UNIVERSITI PUTRA MALAYSIA

CLIMATE AND LAND USE CHANGES IN RELATION TO RUNOFF VARIABILITY IN THE KELANTAN RIVER BASIN USING SCS-CN AND GEOSPATIAL TECHNOLOGY

MOHAMMAD FAIZALHAKIM BIN AHMAD SHAFUAN

FH 2017 9

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By

MOHAMMAD FAIZALHAKIM BIN AHMAD SHAFUAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2017

DEDICATION

My humble effort I dedicated to

My sweet and loving parents
Mr. Ahmad Shafuan Bagimin and Mrs. Azizah Abdul Aziz

My siblings
Aziemah Syazana, Haniesah Rafiedah, Mohammad Nazri Syafie, Iezan Syakila, Aqmar Ruqayyah and Ahmad Syukri Azizi
for the overwhelming support and enormous sacrifices

My supervisory committee
Dr. Siti Nurhidayu Abu Bakar and Dr. Norizah Kamarudin
for valuable opportunities unconditional support

My MSc comrades
Nik Harun, Jamhuri, Husba, Fatimah, Syuhada, Zulfa and Raja Nazrin
for your concern and encouragement

other people who involved directly and indirectly in my MSc journey but not mentioned

thank you for your kind assistance and
only Allah can repay your kindness

THE FLOOD
BY GEORGE C. RHODERICK, JR

Onward speeds the mighty rivers,
In their mad and wild career;
Down through cities, towns and hamlets,
Causing misery far and near.

On through fertile plains and valleys,
On the raging billows ride;
Carrying with them deep destruction
And distress on every side.

Higher, higher, grows the flood-tide.
Deeper, deeper, is the gloom;
Homeless thousands, starving hundreds.
Is the city's awful doom.

Busy streets turned into rivers
Quiet homes made desolate,
Awful ruin, dire destruction.
Is the city's sad, sad fate.

Oh! I hear the saddened cry for help
The wail of sore distress;
Oh! Hear the awful cry of woe
That comes from out the west.

Oh! Sky of dark and sullen clouds.
Give way to sunshine's rays;
Oh! Dashing waves that spread the land,
Give way to happier days.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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September 2017

Chairman: Siti Nurhidayu Binti Abu Bakar, PhD
Faculty: Forestry

Increasing magnitude and frequency of catastrophic natural disasters such as floods proves that climate change is unequivocal. It is related to prolonged and extreme rainfall (>500ARI), in addition to massive land use conversion that contributed to severe flooding in 2014. To clarify the local debate on causes of flooding, this study integrates SCS-CN and geospatial analysis to investigate the effects of land use and climate change on runoff based on historical data from 1984 to 2014 in the Kelantan River Basin. From 1984 to 2014, the climate in Kelantan River Basin is discovered increasing trends in terms of rainfall (41.13 mm year^{-1}), rain days (1.58 days year^{-1}) and temperature (0.07°C year^{-1}). While, the rates of deforestation in Kelantan River Basin was 8,870 ha year^{-1} and an expansion of rubber and oil palm plantations was 1,480 and 4,060 ha year^{-1}, respectively. It is resulting to gradual increase by 120 and 164% in the estimated runoff using SCS-CN in the Kelantan River Basin on 2004 and 2014, respectively. The results suggest that steady deforestation and gradual expansion of oil palm and rubber plantation, as well as global and localised climate change, intensified the runoff generation in the basin. The correlation analysis suggests that the climate change as being more influential than land use changes towards runoff generation. While the SCS-CN method on a localised scale revealed that large agriculture expansion is a major contributor to runoff, as compared to rainfall events. The extensive land clearing areas found in the hilly areas, unclear buffer zone, poor soil conservation practices and poor drainage system as the contributors to high potential runoff areas (i.e. Gua Musang, Lojing, Pergau, Kuala Betis, Jeli, Kuala Krai and Kota Bharu) are among the factors contributing to high runoff. Integrated land use management and river basin management approach should be extensively implemented to lessen the consequences on the environment while maximising the benefit to economic and social aspects.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

