Climate change impact on rainfall pattern in Bangkok Metropolitan region

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Abstract: The extreme rainfall trends in Thailand frequently occurred during the past decades. The climate change problems have caused extreme monsoons and tropical cyclones, with heavier rainfall leading to floods and inundations in cities. This research will focus on the comparison of rainfall pattern maps, between both the observed rainfall (1980 – 2017) and the modelled rainfall (2006 – 2050), are supported on Arc GIS software version 10.3. Average observed rainfall data are recorded by the Thailand Meteorological Department (TMD) during the 1980-2017 period. Metropolitan region consists of Nakhon Pathom, Pathum Thani, Nonthaburi, Samut Prakan and Samut Sakhon provinces. Rainfall pattern is described by interpolation using the rain stations covering eighteen provinces of the central part of Thailand namely, Bangkok, Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, Samut Songkhram, Samut Sakhon, Uthai Thani, Nakhon Sawan, Ang Thong, Phra Nakhon Si Ayutthaya, Kanchanaburi, Ratchaburi, Chai Nat, Lopburi, Saraburi, Sing Buri and Suphan Buri. The interpolation is used for this case because there are only six rain stations in Bangkok Metropolitan region. The achievement of interpolation which is a part of Arc GIS 10.3, is used to estimate the rainfall values. In general, the rainfall values are usually high in the rainy season (mid-May to October), but this approach calculates the wet days all through the year, due to the probability of flood and inundation corresponding to heavy rainfall not only in the rainy season but also in other seasons. The rainfall values should be calculated for the rainfall intensity (defined as mm of rainfall per twenty-four hours) for the natural disaster analysis. To address the research objective, knowledge and study result in rainfall pattern impact due to climate change show in terms of the rainfall intensity classification. It leads to investigate the disaster risk, vulnerability and adaptation plans for water resources management in the future.

Keyword: rainfall intensity, observed rainfall, modelled rainfall and Arc GIS 10.3

INTRODUCTION

Bangkok Metropolitan has been known as the fast growing economy of Thailand, it contributed the national Gross Domestic Product (GDP) and the government budget as well as population growth continuously increased and also high population density. Flood and drainage problem occurred frequently and severely in Bangkok Metropolitan not only rainy season, but also in other seasons. Flood also affects the infrastructure and the transportation system was disrupted, causing drainage system problem in lowland areas. In Thailand, there are three climate seasons a year, which are the dry season, the rainy season and the winter season. In general, during the middle of February until the middle of May, it is the dry season, lasting three months. In February, the north of Thailand is covered by high pressure from China. Then, it is weakened because of warm air and fog remaining in some areas, thus leading to cool to cold weather in north-eastern and northern parts. In March and April, a hot low-pressure cell influences the northern part, moreover, the southeast and the south winds may lie over the north as the result of hot weather in some areas, causing widespread thunder showers and hot weather on some days. In the dry season, the average maximum temperature is around 35 – 40°C (TMD, 2011).

The history of during the 21st century, the greenhouse gases and aerosols were rapidly released into the atmosphere causing warmer weather and increasing monsoon rainfall. The thermodynamic forcing leads to accumulated precipitation in South Asia as the atmospheric moisture content is higher over the Indian Ocean. Over the second half of the twentieth century, the change of monsoon rainfall has been related to increased greenhouse gases and aerosol concentrations leading to the prediction modelled monsoon under equilibrium. The climate simulation of the 21st century RCP scenario is to provide evaluation of global climate change and respond in the region scale in different climate model. In future simulation, it depends on how climate model reproduces the preindustrial, historical and current circumstances, processes and sensitivities. The intensity of rainfall over the western part of the North Pacific and the center is widely increased (Turner et al., 2012). The trend of rainfall decreased to moderate rainfall, while the increased intensity of monsoon rainfall under the model projection remains high. The overall annual rainfall is relatively low, while daily rainfall changes are quite high during the Asian monsoon. This study conducts to analyse rainfall pattern under different modelled future emissions of greenhouse gases in Assessment Report 5 (AR5) in emission scenario RCP 8.5. The RCP8.5 describes both assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading to high energy demand and GHG emissions in the long term for absence of climate change policies (Riahi, 2011). Eventually, rainfall intensity will be evaluated under scenario simulation RCP 8.5 in Bangkok Metropolitan from 2018 to 2050

