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The Effects of Land Use Change and Climate Change on Water Resources in the Eastern Region of Thailand

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Thailand changed the paradigm of development from agricultural to industrialization in the Eastern Seaboard Development Programme was first introduced under the Fifth National Plan: 1982-6. Rapid industrialization development processes to achieve this affluence as a result to the change of land use pattern and utility in the area, as well as the growth in water demand, conflicts in using water is emerged. There are few studies explicitly account for interactive effects of land use and climate change on water resource and its challenge in this area.

The degree and depiction to which land use change and climate change affects to water resources, key challenges to the eastern region of Thailand, are indicated and summarised. In this paper, the effects of land use and climate change are explored by using the simplified normalized difference vegetation index method, which the special analysis are particularized by Remote Sensing (RS) on the visible (band 5, 6 and 4) and thermal-infrared (TIR) channel (band 10) that located in the Landsat-8 Thematic Mapper (TM) sensor and Geographic Information System (GIS), based on data in 2011 to 2016.

The result demonstratie significant increasing trends in temperature and change of land use cover and utility in the eastern. Data from year 1998 to 2016 show land use change pattern by the decreasing of agricultural area (64.87 % to 64.76 %) whereas there are increasing of building area/urban (6.68 % to 7.61%), water area (2.81 to 2.87 %). The change of Land use types effected to land surface temperature (LST) and water resources and rainfalls, an average LST of the eastern between 2011 and 2016 is about 28.51 and 29.27 ℃. However, the hotspot of LST has its maximum during 38.1-56 ℃ that located in some areas by mid-April in many eastern provinces mostly in some part of urban and industrial area. In sum, the eastern of Thailand is affected by land use change and climate change, including higher surface temperatures, floods, and droughts. The consequences of its effects will have enormous impact to environmental of the area (air, water), agriculture, forest, economic, and social.

Keywords: Water Resources, Land Use, Climate Change, Land Surface Temperature

Introduction

Water is finite and irreplaceable resource which is a fundamental to human well-being. Water is a core for sustainable development as well as an important for socio-economic development, healthy ecosystems and human

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survival itself. Water is also at a heart of adaptation to climate change, serving as crucial links among the climate system, human society, environment and land use change. Water can pose a serious challenge to sustainable development. (UN, 2015).

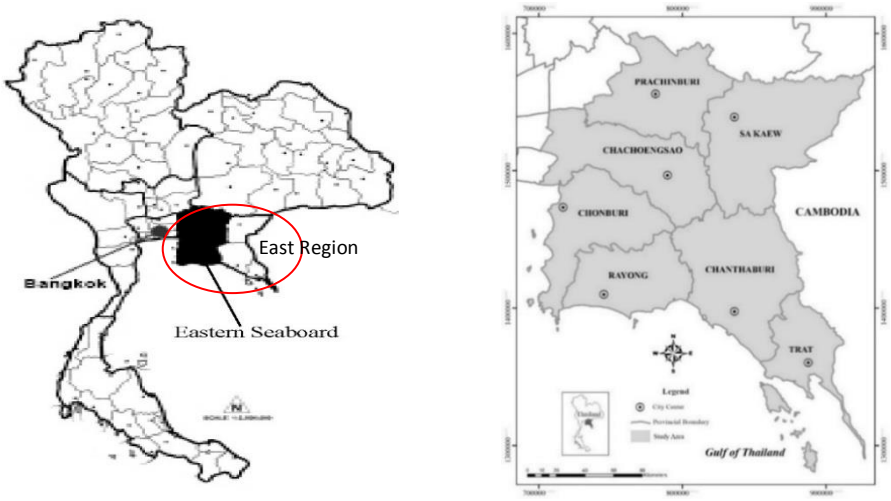
Thailand is a total of 25 river basins. The average of annual rainfall is about 1,700 mm. which 75 % of the amount is lost and the remaining 25 % is in streams, rivers, and reservoirs. The results water quality is in fair condition with a significant trend of improvement. (WEPA, 2003). Thailand changed the paradigm of development from agricultural to industrialization, the eastern region of Thailand was first developed area by Eastern Seaboard Development Programme (ESDP) which first introduced during the Fifth National Plan: 1982-6. The rapid industrialization development process in achieving this affluence as a result to the change of land use pattern and utility in the area, as well as the growth in water demand, people in the eastern region, especially in the eastern seaboard area consume water at the amount of 3,500 Million Cubic Meter (MCM: $10^6 m^3$) per year, (EW, 2006) which the large of amount of water is consumed, although there are a limited of water resource in this region, conflicts in using water is emerged. These put pressure on water resources and stresses that likely to be more by climate change, there are two serious disasters occurs in the past: drought on 2005 and flood on 2011. The balance of water resources would challenge water management to meet the need of growing communities, farmers, manufactuers and ecosystems. There are few studies explicitly account for interactive effects of land use and climate change on water resource.