KESAN PERUBAHAN GUNA TANAH DAN IKLIM KEPADA ALIRAN AIR DI LEMBANGAN SUNGAI KELANTAN MENGGUNAKAN SCS-CN DAN TEKNOLOGI GEOSPATIAL

Oleh

MOHAMMAD FAIZALHAKIM BIN AHMAD SHAFUAN

September 2017

Pengerusi: Siti Nurhidayu Binti Abu Bakar, PhD
Fakulti: Perhutanan

Peningkatan magnitud dan kekerapan bencana alam seperti banjir membuktikan bahawa perubahan iklim tidak boleh dinafikan lagi. Ini dikaitkan dengan hujan lebat melampau (>500ARI) serta perubahan guna tanah secara besar-besaran juga menyumbang kepada bencana banjir pada 2014. Untuk memastikan perbincangan orang tempatan mengenai punca banjir, kajian ini mengintergrasikan kaedah SCS-CN dan analisis geospatial untuk menyiasat kesan perubahan guna tanah dan perubahan iklim kepada aliran air berdasarkan rekod data dari 1984 hingga 2014 di Lembangan Sungai Kelantan. Dari 1984 sehingga 2014, iklim di Lembangan Sungai Kelantan menunjukan peningkatan pada hujan (41.13 mm setahun), hari hujan (1.58 hari setahun) dan suhu (0.07°C setahun). Manakala, kadar pembukaan hutan di Lembangan Sungai Kelantan adalah (8,870 ha setahun) dan pertambahan keluasan kawasan ladang getah (1,480 ha setahun) dan kelapa sawit (4,060 ha setahun) dari 1994 hingga 2014. Sebagai hasilnya adalah peningkatan ketara dalam anggaran aliran air yang menggunakan SCS-CN sebanyak 120 dan 164% pada 2004 dan 2014 di Lembangan Sungai Kelantan. Hasil kajian mendapati pembukaan hutan dan peluasan kawasan kelapa sawit dan getah yang berterusan, serta perubahan iklim dunia dan tempatan, akan meningkatkan penjanaan aliran air dalam lembangan sungai. Analisis korelasi mendapati perubahan iklim adalh lebih mempengaruhi penjanaan aliran air berbanding perubahan guna tanah. Namun, kaedah SCS-CN pada skala tempatan mendapati pembukaan besar kawasan pertanian merupakan penyumbang utama kepada aliran air, berbanding kepada hujan. Pembukaan kawasan secara meluas dijumpai di kawasan berbukit dengan zon pemampan sungai yang tidak jelas, amalan pemuliharaan tanah yang lemah dan sistem perparitan yang tidak terurus dikenalpasti sebagai faktor penyumbang kepada kawasan berpotensi tinggi untuk aliran air seperti di Gua Musang, Lojing, Pergau, Kuala Betis, Jeli, Kuala Krai dan Kota Bharu. Pendekatan bersepadu pengurusan guna tanah dan pengurusan lembangan sungai perlu dilaksanakan secara menyeluruh untuk mengurangkan kesan terhadap alam sekitar, disamping memaksimakan manfaat kepada aspek ekonomi dan sosial

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In the Name of Allah S.W.T., the Most Benevolent and the Most Merciful

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I certify that a Thesis Examination Committee has met on 15 September 2017 to conduct the final examination of Mohammad Faizalhakim bin Ahmad Shafuan on his thesis entitled "Climate and Land Use Changes in Relation to Runoff Variability in the Kelantan River Basin using SCS-CN and Geospatial Technology" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Hazandy bin Abdul Hamid, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mohd Hasmadi bin Ismail, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

Wardah Tahir, PhD
Associate Professor
Universiti Teknologi MARA
Malaysia
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 30 November 2017

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of requirement of the degree of Master of Science. The members of the Supervisor Committee were as follows:

Siti Nurhidayu Abu Bakar, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Norizah Kamaruddin, PhD
Senior Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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I hereby confirm that:

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- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
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Name and Matric No.: Mohammad Faizalhakim B. Ahmad Shafuan (GS44062)

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This is to confirm that:
- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ________________________
Name of Chairman of Supervisory Committee: Dr. Siti Nurhidayu Abu Bakar

Signature: ________________________
Name of Member of Supervisory Committee: Dr. Norizah Kamarudin .