Description of study sites

Bangkok Metropolitan is located in the central part of Thailand, between latitude 13º 95’ and 13º 50’ north and between longitude 100º 90’ and 100º 32’ east. It is bordered by Suphan Buri and Phra Nakhon Si Ayutthaya provinces in the north and, to the east of the Bangkok Metropolitan, by Nakhon Nayok and Chachoengsao provinces, while in the south, it is bordered by the Gulf of Thailand and in the west, by Ratchaburi province (TMD, 2007). Bangkok Metropolitan region is cover Bangkok and five adjacent provinces: Nakhon Pathom, Pathum

Thani, Nonthaburi, Samut Prakan and Samut Sakhon. Bangkok Metropolitan region has a total area of about 7,762 km^2 (TMD, 2011). The study area consists of the following location (Fig 1.):

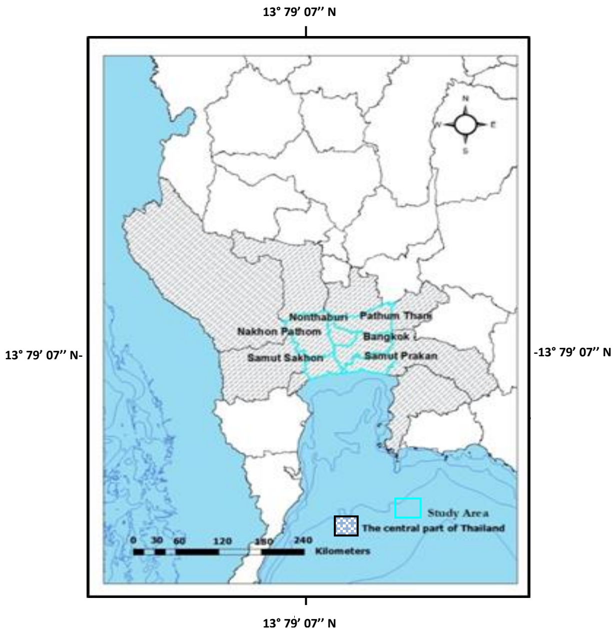

Figure 1. Location of Bangkok Metropolitan consists of Bangkok and five surrounding provinces: Nakhon Pathom, Pathum Thani, Nonthaburi, Samut Prakan and Samut Sakhon.

Methodology

1. Rainfall values analysis

The rainfall calculation was a consideration of both daily rainfall and three-hourly rainfall (Fig. 2). Both daily rainfall and three-hourly rainfall during 1981-2010 are used to calculate the standard hours of daily rainfall. Three hourly data observed rainfall values obtained at the times: 1am, 4 am, 7am, 10am, 1pm, 4pm, 7pm and 10pm (Thai Meteorological Department) and are used to calculate three-hourly rainfall rates for the seventeen rain stations covering eighteen provinces: Bangkok, Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, Samut Songkhram, Nakhon Sawan, Ang Thong, Phra Nakhon Si Ayutthaya, Kanchanaburi, Ratchaburi, Chai Nat, Lopburi, Saraburi, Sing Buri and Suphan Buri. In terms of extreme rainfall indices, a wet day is defined as a day that has a rainfall amount greater than or equal to 1 mm (Maijandee et al., 2014). Figure 2 shows the processing steps in the rain analysis.