This study aims to explore what effects to land use change and climate change on the water resources in the eastern region of Thailand. Possible affects of land use change and climate change are population pressure, limiting water resourses and environmental degradation. The different land use types were tested to analyse their effects on the water resourses. The analysis of climate change situation and effects to the surface water resources of the eastern basin. The combined effects of land use change and climate change on the water resources variability are important developing the sustainable development of Eastern Thailand.

Study Area

Eastern Thailand lies between the Sankamphaeng Range, which forms the border of the northeastern plateau to the north and the Gulf of Thailand to the south. The east of Sankamphaeng Range connects with the Dângrêk Mountains (call Phanom Dong Rak Mountains in Thai), a longer system running in an east-west direction that stretches into Laos. The southern mountainsides of the range drain into the Prachinburi River. The western end of the Cardamom Mountains, known in Thailand as Thio Khao Banthat, extends into eastern Thailand. The geography of the region is

characterised by short mountain ranges alternating with small basins of short rivers which drain into the Gulf of Thailand. (Wikipedia, 2016).



(a) Thailand (b) Eastern Region

Figure 1: Location of the Eastern Region of Thailand and Study Area

Figure 1 presents the scope of the study area which is the eastern region of Thailand. The eastern region of Thailand is located in the east of the Bangkok Metropolitan Administration (Figure 1 (a)) between the Latitude 11 degrees 39 minutes to 14 degrees 30 minutes north and longitude 100 degrees 52 minutes to 102 degrees 58 minutes East. The eastern region covers the area of 7 provinces are Chonburi, Rayong, Chachoengsao, Prachinburi, Chanthaburi, Trad and Sakaeo (Figure 1 (b)) which covers the total area of 34,380.80 square kilometers (km^2) (6.7% of country).

The eastern area is characterized by many short rivers. The eastern region composes with four main river basins: 1) Prachenburi river basin; 2) Tonle sap river basin (Sakaeo and Chantaburi); 3) Bangpakong river basin (Chachengsao and Chonburi provinces) located further inland; and 4) EasternCoast river basin (Chonburi, Rayong, Chantaburi and Trad) located along the coastal areas. (Janchidfa K., 2007). The eastern of Thailand is a largest economic-industrial growth based area. Water supply to support the expansion of agricultural, industrial, residential, commercial and tourism activities in the area is served by various sources i.e. reservoir, rain underground, well and so on. A huge water demand is increasing and it effects from land use change, especially loss of forest cover and agriculture and its change to urbanization and industrialization, as well as climate change is related to threat and effect for water resources in the eastern of Thailand.

Thailand rainfall is 800,000 million cu.m. per year runoff fixed. The average annual water costs 213 300 million cubic meters of water and can be used for a limited amount of approximately 52,741 million cubic meters, while the water demand volume is increasing. The demand for water from all sectors is estimated that approximately 114 485 million. cu. m., can store water for approximately 76,131 million cubic meters of water. The shortage of water for agriculture will occur much. (PRD, 2016).

Eastern will have an average of 23,880 million cubic meters of runoff. But can develop water reservoir to store water in 1077 totaled 2277.37 million cubic meters or 10 per cent, while the demand for water is 19 585 million cubic meters (mcm) per year. Eastern Water Resources Development going to be tough because there are limits to the physical and social landscape. And future water demand will be higher than this, certainly from a growing population. The risk of water shortage is more. The industrial sector The city / tourist sector, especially the Bang Pakong River Basin and the West Coast (Chon Buri, Rayong) Industrial water crisis in the year 2548. (RID, 2016) East water company is supplying water to industries๗ water consumption of the communities in the East, which is expected to be approximately 283 million cubic M. Per year, which will be increased use of water is 400 million cu. m. per year or an increase of 30%. (East Water, 2012). In 2559, Eastern region is expected to have a sufficient amount of water. There may be some provinces that could be monitored closely, as Chon Buri and Chachoengsao. The provision of water must be added to enhance the stability of the water to meet the needs of all sectors during the dry season.