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λ	Ratio initial abstraction
AAR	Average annual rainfall
ABFI	Antecedent base flow index
AMC	Antecedent moisture condition
AOI	Area of interest
API	Antecedent precipitation index
AWS	Automatic weather station
C	Contoured
CC	Cloud cover
CN	Curve number
C&T	Crop and contoured
CRC	Crop residue cover
CRED	Centre for Research on the Epidemiology of Disasters
DID	Department of Irrigation and Drainage, Malaysia
DOA	Department of Agriculture, Malaysia
e.g.	for example
et al	and others
etc	*et cetera*
EV	Evaporation
F	Actual infiltration
FDPM	Forestry Department of Peninsular Malaysia
GIS	Geographical Information System
GR	Global radiation
HSG	Hydrologic Soil Group
i.e.	that is
I_a	Initial abstraction
IPCC	Intergovernmental Panel on Climate Change
ISODATA	Iterative self-organizing data analysis
KFD	Kelantan State Forestry Department
km	Kilometers
KNMI	Koninklijk Nederlands Meteorologisch Instituut
KRB	Kelantan River Basin
L	Hydrologic abstractions
m	Meter
Mm	Millimeter
MMD	Malaysia Meteorological Department
MPOB	Malaysian Palm Oil Board
MRSA	Malaysian Remote Sensing Agency
MRB	Malaysian Rubber Board
MSLP	Atmospheric pressure
m^3s^{-1}	Meter cubic per second
NEH	National Engineering Handbook
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Services
NSE	Nash-Sutcliffe Efficiency
P	Precipitation

MRB	Malaysian Rubber Board
P_a	Annual precipitation
Q	Runoff
Q_a	Annual runoff
RE	Relative error
RF	Rainfall
RH	Relative humidity
RS	Remote sensing
S	Maximum retention
SAR	Safe and rescues
SCS-CN	Soil Conservation Service Curve Number
SH	Sunshine hour
SMI	Soil moisture index
SPOT-5	Satellite Pour l'Observation de la Terre 5
SR	Straight row
SVL	Soil Vegetation Land
TE	Temperature
TR-55	Technical Release-55
UHI	Urban Heat Index
UNEP	United Nation Environment Programme
UNISDR	UN Office for Disaster Risk Reduction
U.S.	United State
USA	The United State of America
USDA	United State Department of Agriculture
USGS	United State Geological Survey
VSA	Variable Source Area
WMO	World Meteorological Organization
WS	Wind speed

CHAPTER 1

INTRODUCTION

1.1 General Background

1.1.1 Climate change

Climate change is a large-scale and long-term shift in the global climate conditions (IPCC, 2015). It is a regular part of the Earth's natural variability, which is related to interactions between the atmosphere, ocean, and land, along with changes in the solar radiation amount that reaching the Earth. At present, warming of the climate system is unambiguous, as evidenced through increasing atmospheric and oceanic temperatures, diminishing amounts of snow and ice, and continuously rising sea levels across the globe (IPCC, 2014) (Figure 1.1).

The global climate is dynamic and changing through the natural cycle (e.g. volcanic eruption and continental drift). However, the anthropogenic factors involved due to human activities gradually accelerated the climate towards rapid natural processes (Goudie, 2013). Burning of fossil fuel (Vitousek *et al*., 1997), release of carbon and greenhouse gases (Cox *et al*., 2000), land clearing and conversion of natural ecosystems (i.e. transformation of forests into agricultural sites and urban areas) (Malhi *et al*., 2002) are examples of human influence towards climate change.

