.

4.2. Annual and monthly analysis

Figure 4.2 shows the mean values for ET, LAI and rainfall in annual (a – c) and monthly (d – f) time scales in Kelantan River Basin between 2010 and 2019. While, Figure 4.3 shows the median values for ET, LAI and rainfall in annual (a – c) and monthly (d – f) time scales in Kelantan River Basin between 2010 and 2019.

Annually, the amount mean of ET are estimated between 2.66mm^2 and 2.98mm^2, with higher amount recorded in 2019 follow by 2010 and 2015. September recorded the highest amount of ET, followed by April and February, and December recorded the least amount of ET. On the other hand, the annual mean LAI showed indices ranging between 0.30 and 0.35 with highest indices observed in 2019. The years with the lowest LAI are 2011 and 2013. March recorded the highest amount of LAI and December recorded the least amount of LAI.

The annual mean rainfall showed 2017 received the highest rainfall in Kelantan, while 2015 received the least rainfall. Here, result suggested that 2019 recorded the least amount of rainfall but that is because the data we collected for rainfall was only available up to eight months (Figure 4.2 c). In terms of monthly variations, February recorded the least amount of rainfall, while December recorded the highest amount of rainfall. (Figure 4.2 f).

Annually, the amount median of ET are estimated between 25.81mm^2 and 30.67mm^2, with higher amount recorded in 2010, 2015 and 2019. March recorded the highest amount of ET, followed by June and May, and January recorded the least amount of ET. On the other hand, the annual median LAI showed indices ranging between 2.92 and 3.73 with highest indices observed in 2019. The years with the lowest LAI are 2013 and 2014. September recorded the highest amount of LAI and January recorded the least amount of LAI.

The annual median rainfall showed 2017 received the highest rainfall in Kelantan, while 2015 received the least rainfall. Here, result suggested that 2019 recorded the least amount of rainfall but that is because the data we collected for rainfall was only available up to eight months (Figure4.3 c). In terms of monthly variations, June recorded the least amount of rainfall, while January recorded the highest amount of rainfall. (Figure 4.3 f) However, it is widely known that Kelantan often receives the most rainfall in the month of December due to the north-east monsoon that brings heavy rain annually (Alias et al., 2016).

Based on the results presented in figure 4.2 and figures 4.3 (a – c) the annual median ET and LAI 2019 the highest, suggesting an increase in vegetation which may have contributed to the increase in ET (Bai et al., 2019).

Theoretically, an increase in ET may lead to increased rainfall, however, this was not captured in the results as the rainfall data for 2019 covered only rainfall between January and August. Another way to infer the relationship between ET, LAI and rainfall is to look at the monthly average median values (Figures 4.3 (d – f). In September, the values of ET and LAI were the highest, however, the rainfall amount was low.