Methodology

For water resource management, Landsat has played a key role in providing objective and continuous data. Landsat satellite images provide valuable spatially investigations of the effects of land use changes on climate change and water resources.

The overall research methodology steps were accomplished using three major procedures: image classification and analysis Land Surface Temperature (LST), modeling LULC changes and related with Land-Use/Land Cover (LULC) in 2013–2016. LULC data for this study was classified 5 types of LULC and analyzed the Land Surface Temperature (LST) and climate change form LANDSAT-8 Operational Land Imager (OLI) and (Thermal Infrared Sensor (TIRS). LST is one of the must variables from Landsat-8 TIRS Using a Split Window Algorithm from the United States Geological Survey (USGS).

Remote Sensing (RS) was downloaded multispectral images consists of several bands of data. The false color composites of LULC data were used three primary colors for NIR band (Red), SWIR band (Green) and Red

Band (Blue). Remote sensing Image was mosaic image path/row: 129/50 129/51 128/50 128/51 128/52 and 127/52 in 2016 and clip boundary of study area. LULC classified 5 types using supervised classification using the probability of maximum likelihood classification as: forest, water, agricultural, and urban and miscellaneous area.

Land Surface Temperature for LANDSAT-8 and Toolset has a step as follows:

Step 1: Convert Digital Numbers to Top of Atmospheric Spectral Radiance for LANDSAT-8 (TIRS) Band 10.

Step 2: Estimation of Brightness Temperature (EBT) of LANDSAT-8 (TIRS) Band 10 Brightness Temperature is the electromagnetic radiation using equation from (USGS, 2013) as shown:

$$EBT = \frac{K_2}{ln\left(\frac{K_1 \varepsilon}{L_\lambda} + 1\right)} \quad (1)$$

When EBT is Brightness Temperature (°K); K_1 and K_2 is Thermal constant of Bands from Landsat -8 metadata file (K_1 = 774.89 and K_2 = 1321.08); L_λ is Top of Atmospheric Spectral Radiance layer

$$L_\lambda = M_L Q_{cal} + A_L \quad (2)$$

When M_L is Radiance Multi Band = 0.0003342; A_L is Radiance Add Band = 0.10000; Q_{cal} is Digital Number values of each pixel.

Step 3: Combination of Land Surface Emissivity (LSE) for LANDSAT-8 (OLI) Band 10 and obtain from step-2.

Estimation of Land Surface Emissivity (LSE) from proportions of vegetation (Fractional Vegetation Cover: FVC) layer obtain from NDVI-Base technique using algorithm in equation-3. Which, it is radiation values of real object and earth surface and necessary for Land Surface Temperature. Can be calculated from equation (Sorbrino et. al., 2006).

$$LSE = \varepsilon_s(1 - FVC) + \varepsilon_v * FVC \quad (3)$$

When LSE is Land Surface Emissivity; ε_v is Emissivity for vegetation; ε_s is Emissivity for soil; FVC is Fractional Vegetation Cover (FVC) from Normalized Difference Vegetation Index (NDVI) by using OLI sensor. NDVI is calculated from the red and near infrared band reflected by vegetation. The maximum value and the minimum value of the difference vegetation index can be calculated from equation. …

$$FVC = \frac{NDVI - NDVI_s}{NDVI_v - NDVI_s}$$

When $NDVI_V$ is the highest value of the index is the difference in the area of plants studied; $NDVI_S$ is the minimum value of the difference in vegetation index space studies; NDVI is Normalized Difference Vegetation Index from equation.

$$\frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}}$$

When ρ_{NIR} is spectral reflectance of near-infrared band; ρ_{Red} is spectral reflectance of red band; ρ is Reflection of spectral electromagnetic can be calculated from equation...for Landsat-8.

$$\rho = M_\rho Q_{cal} + A_\rho$$

When ρ is reflectances; M_ρ is Reflectance Multi Band; A_ρ is Reflectance Add Band; Q_{cal} is Digital Number values of each pixel.