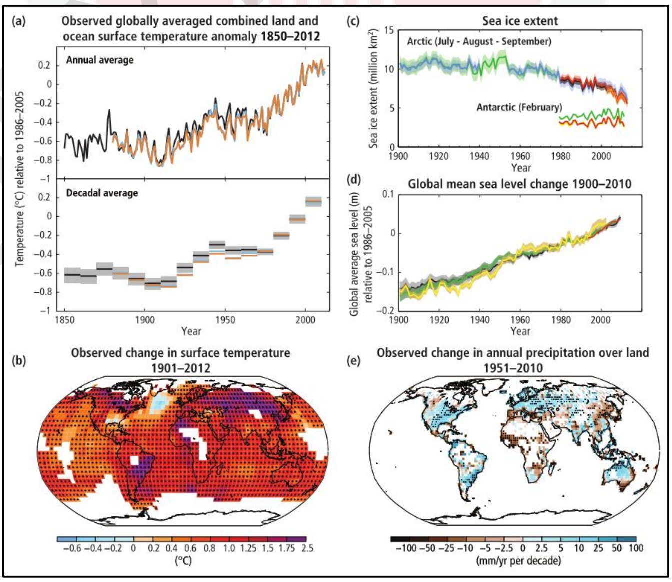

Figure 1.1 : Changing global climate system observed by multiple observed indicators (Source: IPCC, 2014)

Observed cumulative records in the 5th Assessment Report by Intergovernmental Panel on Climate Change (IPCC) affirmed clear and expanding human influence on the global climate system, with noticeable effects based on worldwide hydroclimate data - encompassing rainfall, temperature, extent of ice and sea levels (Pachuari *et al*., 2014). These are accelerated by human activities (e.g. emission of greenhouse gases and land use conversion). The human influence on land use changes was once considered a local environmental problem but is quickly becoming a worldwide concern (Foley, 2005).

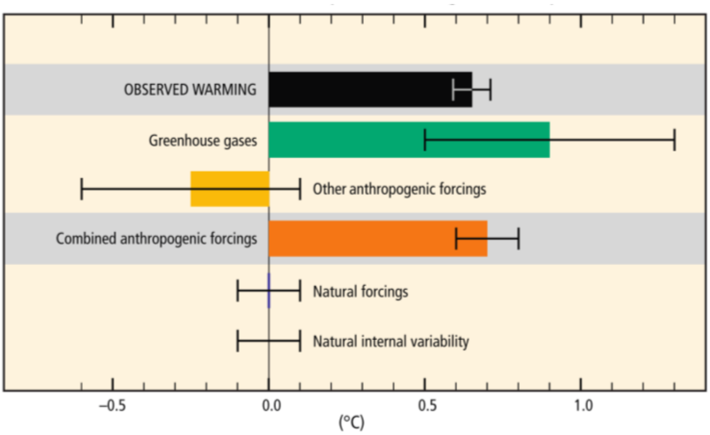

Figure 1.2 : Contributions to observed global surface temperature over the period 1951-2010 (Source: IPCC, 2014)

The human interference through land use changes can contribute significantly to climate change, as interference of natural vegetation and land storing carbon and greenhouse gases leads to global warming (Malhi *et al*., 2002) (Figure 1.2). Large-scale land use conversion from forests into agricultural sites (Costa *et al*., 2003) and urban areas are performed to meet the demand for food and obtain economic benefits. In addition, residential and industrial areas can amplify anthropogenic climate change (Satterthwaite, 2009) by altering functions of ecosystem (e.g. climate regulation, carbon storage), particularly in tropical areas. The changes in land use and land cover affect climate processes in local, regional, and global scale.

1.1.2 Land use change

According to FAO/UNEP (1999), land use is "characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it". On the other hand, United Nations Framework Convention on Climate Change (UNFCCC) combines land use, land use change and forestry (LULUCF) as "a greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land use change and forestry activities" (Noble *et al*., 2000). LULUCF was addressed in the UNFCCC Convention due to it being one of the contributing factors towards the concentration of CO_2 in the atmosphere, thus considered as a global concern in influencing climate change.

