CLIMATE VARIABILITY AND CHANGES IN THE RAINFALL TRENDS IN THE EAST COAST OF PENINSULAR MALAYSIA

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ABSTRACT

The coastlines have been identified as the most vulnerable region with respect to response to hydrological hazards as a result of climate change and variability. The east coast of Peninsular Malaysia is not an exception in this regard considering the evidence of heavy rainfall resulting in floods as an annual phenomenon and also the drought that is brought about as a result of long dry spell in the region. It is envisaged that future climate changes may bring about climatic variability which may in turn produce large changes in the in the probability of occurrence of extreme hydrologic events. A study has been carried out to understand the recent trends in rainfall amount and rainfall related extreme events such as maximum daily rainfall, number of rainy days, average rainfall intensity, heavy rainfall days, extreme rainfall days, and precipitation concentration index in the east coast of Peninsular Malaysia. Long term (1971-2010) data of 40-year daily rainfall records at 55 stations along the east coast of Peninsular Malaysia have been analyzed by using non-parametric Mann-Kendall test and Sen's slope method to understand the trends and estimate the magnitude of change. The study shows that annual rainfall, precipitation concentration index, high rainfall and extreme rainfall have increased significantly at many stations in the east coast of Peninsular Malaysia. The study concluded that the rainfall has become more distributed over the year which has reduced dry spells, however, the extreme rainfall events have increased which may be the cause of extreme hydrologic event of floods that is experienced in the region.

ABSTRAK

Persisiran pantai telah dikenalpasti sebagai rantau yang paling lemah dalam bertindak balas terhadap bahaya hidrologi akibat daripada perubahan dan kepelbagaian iklim. Pantai timur di Semenanjung Malaysia juga tidak terkecuali apabila mempertimbangkan bukti hujan lebat yang mengakibatkan banjir sebagai fenomena tahunan dan juga kemarau akibat daripada musim kering yang panjang di rantau ini. Adalah dijangkakan bahawa perubahan iklim pada masa depan boleh membawa kepelbagaian iklim yang mungkin pula menghasilkan perubahan yang besar dalam kebarangkalian berlakunya peristiwa hidrologi yang melampau. Satu kajian telah dijalankan untuk memahami trend terkini dalam kuantiti hujan dan peristiwa yang melampau berkaitan dengan hujan seperti hujan maksimum harian, bilangan hari hujan, purata keamatan hujan, bilangan hari hujan lebat, hari hujan yang melampau, dan indeks kepekatan hujan di pantai timur Semenanjung Malaysia. Data jangka panjang yang mengandungi 40 tahun rekod hujan harian (1971-2010) di 55 stesen di sepanjang pantai timur Semenanjung Malaysia telah dianalisis dengan menggunakan ujian non-parametric Mann-Kendall dan kaedah Sen's slope untuk memahami trend dan menganggar magnitud perubahan. Kajian berkenaan menunjukkan hujan tahunan, indeks kepekatan hujan, hujan lebat dan hujan yang melampau telah meningkat secara ketara di banyak stesen di pantai timur Semenanjung Malaysia. Kesimpulannya, hujan menjadi lebih berselerak sepanjang tahun telah mengurangkan musim kering, tetapi hujan yang melampau telah meningkat dan hal ini mungkin merupakan punca kejadian banjir hidrologi yang melampau dialami di rantau ini.

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LIST OF ABBREVIATIONS AND SYMBOLS

AnnRain	-	Annual Rainfall
CDD	-	Consecutive Dry Days
CDR<1	-	Low Rainfall Days
CWD	-	Cumulative Wet Days
C5DPT	-	Cumulative 5-Day Precipitation Total
DJF	-	December-January-February
ENSO	-	El-Nino Southern Oscillation
GCMs	-	Global Climate Models
GIS	-	Geographic Information System
HPE	-	Heavy Precipitation Models
ITCZ	-	Inter-Tropical Convergence Zone
Max1DR	-	Maximum 1-Day Rainfall
MonRain	-	Monsoon Rainfall
M5DR	-	Maximum 5-Day Rainfall
NEM	-	North East Monsoon
OLR	-	Outgoing Long-wave Radiation
P	-	Annual Precipitation
PCI	-	Precipitation Concentration Index
P_i	-	Precipitation of i-th Month
Rain>20m	-	High Rainfall Days
Rain>95pctl	-	Extreme Rainfall Days
RegHCM-PM	-	Regional Hydroclimate Model of Peninsular Malaysia
RI	-	Rainfall Intensity
SIO	-	Southern Indian Ocean
SON	-	September-October-November

SWM	-	South West Monsoon
TWD	-	Total Wet Days
WNP	-	Western North Pacific
%	-	Percentage
Σ	-	Total

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Hydrologic changes are the most significant potential impacts of climate change in many regions of the world (IPCC, 2007). Future climate changes may involve modifications in climatic variability as well as changes in averages (Mearns *et al*., 1996). As the primary impacts of climate change on society results from extreme events (Rodrigo, 2002), it might have severe negative consequences in the regions which are already under stress. Coastal regions of Peninsular Malaysia are more vulnerable to climate change compared to others parts of the country. Among the coastal regions, the east coast of Malaysia is considered as the most vulnerable to climate change (Yusuf and Francisco, 2009). The future projections of climate by means of Global Climate Models (GCMs) revealed that annual rainfall in the east coast of Malaysia will increase by 10% in the end of this century. High variability in inter-annual and inter-seasonal rainfall and river discharge is also projected by climate models. In some parts of the east coast of peninsular Malaysia, the frequency of long dry periods tended to be higher with a significant increase in the mean and variability of the length of the dry spells (Deni et al., 2008). The coastal zone of Peninsular Malaysia is already vulnerable to hydrological hazards. Floods triggered by heavy rainfall are almost every year phenomena in the region (Malaysian Meteorological Department, 2009). Unlimited industrial enlargement, extensive agricultural irrigation, and the continuing improvement of living standards constitute the main factors in the

human dimension that influence the changing balance between water supply and demand in the region. Variability in inter-annual and inter-seasonal rainfall and river discharge will cause more hydrologic extremes in the east coast of Malaysia and make the livelihood and infrastructure more vulnerable.