Analysis of climate data from the secondary through the GIS spatial analysis method. Import coordinate measuring station, the climate and the database connection. (Joins and Relates Table) Do the estimation interval (Interpolation), Kriging of temperature. Rainfall and humidity, etc, in each measure in spatial data. In other words, it is remotely recognition application for estimating surface temperatures. From Landsat 5 and Landsat satellite data, 8-year B.E. 2549 and-2559.Which is one of the factors of climate change. From the thermal infrared data Has wavelength between 10-12 μm, using the technique to estimate temperature Single-Chanel and therefore Split-Window equation and equation 5-shared with NDVI-Base technique, threshold to eliminate the influence of various factors that affect the value of the parameter estimates are important.Atmospheric Upwelling Radiance, Atmospheric Water Vapor, Downwelling Atmospheric Radiance and Emissivity by writing the equation estimates the Raster Calculator commands in the program through a geographic information system.

$$T_s = \gamma\left[\frac{1}{\varepsilon}(\varphi_1 L_{sen} + \varphi_2) + \varphi_3\right] + \delta \quad (4)$$

When

$$\gamma \approx \frac{T_{sen}^2}{b_\gamma L_{sen}}$$

$$\delta \approx T_{sen} - \frac{T_{sen}^2}{b_\gamma}$$

$$\varphi_1 = \frac{1}{\tau}\,;\, \varphi_2 = -L_d - \frac{L_u}{\tau}\,;\, \varphi_3 = L_d$$

Upon T_s *is Land Surface Temperature;* T_{sen} *is Brightness Temperature,* L_{sen} *is Spectral Radaince;* ε *is Land Surface Emmisivity;* τ *is Atmospheric Transmittance;* L_d is Downward Atmospheric Radiance*;* L_u is Upward Atmospheric Radiance.

Step 4; Statistical analysis of climate information, only strips with Zonal Statistics as Table through the geographic information system, both the minimum value, the average, maximum value and Standard Deviation as the scope or the scope of the category, e.g. the utilization of land. The boundaries of each district and sub-district, province, urban consolidation, etc.

For this paper, consideration two drivers affect to water resources: climate and land use. Effect of climate change and land use on water resources are assessed by applying climate projections (rainfall, ranoff and temperature) derived from landsat data on the eastern region. Mapping and

modeling water resource toward land use related weather and climate with geographic information system (GIS) technology can be coupled with physical, land use, meteorologists, atmospheric and climate sciences data to do research. The relationship between land use water resource and climate change has become an increasingly important focus for the use of GIS to help identify effective water conservation strategies, flood and drought risk reduction. Eastern's climate has undergone radical increase and changes of urbanization, industrialization, population. The use of GIS and Remote Sensing is applied a set of methods and techniques for the water resource and land use and monitoring of climate change analysis in the Eastern of Thailand.

Land Use Change in Eastern Region

Land use cover and uitility of the eastern is conprised a total area of 34,380.80 km^2 or 21,488,000 rai which is only 6.7 % of Thailand area. Land use classied shown in Table 1.

Table 1 Land use Cover in 2001, 2005, 2011 and 2015 (km^2)

Land use	2001	2005	2011	2015
Forest	8012.86	7985.14	7819.85	7748.51
Agriculture	22301.63	22284	22272.64	22264.25
Others	805.83	799.56	789.02	786
Urban	2295.20	2326.53	2533.55	2617.04
Water	965.28	985.57	965.74	965
Total	**34380.8**	**34380.8**	**34380.8**	**34,380.80**