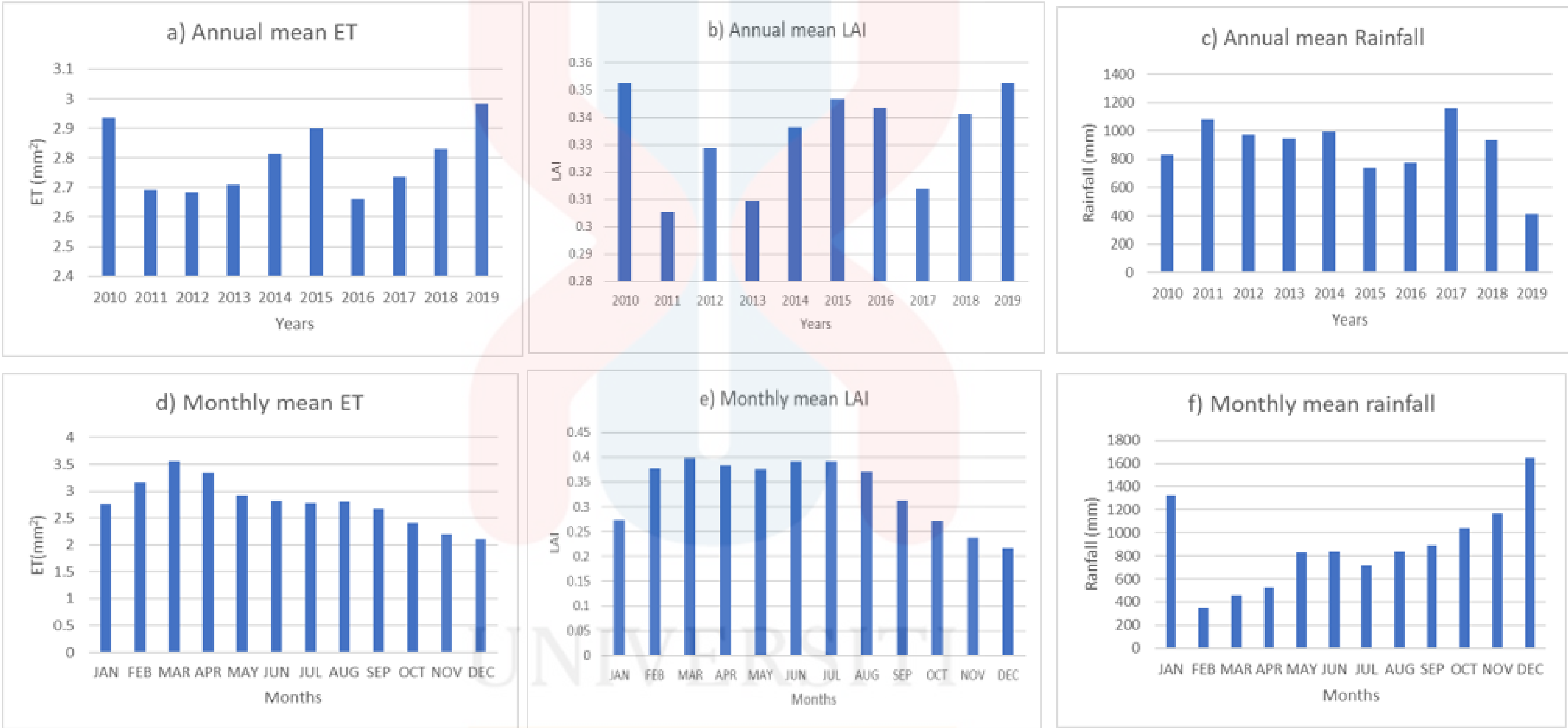

Figure 4.2: Annual mean (a) ET, (b) LAI, (c) Rainfall, and monthly mean (d) ET, (e) LAI, (f) rainfall in Kelantan River Basin from 2010 to 2019