Another term used is land-use and land cover change (LULCC), which became a focal subject in global climate change study. It is a prioritized for improving the essential understanding of LULCC in relations with human, biogeochemical, and biogeophysical dynamics (Houghton *et al*., 2012). Also, LULCC impacts regional and global climate system, and also the functioning of the socioeconomic system (Ward *et al*., 2014). Land use comprises the alteration of natural into built environment (i.e. settlements) and semi-natural habitats (i.e. arable fields, pastures, and managed woods).

About one-third of the global land surface has been transformed by LULCC (Vitousek *et al*., 1997), generally through deforestation and natural conversion to cropland (Ellis, 2011). The influences of past, present and potential future of LULCC on climate and the carbon cycle were revealed in some recent studies (i.e. Mahowald *et al*., 2017; Quesada *et al*., 2017). Land use change is linked to economic development, population growth, technology, and environmental change. Houghton (1994) found the rate of land use change frequently corresponding to population growth, where it diminishes locally as economic development increases.

Lethal local and regional effects of deforestation include lesser rainfall, amplified frequency and severity of floods, soil erosion, reduced capacity of soils to hold water, and siltation of dams (Houghton, 1990; Guimberteau *et al*., 2017). Changes in land use are projected to contribute about 25% to the enhanced greenhouse effect intended by human-caused of greenhouse gases emissions (Houghton, 1990). Most of this contribution are released by carbon dioxide into the atmosphere as a consequence of deforestation. Additionally, land use change releases significant amounts of other gases (i.e. methane, carbon monoxide, and nitrous oxide) and particulates affecting the radiative and chemical properties of the atmosphere (Houghton, 1994).

1.1.3 Impacts of climate change and land use change

Changing climates and land use changes have a notable impact on the natural system over continents and across the oceans (Pachauri *et al*., 2014; Nobre *et al*., 2016). Many terrestrial, freshwater and marine species have shifted the geographic ranges, seasonal activities, migration patterns, abundances and interactions in reaction to climate change (Thuiller, 2007). Many studies over a broad range of regions and crops reveals that adverse impacts of climate change on crop yields have been overtake the positive impacts (IPCC, 2014).

The changing precipitation or melting snow and ice are changing hydrological systems, subsequently disturbing the quantity and quality of water resources (Mujere & Moyce, 2016; Petersen *et al*., 2017). Impacts from recent climate-related disasters, i.e. droughts, floods, cyclones and wildfires, expose significant susceptibility and exposure of ecosystems and human systems to present variability of climate (IPCC, 2014) (Figure 1.3).

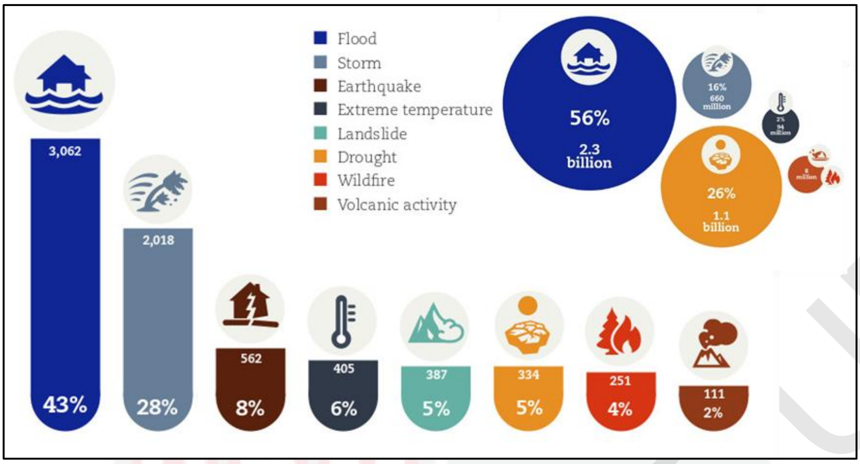

Figure 1.3 : Percentage of natural disasters occurences by disaster type (bar chart) and number of people affected by weather-related disasters (pie chart) (1995-2015) (Source: UNISDR and CRED, 2015)