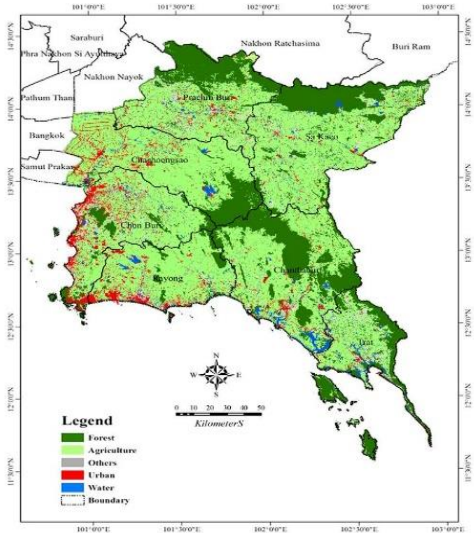


Fig.2: Land Use in the Eastern Region in 2001

In year 2001, the area is consisted of agricultural area (22301.63 km^2/ 64.87 %), forest area (8012.86 km^2 / 23.31 %), community area and construction (2295.20 km^2/ 6.67 %), water area (965.28 km^2 / 2.81 %) and others (805.83 km^2/2.34%), the detail as shown in Fig. 2.

In year 2005, the area is consisted of agricultural area (22284 km^2/ 64.82 %), forest area (7985.14km^2 / 23.23 %), community area and construction (2326.53 km^2/ 6.77 %), water area (985.57 km^2 / 2.87 %) and others (799.56 km^2/ 2.33%), the detail as shown in Fig. 3.

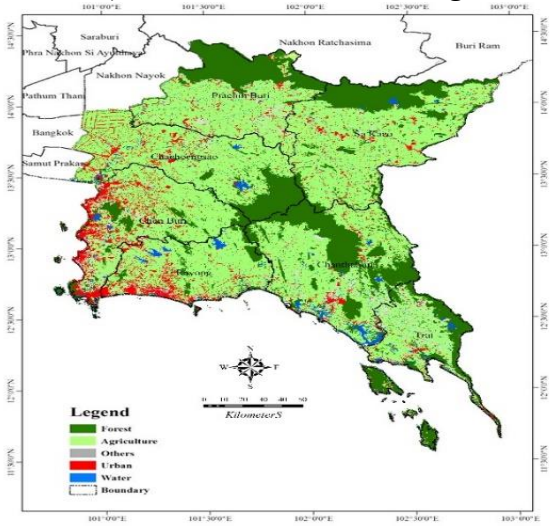


Fig 3: Land Use in the Eastern Region in 2005

In year 2011, the area is consisted of agricultural area (22272.64 km^2/ 64.76 %), forest area (7819.85 km^2 / 22.74 %), community area and construction (2533.55 km^2/ 7.37 %), water area (965.74 km^2 / 2.81 %) and others (786 km^2/ 2.29 %), the detail as shown in Fig. 4.

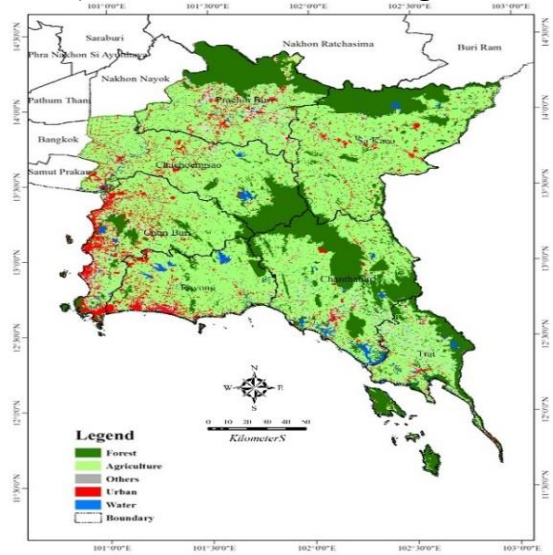


Fig. 4: Land Use in the Eastern Region in 2011

In year 2015, the area is consisted of agricultural area (22264.25 km^2/ 64.76 %), forest area (7748.51km^2 / 22.54 %), community area and construction (2,617 km^2/ 7.61 %), water area (965 km^2 / 2.81 %) and others (786 km^2/ 2.29 %), the detail as shown in Fig. 5.