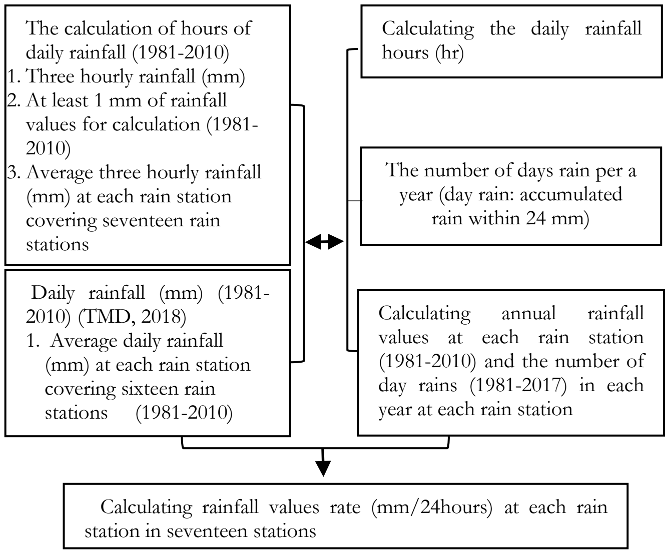

Figure 2. Methodology of rainfall intensity calculation

2. The future simulation

The General Circulation Model (GCM) explains the relationship between the rising greenhouse gasses and climate conditions at a global and regional scale. But the GCM cannot extend to explain climate change conditions in the local scale, as it displays at coarse a spatial resolution. Therefore, the simulation of the Regional Climate Model (RCM) is necessary to assess the impact of climate change at the local scale.

The Southeast Asia Regional Climate Downscaling (SEACLID) was established as a collaborative project in regional climate downscaling from various countries within the Southeast Asia region. SEACLID aims to downscale a number of CMIP5 GCMs for the Southeast Asia region through task-sharing basis among the institutions and countries involved. The products would be the high-resolution climate change scenarios (25 km x 25 km) for the Southeast Asia region (SEACLID, 2018). For climate change in Thailand, the high-resolution of simulation scenarios are the basic requirement for climate change impact, vulnerability and risk assessment to study at local and regional scales. The precipitation input is needed to predict for future climate, was used to assess the simulation scenario of future change for latitude 13° 56′ and 15° 66′ north and between longitude 99° 29′ and 101° 40′ east. During the 2006 to 2017 period, the comparison between observed and modelled annual rainfall is presented for calibration.

Over the baseline period 2006 to 2017, for seventeen central rain stations covering eighteen provinces, there are four rain stations in Bangkok, two rain stations in Lop Buri, Suphan Buri, Kanchanaburi, one rain station in Samut prakan, Pathum Thani, Nakhon Pathom, Ratchaburi, Chai Nat, Si Ayuttaya and Nakhon Sawan respectively. The average of observed annual rainfall volumes and the annual modelled rainfall volumes are compared covering seventeen rain stations. The comparison between observed and modelled rainfall presented approximately 2.20% - 15.3% difference from 2006 to 2017 respectively.

Results and Discussion

1. Observed rainfall calculation

The average observed rainfall values between 1981 and 2017 were calculated, covering eighteen provinces: Bangkok, Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, Samut Songkhram, Samut Sakhon, Uthai Thani, Nakhon Sawan, Ang Thong, Phra Nakhon Si Ayutthaya, Kanchanaburi, Ratchaburi, Chai Nat, Lopburi, Saraburi, Sing Buri and Suphan Buri. This spatial scale was selected as the downscaling of the SEACLID covered all eighteen provinces, including the study site (Figure 1). The average annual rainfall values were calculated in mm/24 hours for accumulated rainfall within 24 hours, i.e. the wet time period, according to the natural disaster analysis. Thus, average three-hourly rainfall totals from 1981 to 2010 were used to calculate the standard of days rain per year for rain stations covering eighteen provinces. The days-rain per year and annual rainfall were used to calculate rainfall in mm/24 hours as in Table 1.

The interpolation of rainfall intensity values in seventeen rain stations covering the eighteen provinces for spatial analysis. Then, the interpolation map is presented with rainfall values (mm/24 hours) covering the eighteen provinces. This result is divided into two parts. The first part describes the intense rainfall distribution map for the observed rainfall in Bangkok metropolitan regions, calculating rainfall values from 1980 to 2017. The second part, the intense rainfall distribution map in the future simulation during 2017-2050 will be forecast by SEACLID. Finally, the comparison of rainfall patterns, between both the observed rainfall present-day and the modelled rainfall, are described by maps.