In Malaysia, the severe disaster e.g. flood, landslide, mud floods, and mass movement was regarded as the potential consequences of land use change and changing climate (Khalid & Shafiai, 2015). It prompts to enormous costs in term of economics, social and environment losses. Over all the disasters in Malaysia, floods are most frequent and severe natural destruction which occurred almost every year. Literally, there have been huge flood events in 1886, 1926, 1931, 1947, 1954, 1957, 1965, 1967, 1970/1971, 1988, 1993, 1996, 2000, 2006/2007, 2008, 2009, 2010 and 2014 (Lee & Mohamad, 2014).

Floods are the major and high relative frequency natural disaster threat facing Malaysia. The floods prompted by Northeast and Southwest monsoon, land use change and climate change (Adnan & Atkinson, 2011). Also, Khailani & Perera (2013) reported inadequate drainage system and siltation in waterway induced flash floods. Petersen *et al*. (2017) found the localised consecutive extreme rainfall reduce flood storage capacity and sea water level rise led to tidal backwater effect (Midun & Lee, 1995) and tsunami (Mohamed Shaluf & Ahmadun, 2006) cause the floodwater to accumulate longer in flood plain area.

Tropical Storm Greg flooded Keningau, Sabah in 1996, caused more than RM 400 million loss of infrastructures and properties, claimed 241 lives, and destroyed thousands houses (Isah, 2016). While, floods in Johor in 2007 and 2008 killing 18 people and causing damage estimated at RM216 million, and caused 28 deaths, RM95 million in damage, respectively (Chan, 2012). In the “Rice Bowl” of Malaysia in Northern Malaysia particularly Kedah and Perlis in 2010, approximately 45,000 ha of rice fields was destroyed by flood. The floods killed four people, with more than 50,000 evacuees. (Isah, 2016).

Kelantan is the most flooded state in Malaysia which arised every year. In 1926 (the 1st Bah Merah) (Figure 1.4), it's "the biggest flood in living memory" in Malaysia where almost the entire Peninsular Malaysia was sunk (Winstedt, 1927). The catastrophic floods in 1967 surged across the Kelantan, Terengganu and Perak, killing 55 people. In 2000, floods caused by heavy rains take 15 lives and caused more than 10,000 people loss their homes in Kelantan and Terengganu (Isah, 2016).

Figure 1.4 : Collection of pictures showing the 1st Bah Merah in 1926 in Kelantan State (Source: Saufi, January 6, 2016)

1.2 Highlight and Issues

The recent 'Great Yellow Flood' in Kelantan River Basin in December 2014 resulted in an estimated RM1 billion worth of loss (Mustapa, 2015). Speculation on uncontrolled logging and illegal land clearing in the upstream of the basin as the focal factor contributing to the flood in Kelantan spread, yet there is no strong proof to support this claim. These actions reduce the capacity of the basin storage if the higher proportion of land cover in a basin is covered with less infiltration capability (Bruijnzeel, 2004) (Figure 1.5).

12 UTUSAN KONSUMER May-June 2015 — LESSONS FROM NATURE — UTUSAN KONSUMER May-June 2015 13

Apocalypse Now in Malaysia

5 Months After The Kelantan FLOODS

Staff from *Sahabat Alam Malaysia* recently revisited the areas ravaged by the floods in Kelantan last December and these were the shocking images brought back by them. What we saw seem to be giving us very important messages.

Message from a River

Even 5 months after the floods, I am still not my normal self. I used to be clean and pure. And fishes thrive in my clear waters. Now I am still muddied even in this dry season. Some other parts of myself have dried up (see inset).