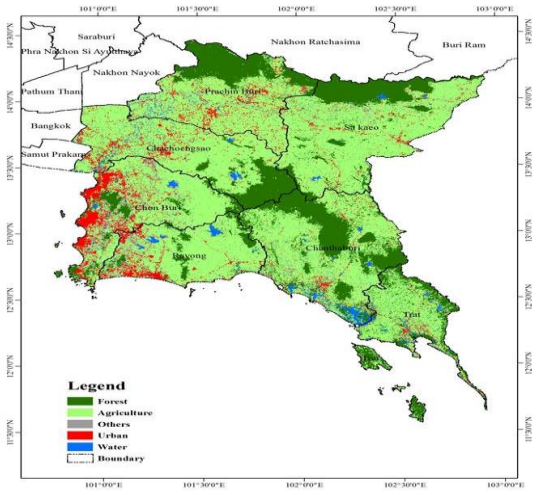


Fig. 5: Land Use in the Eastern Region in 2015

Farming area consists with the categories of planting: paddy fields (774 km^2), sugarcane area (632 km^2), corn acreage/crop (838 km^2), cassava area (1,225 km^2), planting fruit trees/perennials (5,178 km^2), and horticulture (304 km^2). In addition, the pasture area and a menagerie (75 km^2), aquaculture (555 km^2), local water ponds (599 km^2) and other areas (1,038 km^2).

The tropical rain forest of the eastern is located in Chonburi, Rayong, Chantaburi, Trad, Prachinburi provinces which because rainfall fell over the area. The swamp forest, mangrove swamp forest, beach forest are located in Chachoengsao, Chonburi, Rayong, Chantaburi and Trad provinces, where as mixed deciduous forest and grassland forest are located in inland of region. Dry evergreen forest is covered mountains line Phanom Dong Rak mountain range down to Rayong with altitude from sea level to about 100 meters up to 800 meters. Peat swamp is located in Trad about 19.17 km^2 and some in Rayong and Chantaburi provinces. Mostly area of the foreast area in the eastern are a composition of the Eastern Forest Complex (EFC) which is the main system of terrestrial protected areas in the region (Royal Forest Department 2000, Prayoonsit, Chaiwattana and Napom 1999), with a total area of 2,316 km^2 (1,447,954 rai). It is bounded by five provinces: Chachengsao, Chonburi, Rayong, Chanthaburi and Sakeao.

The land use changes caused by the increase of urbanization, agricultural activities and devastated forests area that are cause factors of water balance changes and impact of the hydrological processes and river

discharge as well as temperature average while winters tend to be shorter. The amount of rain fell in some areas due to drought or flooding.

Climate Contexts

The climate of Thailand toward the eastern region is under the influence of southwest and northeast monsoons system. The southwest monsoon brings a stream of warm moist air from the Indian Ocean towards Thailand causing abundant rain over the country, especially it produces a large amount of rainfall in the southern and eastern parts from May-August, rainy season of Thailand. In the contrast, the northeast monsoon brings cold and dry air from the China mainland over major parts of Thailand which causes mild weather and abundant rain along the eastern coast of the part during October-February, winter season. The summer season is transitional period during mid-February to mid-May from the northeast to southwest monsoons. Most of Thailand has a tropical wet and dry or savanna climate type.

Table 2: Average of Climate Data in Eastern Region by Provinces, 2001-2015

Province	**Weather/Climate Situation**								
	Average Temperature ℃			Average Humidity %			Average Rainfall (mm.)		
	2001-2005	**2006-2011**	**2011-2015**	**2001-2005**	**2006-2011**	**2011-2015**	**2001-2005**	**2006-2011**	**2011-2015**
Chon Buri	28.42	28.31	28.48	75.33	76.72	76.47	1,150.89	1,231.08	1,197.93
Rayong	28.53	28.20	28.16	77.83	77.75	77.80	1,275.80	1,480.43	1,448.26
Chachoengsao	27.83	28.17	28.07	68.35	69.99	70.33	1,285.63	1,574.50	1,715.20
Prachinburi	28.48	28.50	28.72	73.17	73.63	73.80	1,628.93	1,664.46	1,708.62
Chanthaburi	27.62	27.66	27.84	78.50	78.00	78.26	2,906.82	3,344.93	2,902.68
Trad	27.42	27.47	27.64	80.33	81.50	82.00	4,967.32	5,188.92	4,849.34
Sa Kaeo	28.13	28.20	28.38	73.17	73.63	74.54	1,279.02	1,406.70	1,404.92
Total Average	28.06	28.07	28.18	75.24	75.89	76.17	2,070.63	2,270.15	2,175.28

Note: (Meteorological Department, 2016)