Rainfall values (1980-2017)	Bangkok	Ayutthaya	Nakhon Sawan	Chai Nat	Pathum Thani	Ratcha Buri	Lopburi	Samut Prakan	Kanchanaburi	Nakhon Pathom	Suphan Buri
Average annual rainfall	1,499.2	1,131.4	1,309	1,127.1	1,239.8	1,098.6	1,113.5	989.6	1,412.7	1,010.0	1,027.5
Days rain per a year	21	8	13	9	10	9	13	18	18	9	14
Average rainfall (mm/24 hours)	71.4	141.4	100.7	125.2	124.0	122.1	85.6	55.0	78.5	112.2	73.4

Table 1 The average annual rainfall and the rainfall value rates from 1981 to 2017

As a result of the spatial rainfall intensity distribution, the rainfall amount (mm/24 hours) in the Bangkok Metropolitan region was less than other regions in the central part from 1980 to 2017. The average observed rainfall values between 1980 and 2017 were calculated, covering six provinces: Bangkok, Nakhon Pathom, Pathum Thani, Nonthaburi, Samut Prakan and Samut Sakhon provinces. The average annual rainfall values were calculated in mm/24 hours for disaster analysis because this unit will show accumulated rainfall within 24 hours, i.e. the wet time period. There was a large rainfall intensity amount in the northern of central part, from around 90 -130 mm/24 hours during 1980 – 2017 period. The rainfall patterns slightly increase in Bangkok Metropolitan regions from 1980–1990, 1990–2000, 2000–2010, and 2010–2017 respectively as shown in Fig. 3 – Fig 6.

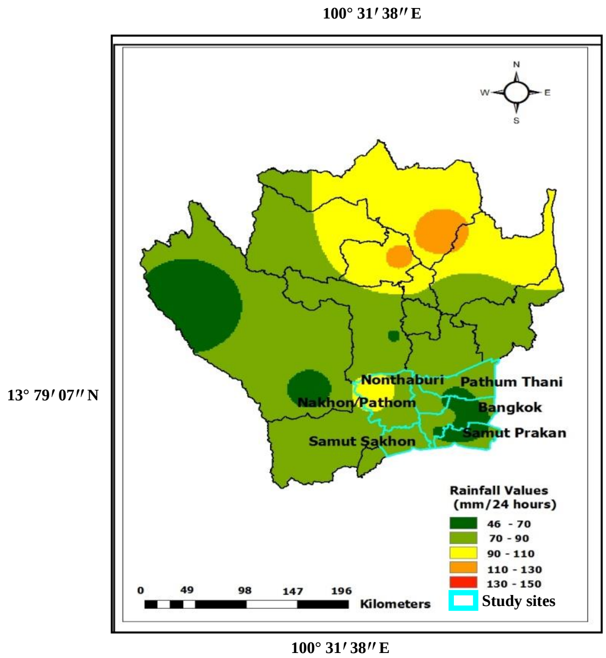

Figure 3 The interpolated map covering eighteen provinces from 1981 to 1990 and the rainfall values focusing on Bangkok Metropolitan region

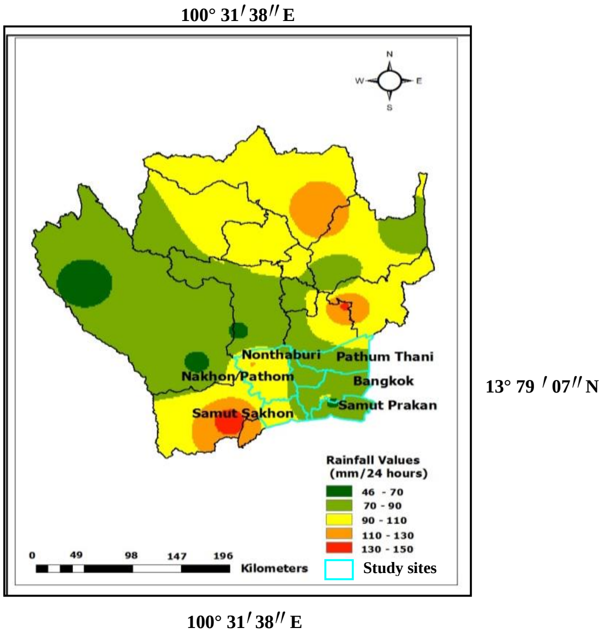

Figure 4 The interpolated map covering eighteen provinces from 1991 to 2000 and the rainfall values focusing on Bangkok Metropolitan region