You can see from the picture how ugly and destructive I can become if human beings do not care for me or the forests. See the debris I created. The debris that is left tangled on the tree in the foreground shows how high my water level was during the floods. Save me to save yourselves!

Message from a Landslide

I am almost all the time created by people. People with power, money and authority. They came and shaved me bald. We have so many "Botak Hills" here in Kelantan. And they took away the trees which prevented me from creating havoc to people staying near and far. I now wash away homes and kill as a result.

The rivers carry my earth which makes them shallow, making them ready to create even more damage when the next monsoon comes.

The water becomes undrinkable and unusable.

I wonder why people do such devastating things, all in the name of "development". Such "development" kills and destroys the lives of many people.

You cannot call such actions as "development". They make people angry. Stop them NOW!

Message from a Broken Home

Thick mud came and washed away my walls, windows and doors.

The whole house moved and crumbled.

Soon the mud was right on top of my roof. Mud was everywhere and made their marks which are still evident today on the broken walls and columns.

My inhabitants were completely shocked by the swiftness of the mud flow. They had no time to salvage their belongings and valuables. Their whole life's efforts in building me was crushed instantly.

Today they are homeless and are still living in temporary shelters, in plastic tents.

I don't know how they are going to rebuild their lives. It took them many years to build me.

I was destroyed due to the greedy people who cut the hills and the authorities who gave them permission to do it. I hope they will never vote for politicians who destroy the livelihood of people.

Message from a "Refugee Camp"

If you look at the plastic tents, you may feel that the occupants are refugees. But they are refugees in their own land. Yes, it is possible, not because of political reasons, but because of environmental reasons (and yes, politicians are mainly responsible because they allowed the cutting of the forests).

The homeless have been living in these tents for months now. It will take years for them to save enough to build a new house. Everything here is temporary and the homeless cannot have their normal conveniences like running tap water or a toilet in their homes.

Living here is tough as hell.

Message from *Botak* Hills

Kelantan has become a centre for "Botak Hills". We are so destructive that we created the most devastating floods ever seen in Malaysia.

You see, many human beings do not understand how important is the forest in protecting water resources. The forests actually act like a sponge, absorbing the excess water during the wet season — preventing floods. And during the dry seasons, the forests release the stored underground water — preventing drought.

Human beings think they can simply shave us botak by logging all the trees, not knowing that without the trees — I can create havoc, like creating floods and landslides, and destroying your farms and properties. And I can even create climate change.

Ask your politicians to keep my trees; logging them and replanting me with oil palm is a recipe for disaster.

Message from a Green Hill

They think I am useless and not productive, not knowing how valuable I am in protecting people's lives and properties from floods, in providing them food, water and medicines, and in keeping the climate conducive to human habitation.

I am home to thousands of trees, wildlife, insects and microbes — all of which are God's creation and which have a definite function and role on this planet. I am the cradle of biodiversity.

Human beings think they are the masters of the universe. How wrong can they be! They think they can do whatever they wish, destroying others — and mitigate the problems they cause by creating solutions which in turn, cause more problems. They will lead themselves to ruin if they continue to think and act selfishly. Just look behind me at the hill which they have destroyed and you will understand what I mean.

But will they ever learn!

Figure 1.5 : Newspaper cutting showing the post-flood impact and speculation on the causes of 2014 flood (Source: HAKAM, 2015)

Also, some studies found prolonged, extreme and intense rainfall (climate) falling over the Kelantan state for two continuous weeks (17-30th December 2014) as the major factor influencing the extreme flood. Many rainfall stations experienced over 100 years ARI of rainfall events and several received rainfall events with more than 500 years ARI (Eliza *et al*., 2016) (Figure 1.6). These continuous and rare events exceeded the limit of soil storage capacity, causing direct runoff to occur.