In the line of global warming, Peninsular Malaysia is also experiencing a warming trend for the past few decades (Begum et al., 2011). Though Malaysia is considered as moderately vulnerable to climate change, the vulnerability is not evenly distributed over the country (Yusuf and Francisco, 2009). Coastal regions of Peninsular Malaysia are more vulnerable to climate change compared to others parts of the country. Among the coastal regions, the east coast of Peninsular Malaysia is considered as the most vulnerable to climate change (NAHRIM, 2006; Yusuf and Francisco, 2009). The coastline of East Malaysia is 2,607 km long and passed through the states of Kelantan, Terengganu, Pahang and Johor. According to Yusuf and Francisco (2009), hydrologic extremes are the most sever consequences of climate change in the east coast of Malaysia. The future projections of climate by means of Global Climate Models (GCMs) revealed that annual rainfall in the east coast of Malaysia will increase by 10% in the end of this century (NAHRIM, 2006). An increase in mean monthly rainfall in the northeast coastal region is also predicted. In term of river discharge, the maximum monthly flow is projected to increase by 11% to 43% from the base years (1961-1990). High variability in inter-annual and inter-seasonal rainfall and river discharge is also projected by climate models (Shaaban et al., 2008; NAHRIM, 2006). In some parts of the east coast of peninsular Malaysia, the frequency of long dry periods tended to be higher with a significant increase in the mean and variability of the length of the dry spells (Deni et al., 2008). At the same time, there will be significant increase in the overall mean monthly streamflow in the watersheds of Kelantan and Pahang and the high flow conditions will be magnified in Kelantan, Terengganu, Pahang and Perak River watersheds during the wet months (Shaaban et al., 2008).

The coastal zone of east Malaysia is already vulnerable to hydrological hazards. Floods triggered by heavy rainfall are almost every year phenomena in the region (Malaysian Meteorological Department, 2009). On the other hand, the northern coastal state is suffering from an extremely serious water deficiency for decades (Toriman et al., 2009). Unlimited industrial enlargement, extensive agricultural irrigation, and the continuing improvement of living standards constitute the main factors in the human dimension that influence the changing balance between water supply and demand in the region. Variability in inter-annual and inter-seasonal rainfall and river discharge will cause more hydrologic extremes in the east coast of Malaysia and make the livelihood and infrastructure more vulnerable. Most of the areas of east coast of Peninsular Malaysia are low-lying areas that are less than 0.5 m above the highest tide or are within 100 m inland of the high-water mark (DID, 2011). Therefore the region is highly vulnerable to sea level rise leading to coastal erosion, inundation, coral bleaching, saltwater intrusion, soil salinity, reduced productivity in crop lands, etc. National Coastal Erosion Study revealed that about 29% coastline of Malaysia facing erosion (DID, 2011). According to INC (2000), the rise in sea level is about 13-94 cm in 100 years in the east coast of Malaysia. Therefore, study the changing pattern of climate and climate related hydrologic extremes; assess the impacts of these changes on different sectors which are already under stress, and explore the possible adaptation responses are necessary to reduce the risks and challenges posed by climate change on coastal livelihood and infrastructure in the east coast of Peninsular Malaysia.

Rainfall extremes will bring huge disaster to human society and nature ecosystem. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) pointed out that the heavy precipitation events (HPE) in many mid-latitudes were likely to increase, and the total area affected by drought since the 1970s has been likely to increase (Alexander et al., 2006; IPCC, 2007; Li et al., 2010). Water is the foundation of composition, development and stability of oasis ecosystems in arid areas and determines the evolution of the ecological environment (Chen et al., 2007)

1.2 Problem Statement

According to Toriman et al. (2012), the future impacts of climate change on the hydrology of a geographical region needs to be studied in order to quantify in details the potential changes which may occur in hydrological water balances in that region due to such a climate change. Extreme precipitation events can influence flood and soil erosion differently with changes in frequency versus intensity. Assessing changes in extreme rainfall events at the regional scale can identify indicators that cause environmental and other problems and help us to obtain positive information for rational countermeasures (Wang et al., 2012). Therefore, the study of climate variability and changes in the rainfall trends and related extreme events in the East Coast of Peninsular Malaysia is needed to understand and assess the impact of climate changes toward the hydrologic changes in the coastal zones of Peninsular Malaysia.

1.3 Study Objectives

The following are the objectives of the study:

1. To assess the changing pattern of rainfall and rainfall-related extreme events in the east coast of Peninsular Malaysia
2. To study the characteristics and trends of rainfall in East Coast of Peninsular Malaysia.

1.4 Scope of Study

This paper studies the variability and changes in rainfall trend in response to the climate change in the east coastal states of Terengganu, Kelantan and Pahang of Peninsular Malaysia over a period of forty years (1971-2010). Various indices of

rainfall extremes covered by the study include Annual Rainfall, Rainfall Intensity, Total Wet days, Monsoon Rainfall, Consecutive Dry Days, Low Rainfall Days, Consecutive Wet Days, Cumulative 5-Day Precipitation Total, Maximum 1-Day Rainfall, Maximum 5-Day Rainfall, High Rainfall Day, Extreme Rainfall Day and Precipitation Concentration Index (PCI).

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