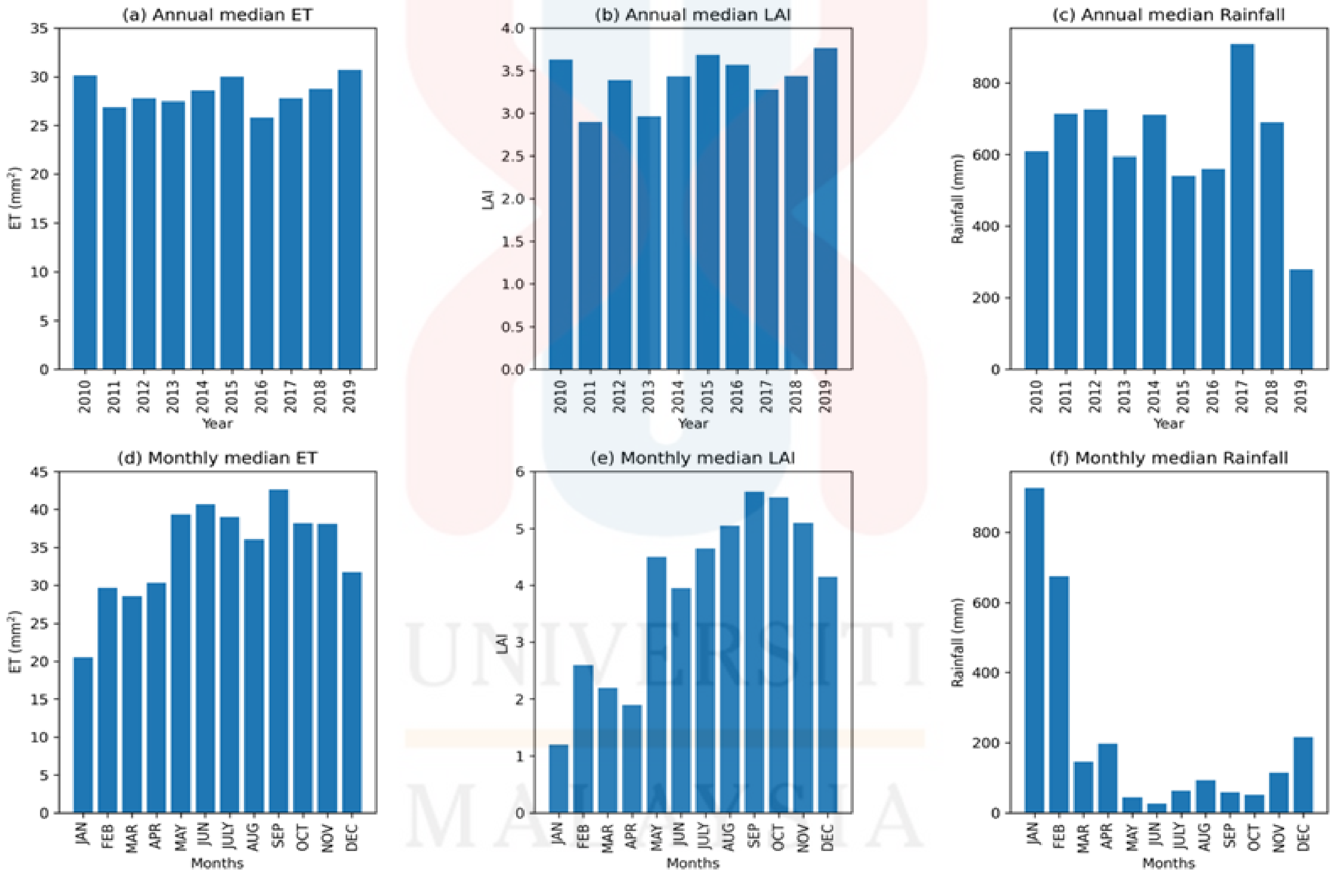

Figure 4.3: Annual median (a) ET, (b) LAI, (c) Rainfall, and monthly median (d) ET, (e) LAI, (f) rainfall in Kelantan River Basin from 2010 to 2019

4.3. Time – series analysis through 2010 -2019

Figure 4.2 shows the annual time series plot for (a) ET, (b) LAI and (c) rainfall. Generally, each plot showed similar yearly trends. For example, the ET trends showed increasing trend from the beginning of the year and remained fairly constant between the summer months before it started to decrease towards the year end. This pattern continued every year. Similarly, LAI showed increasing trend to begin and ending with a decreasing trend towards the end of year, and this pattern continued for the other years. For rainfall, the amount of rainfall showed a generally increasing trend that tend to peak towards end of the year.

A time-series analysis using the Mann-Kendall analysis was conducted for all three parameters as presented in Table 4.1. In general, the results showed a decreasing trend in both ET and LAI, and an increasing trend in rainfall. No trends were found for ET in 2011, 2012 and 2017, and no trends were found for LAI in 2011, 2012, 2013, 2015, 2017, 2018. Meanwhile, for rainfall, no trends were found in 2011, 2012, 2013, 2016 and 2017, and a decreasing trend was found in 2019, but this decreasing trend could be affected by the lack of rainfall data in 2019. The magnitude of change ranges between -6.39 and -1.85 for ET, -0.95 and -0.05 for LAI, and -55.17 and 305.39 for rainfall. The p–value of change ranges between 0.00066482 and 0.000000004125 for ET, 0.00090585 and 1 for LAI, and 0.00333335 and 0.000023491 for rainfall.