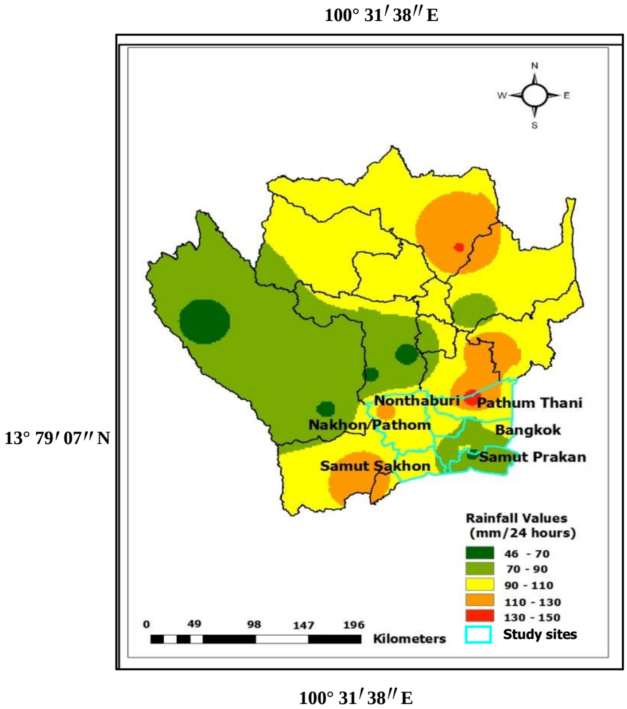

Figure 5 The interpolated map covering eighteen provinces from 2001 to 2010 and the rainfall values focusing on Bangkok Metropolitan region

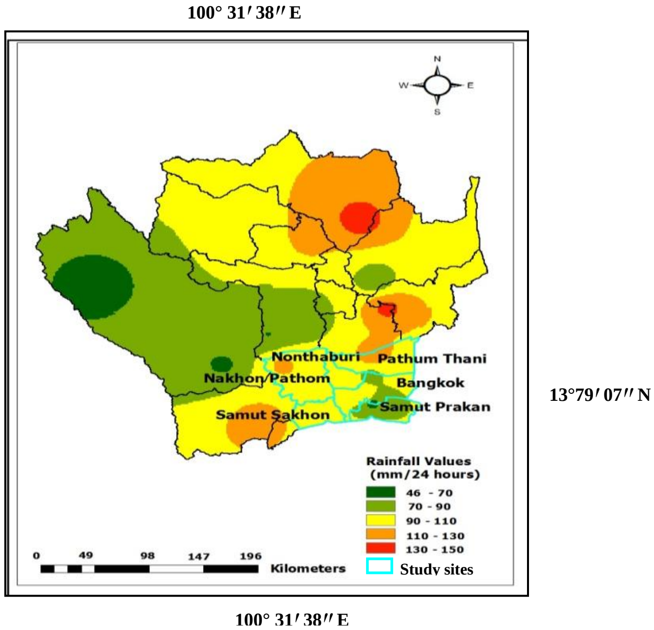

Figure 6 The interpolated map covering eighteen provinces from 2010 to 2017 and the rainfall values focusing on Bangkok Metropolitan region

The rainfall values analysis focused on Bangkok Metropolitan region, the strongly intense rainfall present in six provinces: Bangkok, Pathum Thani, Samut Sakhon: 46-90 mm/24 hours, Nonthaburi, Samut Sakhon are 70-90 mm/24 hours and between 70 - 110 mm/24 hours in Nonthaburi from 1981 to 1990, while Bangkok, Samut Sakhon and Samut Sakhon: 70-110 mm/24 hours, between 90 - 130 mm/24 hours in Nakhon Pathom, Nonthaburi and Pathum Thani from 2000 to 2017 respectively. The trend of rainfall pattern slightly increased from 1981 to 2017.