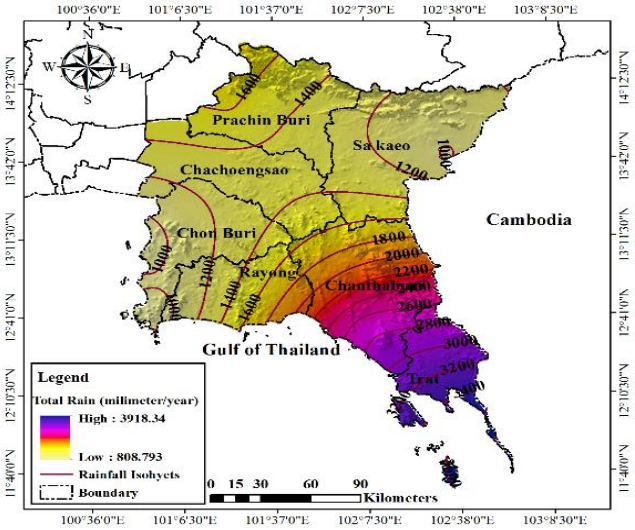


Fig 6. Rainfall in the Eastern Region in 2016

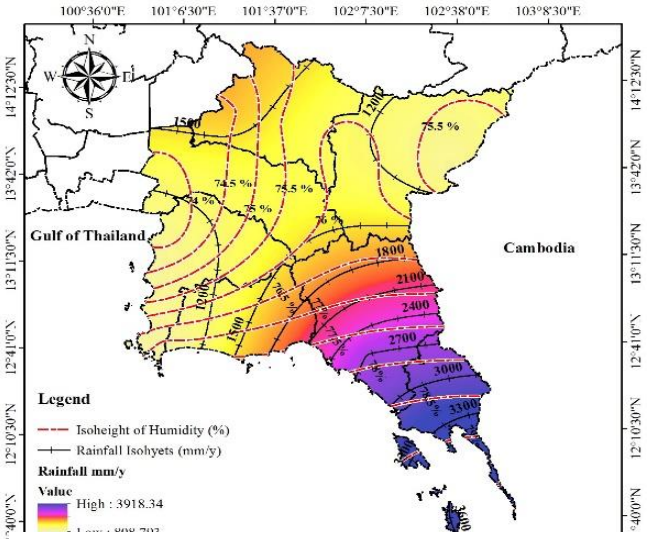


Fig 7. Rainfall and Humidity in the Eastern Region of Thailand in 2016

The climate pattern and meteorological conditions of the eastern is savanna climate (Aw) in the upper part of Sakaeo, Prachinburi, Chachoengsao and Rayong. In the upper part of Chanthaburi and Trad has a tropical monsoon climate (Am), wettest tropical climate. Trad province has the highest amount of rainfall, where as Chonburi is minimum rainfall. The general climate data since 2001 to 2015 of the eastern region which separated by provinces as presented in Table 2. Thailand humidity is covered by warm and moist air reduces in summer, winter and rainy from minimum to maximum about 63 to 84 % and annual average about 73-80 % and evaporation (from 73.9 to 251.9 mm.), cloud cover (1.5-9.5 unit), and wind speed (from 10 units 0.3-5.4 knots) (Meteorological Department,

2016). The eastern wasther is consisted with amount of annual average temperature, humidity and rainfall from 2001-2015 (28.06-28.15 ℃, 75.24-76.17 % and 2,070.63-2,270.15 mm.) as shown in Table 2. Trad province is highest rainfall, humidity average but low temperature average. Chon Buri, Sa Kaeo and Rayong provinces are lowest rainfall, humidity but high temperature average. The rainfall and humidity analysis of landsat data in february in 2016.

The eastern humidity is analysed from Landsat remote sensing data in 2016 about 73.60-79.62 % as shown in Fig. 6 Humidity related with the rainfall about 808.79-3918.34 mm. as shown in Fig.7 Most of humidity and rainfall is located around Trad and Chantaburi.