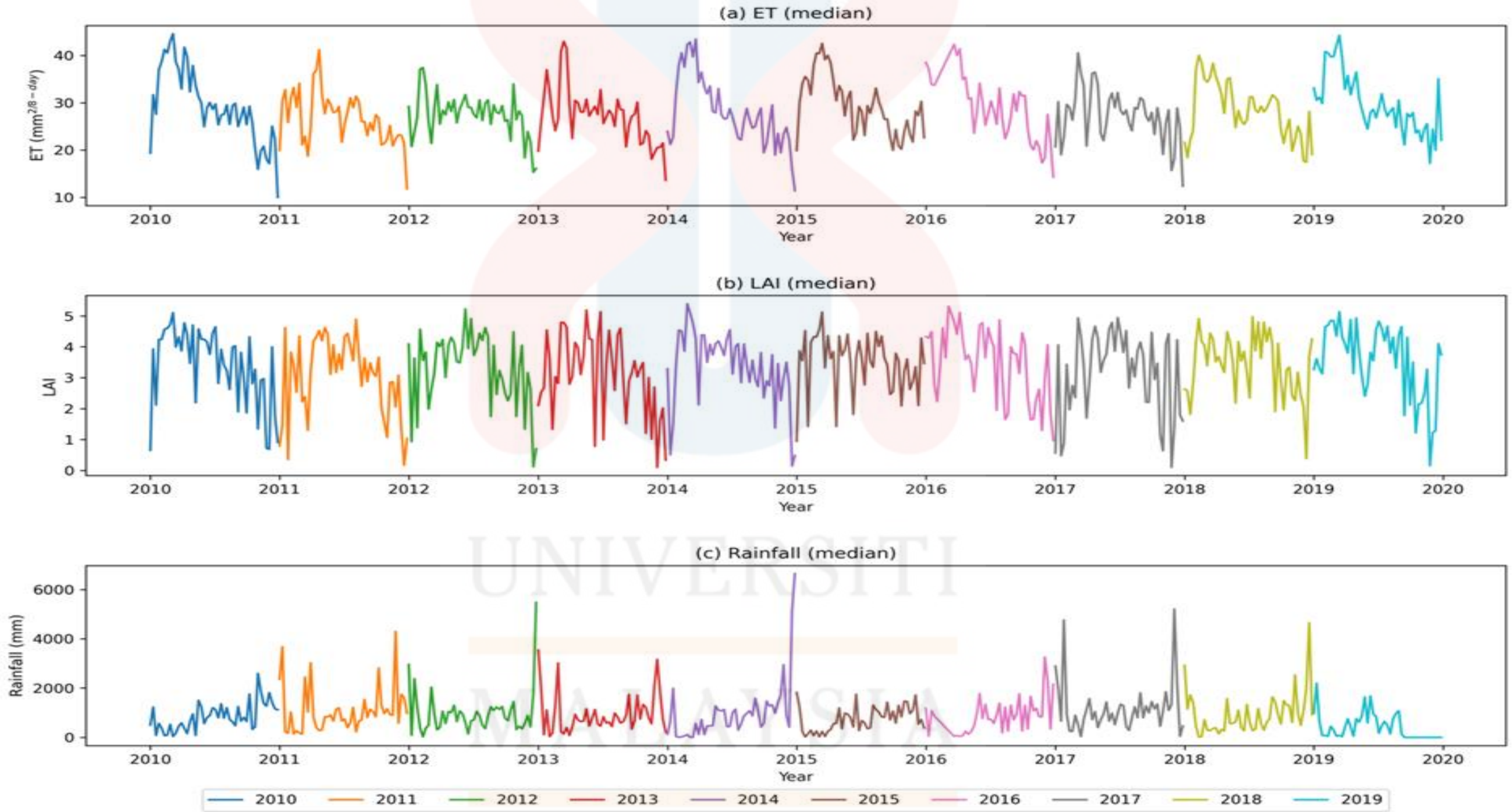

Figure 4.4: Annual time-series plot for (a) ET, (b) LAI, (c) rainfall in Kelantan River Basin from Jan 2010 to Dec 2019

Table 4.1: Mann – Kendall plot for (a) ET, (b) LAI, (c) rainfall in Kelantan River Basin from Jan 2010 to Dec 2019.