2. Rainfall pattern in the simulation scenario at local scale: downscaling

The prediction of daily rainfall is obtained by SEACLID from 2018 to 2050 under simulation scenario RCP 8.5, which is only 365 days per year. In this study, the precipitation data is downscaled from latitude 13^{o} 56′ and 15^{o} 66′ north and between longitude 99^{o} 29′ and 101^{o} 40′ east, which is the central part of Thailand. The average three-hourly rainfall totals from 1981 to 2010 are used to calculate the standard of days of rain per year for each rain station covering nine provinces. The days of rain per year and annual rainfall were used to calculate rainfall in mm/24 hours as in Table 1. The modelled rainfall intensity values will be averaged by the interpolation approach and represented by the rainfall intensity rate on the map as show in Fig 7 - Fig 9.

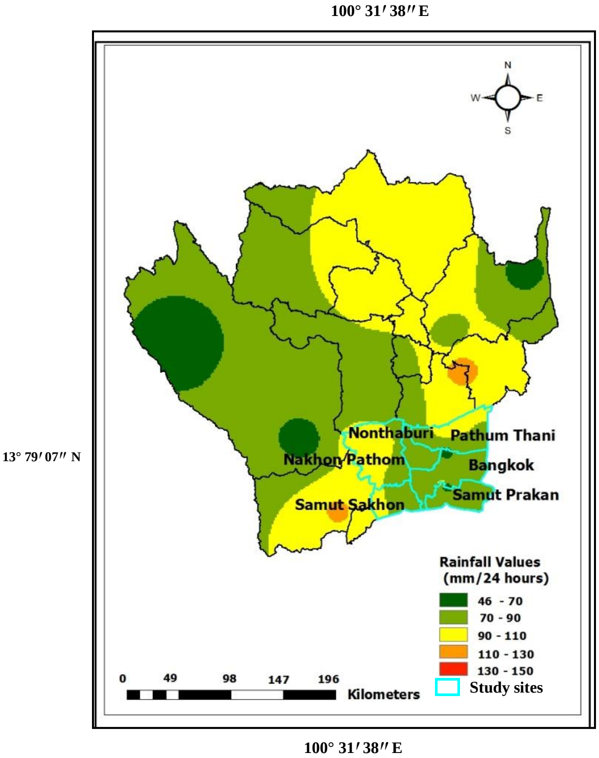

Figure 7 The interpolated map covering eighteen provinces from 2017 to 2027 and the rainfall values focusing on Bangkok Metropolitan region

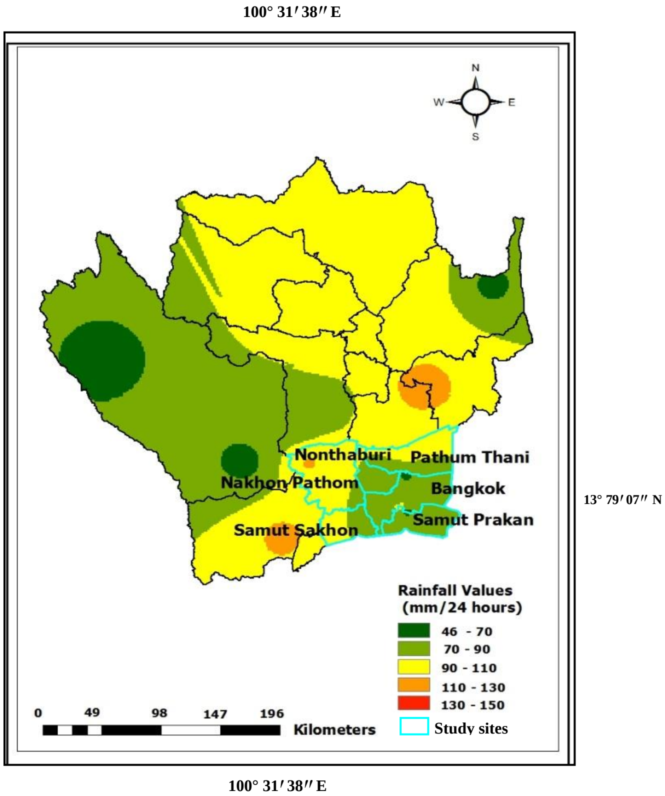

Figure 8 The interpolated map covering eighteen provinces from 2028 to 2037 and the rainfall values focusing on Bangkok Metropolitan region