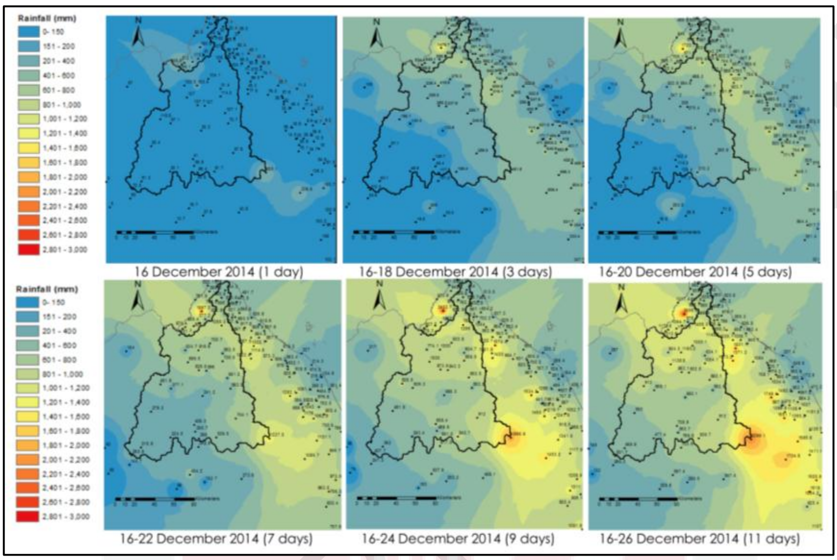

Figure 1.6 : Spatial distribution of the cumulated rainfall depths during 2014 flood in the Kelantan (16-26 December 2014) (Source: Eliza *et al*., 2016)

Various structural and non-structural measures were implemented or planned by related government agencies to mitigate the flood impacts or reduce the occurrence of the flood (e.g. National Water Resources Study), but none has looked into the past land use and climate change impacts on the flooding at the river basin. Therefore, recognizing the result of climate and land use change scenarios to runoff generation process could assist in flood mitigation measures, especially in land use and water resources management.

1.3 Objectives

This research aimed to investigate the runoff response on the changing land use and localised climate changes using SCS-CN and GIS in the Kelantan River Basin over a period of 30 years. The following objectives are:

(i) To analyse the temporal trends of the climate and hydrological characteristics in KRB from 1984 to 2014.
(ii) To analyse the spatial changes of land use in KRB from 1994, 2004, 2014.

(iii) To assess the relationship of runoff variabilities in relation to land use and climate changes.
(iv) To estimate runoff using SCS-CN method in KRB for 1994, 2004 and 2014.
(v) To identify hotspots (high runoff potential) in KRB to assist relevant stakeholders and land managers in the planning of the disaster mitigation and prevention measures.

1.4 Research Questions

(i) What is the trend of climate, hydrological and land use change in Kelantan River Basin from 1984 to 2014?
(ii) Which type of land use contributes towards more runoff generation in KRB?
(iii) Do land use and climate changes affect the runoff in the river basin?
(iv) Can forest or natural area in the basin reduce the runoff under extreme climatic conditions, and what happen if this area is cleared or converted into other land uses?
(v) Which sensitive areas should be protected and preserved in Kelantan River Basin?

1.5 Significance of this Study

The benefits of this study are:
(i) In terms of theoretical significance, this study provides a recent and additional information on effects of climate change and land use change related to flood in Kelantan River Basin.
(ii) In terms of practical significance, this study provides supporting information for relevant stakeholders and land managers in their decision-making related to landscape management in Kelantan River Basin.

1.6 Scope of this Study

This study focuses on climate change and land use changes in Kelantan River Basin towards runoff response over a period of 30 years (1984-2014). Further runoff estimation using SCS-CN and GIS helps to observe and identify hotspots area with high runoff potential. The climate and hydrological data is limited to only 30-years period of data and the information gather by the weather and hydrological station provided. Also, a lot of stations was newly establish and malfunction reduce the variation of the climate and hydrological characteristics over the basin. In addition, the land use information is limited to 1994 due to availability of the land use data and satellite images.

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