Year	ET			LAI			Rainfall		
	P – Value	**Slope**	**Trend**	**P – Value**	**Slope**	**Trend**	**P – Value**	**Slope**	**Trend**
2010	0.00000064455	-6.39167	decreasing	0.00090585	-0.9	decreasing	0.000023491	305.39061	increasing
2011	0.17996993	-2.9	no trend	0.3532628	-0.33333	no trend	0.05003082	149.400291	no trend
2012	0.17996993	-1.85	no trend	0.1178509	-0.45	no trend	0.07953061	56.0355479	no trend
2013	0.00066482	-3.55	decreasing	0.34808262	-0.375	no trend	0.17996993	80.3716023	no trend
2014	0.0000092025	-6.35	decreasing	0.0010843	-0.95	decreasing	0.000023491	290.724191	increasing
2015	0.00013549	-4.18333	decreasing	0.25145219	-0.38333	no trend	0.0013867	170.112589	increasing
2016	0.000000004125	-7	decreasing	0.00042247	-0.83333	decreasing	0.60605653	59.8446268	no trend
2017	0.25655831	-2.06667	no trend	1	-0.05	no trend	0.17996993	138.615924	no trend
2018	0.0013867	-4	decreasing	0.83570503	-0.15833	no trend	0.00535546	185.587659	increasing
2019	0.000000004125	-5.275	decreasing	0.01767922	-0.71667	decreasing	0.00333335	-55.171	decreasing

4.4. The relationship of ET, LAI and rainfall

Figure 4.5 shows the relationship between (a) LAI and ET , (b) LAI and rainfall and (c) ET and rainfall. Positive correlation was found between LAI and ET with Spearman's rho of 0.65, R^2 of 0.39 and a regression line of $y = 2.52x + 19.8$ .The relationship between of LAI and ET is very strong as we know that ET is come tree and represent by LAI. Negative correlation was found between LAI and rainfall with Spearman's rho of – 0.18, R^2 of 0.06 and a regression line of $y = -80.29x + 906.5$. The connection between rainfall and LAI is weak as the Rainfall is not dependent overall to LAI. Negative correlation was found between ET and rainfall with Spearman's rho of – 0.34, R^2 of 0.10 and a regression line of $y = -26.1x + 1374.05$. The connection between rainfall and ET is weak as the Rainfall is not dependent overall to ET and can come to various of sources of contribution to rainfall. All of the p-values obtained were zero, meaning that the null hypothesis is highly significant true the related variable.