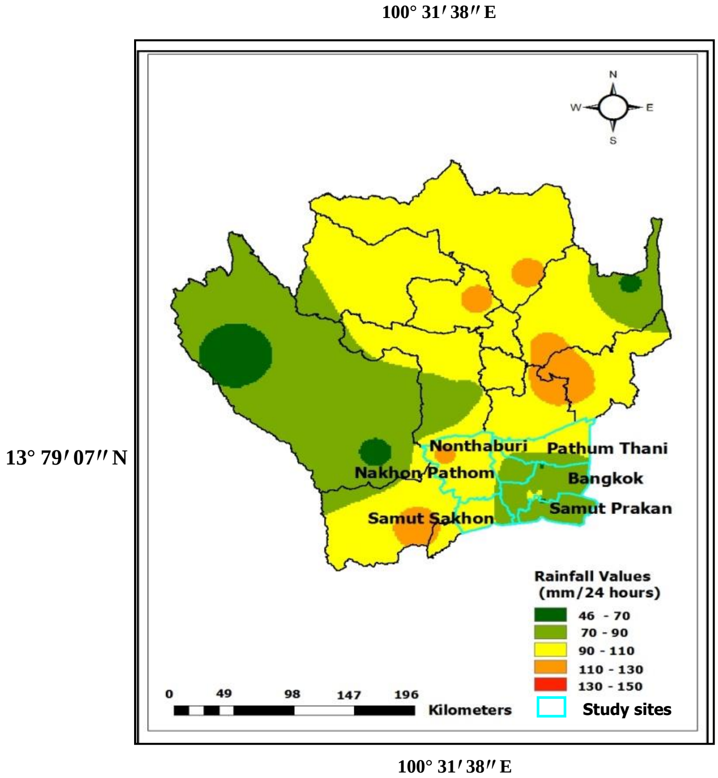

Figure 9 The interpolated map covering eighteen provinces from 2037 to 2050 and the rainfall values focusing on Bangkok Metropolitan region

The rainfall values analysis focused on Bangkok Metropolitan region, the strongly intense rainfall present in six provinces: Bangkok, Nonthaburi, Samut Prakan: 70-90 mm/24 hours, Pathum Thani Samut Sakhon and Nakhon Pathom are 70-110 mm/24 hours from 2018 to 2027, while Bangkok and Samut Prakan: 70-90 mm/24 hours, between 90 - 130 mm/24 hours in Nonthaburi and Pathum Thani, and 90 and 130 mm/24 hours in Samut Sakhon and Nakhon Pathom from 2037 to 2050 respectively. The trend of rainfall pattern slightly increased from 2018 to 2050.

3. The comparison of observed and modelled rainfall density in Bangkok Metropolitan region

Bangkok Metropolitan region is focused on the urban areas because population growth population density increased continuously in city. Therefore, rainfall values should be calculated for the rainfall intensity (defined as mm of rainfall per twenty-four hours) for the disaster analysis such as flood and drainage in city. The trend of both observed and modelled rainfall intensity from 1981 to 2050 slightly increases: Bangkok is 40 – 70 mm/24 hours from 1981 to 1990 and 70 - 90 mm/24 hours from 2037 to 2050. During 1981 to 2017 period, the increasing of rainfall intensity leaded to rainfall pattern areas. The observed rainfall intensity (mm/24 hours) increased from 40 – 70, 70 – 90, 90 – 110 in Bangkok respectively (Fig 7 – Fig 8). In terms of modeled rainfall intensity (mm/24 hours), the increasing of both observed and modelled rainfall intensity also leaded to bigger impact of rainfall pattern areas in Pathum Thani and Nonthaburi provinces from 1981 to 2050 (Fig 3 – Fig 9).

Finally, both observed and modelled rainfall pattern are almost in the same direction however the trend of rainfall intensity increase gradually from 1981 to 2050.

Turner (2012) observed change in rainfall has been responding to anthropogenic activity over the decades in the twentieth century. The result of aerosol concentration and greenhouse gases have increased and linked with human activity. By the end of the twenty-first century, these phenomena will lead to increased rainfall. The IPCC (2012) insists that extreme weather conditions rapidly growing in the future will lead to changed rainfall, both in intensity and seasonality.

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