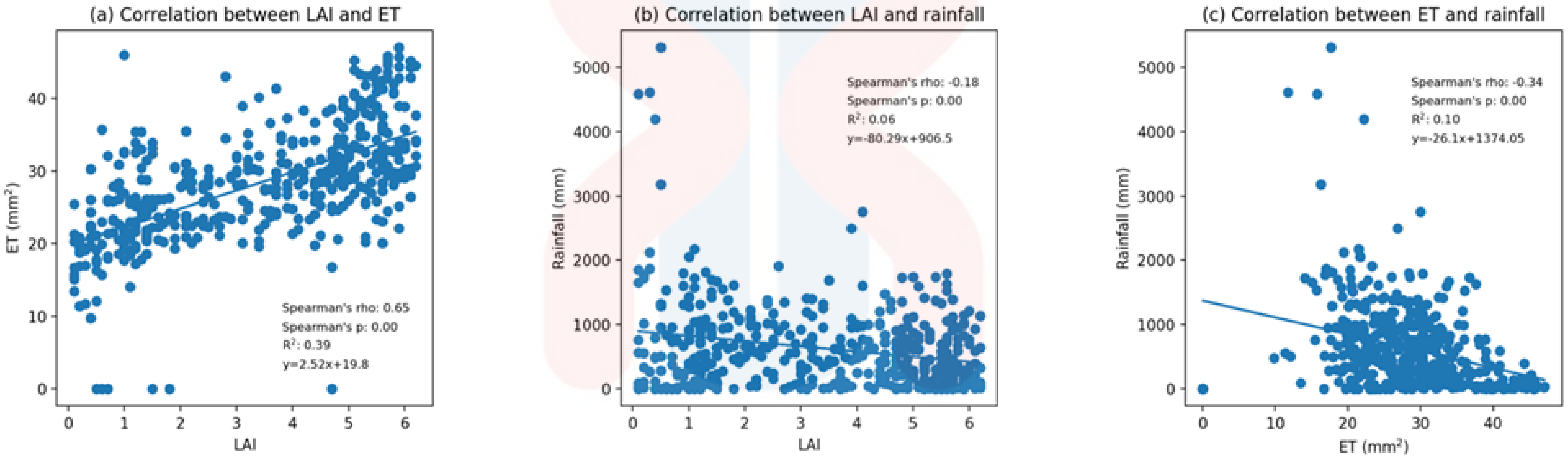

Figure 4.5: Scatter plots of the correlation between (a) LAI and ET, (b) LAI and rainfall, (c) ET and rainfall.

Table 4.2 shows the descriptive statistics for rainfall, LAI and ET. The mean for rainfall, LAI and ET are 889.58mm, 3.321 and 27.853mm^2. The standard deviations for rainfall, LAI and ET 843.817, 1.1846 and 6.972. The N – value for all variable is the same 460. Table 4.3 shows the results for multilinear correlation analysis. The Pearson Correlations between LAI and rainfall (-0.328) as well as between ET and rainfall (-0.313) were negative, suggesting a weak correlation. This suggests that ET and LAI do not necessarily contribute to increase amount of rain, as was theorised. Nonetheless, it is acknowledged that the results may be influenced by variability in seasonal weather patterns such as the north-eastern and south-western monsoon seasons or El Niño and Southern Oscillation (ENSO).

Table 4.2: Descriptive Statistic of Multilinear Regression

Descriptive Statistics		
	Mean	**Std. Deviation**
Rainfall (mm)	889.58	842.817
LAI	3.321223	1.1846236
ET (mm^2)	27.853190	6.9723475

Table 4.3: Multilinear Correlation Analysis

Correlations				
		Rainfall	**LAI**	**ET**
Pearson Correlation	Rainfall	1.000	-.328	-.313
	LAI	-0.328	1.000	0.599
	ET	-0.313	0.599	1.000
Sig. (1-tailed)	Rainfall	.	0.000	0.000
	LAI	0.000	.	0.000
	ET	0.000	0.000	.
N	Rainfall	460	460	460
	LAI	460	460	460
	ET	460	460	460

CHAPTER 5

Conclusion and Recommendation

5.1. Conclusion

This study aims to study the impact of forest cover change on rainfall in Kelantan River Basin based on the relationship between LAI, ET and rainfall between 2010 and 2019. Satellite data products were used to get the data for LAI, ET (both from MODIS) and rainfall (from Global Precipitation Measurement).

The results from this study showed a decreasing trend in ET and LAI from 2010 and 2019, and an increasing trend in rainfall from 2010 and 2019 (Figure 4.3). Further regression analysis showed a negative correlation between LAI and rainfall, as well as ET and rainfall, yet under-studied argument that higher LAI and/ or ET leads to higher rainfall. It should also be noted that the rainfall data for 2019 consisted of only the first eight months, which may affect the analysis and interpretation of the results of this study, and is thus acknowledged as one of the limitations in this study. More limitations are described in the Section 5.2, followed by recommendations for future studies in Section 5.3 in order to better explore and understand this relationship.

5.2. Limitation of study

Several limitations in this study are acknowledged to may have affected the results and discussion of the study. Firstly, as mentioned in Chapters 3 – 5, the rainfall data in 2019 was limited to only the first eight months which may affect the trend, correlation and regression analyses performed in this study. Secondly, bias correction and validation of satellite data with ground data were not performed prior to this study and is thus recommended to be included in future studies as presented in Section 5.3.

5.3. Recommendations for future studies

To understand the relationship between ET, LAI and rainfall better, this study can be extended to include validation of the satellite data products to ensure the accuracy and reliability of the satellite data obtained. A bias correction upon the satellite data is also recommended as this was not included in the current study. Next, more parameters can be included to investigate other hydroclimate parameters that may have influence on the rainfall amount in Kelantan River Basin, as this study only investigated the effects of only two parameters (ET and LAI) on rainfall. Last but not least, the study can be categorised according to monsoonal periods or narrowed down to when synoptic disturbances such as ENSO is minimal or inactive.

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