Result and Discussion

Paradigm Shift Agriculture and Industrialize Development

During the past decades, Thailand has experienced mixed results of development. In 1960s, Thailand has economic based on the agricultural, industrial economic characteristic. Industrialization and urbanization were very limited. The capital, Bangkok, was the only significant urban place of Thailand. (Phongpaichit, & Sarntisart, 2000: 5). Conversely, Thailand had been transformed social and economic dimension, industrialization has been boosted by policies that formed part of the economic and social-development plan. Following the national plan, in the 1980s Thai government initiated a program to create eastern seaboard development area, the Eastern Seaboard Development Programme (ESDP) was formulated, a large-scale industrial development programme which marked a changes in the Thai industrialization policy, soon after that eastern seaboard area became 'the main growth center and location of future basic industries'. There are two phases of the ESDP that covered eleven provinces along the eastern region and some part of central region which comprising of are Chonburi, Rayong, Chachoengsao, Chantaburi, Trad, Prachinburi, Sakaeo, Nakhonnayok, Lopburi, Ayutthaya, and Saraburi. This is a core area of the ESDP presented a strategy of regional industrialization and large-scale planned investment.

Eastern Seaboard development is most impact part from nation development plan, which emphasized industry over service and agriculture, the transformation of agricultural based in the area to be industrial cluster continues appearing. The plan originally comprised Chonburi province, the Laem Chabang area was the designated location for light and export-oriented industries, labor-intensive light industry. The Rayong province was house heavy chemical industries, which focuses on the development of the petrochemical complex at Map Ta Phut utilizing natural gas from the Gulf of Thailand. (Medhi, 1995: 104-105; Lauridsen, 2005: 4; Shimomura, 2000: 3) Further inland is the Chachoengsao area, which was to site various agro-

based industries (Medhi, 1995: 105). Along the coast, Chanthaburi Province is the industry related to the processed agricultural food industry, also Trad province is the food industry.

According to the development paradigm of country, Currently, the industrial estates have located in the four provinces of the eastern region namely Chachoengsao, Chonburi, Rayong, and Prachinburi with 33 industrail estates, around more than 108,900 rai or 69 % of country (IEAT, 2015). There is a significant change on the land use in the eastern region of Thailand. In 1998, land use in the eastern region covered by agriculture (73.5 %; rice paddy/4.2 %; upland crops/18.9 %; lowland and pasture/5.1 %; and other/45.3 %), forestry area (22.3 %), urban area (2.1 %) and water area (2.1 %). In 2001, the eastern area covered by agricultural area (64.87%), forestry area (23.31 %), urban area (6.68 %), water area (2.81 %), and others area (2.34 %). However, 15 year later, there are significant change of land use in the eastern region as in 2015, the urban inclusding industrial area is increased as 7.61%, respectively, whereas agricultural and forest areas are decreaed as 64.76% and 22.54 % as shown in table 3.

Table 3: Percentage of Land Use / Land Cover Change in 2001 and 2015

Land use Types	Year and Persent (%)							
	2001	%	2005	%	2011	%	2015	%
Forest	8012.86	23.31	7985.14	23.23	7819.85	22.74	7748.51	22.54
Agriculture	22301.63	64.87	22284	64.82	22272.64	64.78	22264.25	64.76
Others	805.83	2.34	799.56	2.33	789.02	2.29	786	2.29
Urban	2295.20	6.68	2326.53	6.77	2533.55	7.37	2617.04	7.61
Water	965.28	2.81	985.57	2.87	965.74	2.81	965	2.81
Total	34380.80	100.00	34380.80	100.00	34380.80	100.00	34,380.80	100.00

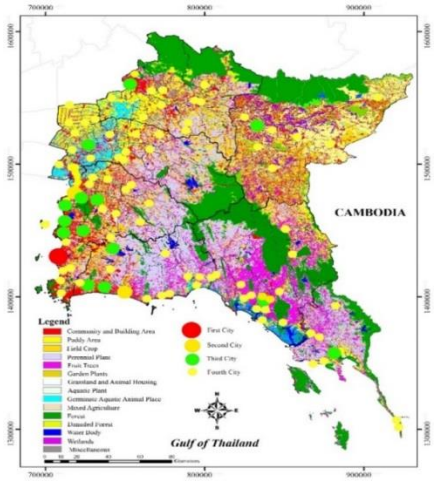


Fig.8: Land and City Cover in Eastern Region in

This trend of change is continuing occurs in the area as the result of industrialization and urbanization in the region. Accordint to urbanization, the eastern region has 110 cities wich classified as a city by a largest city or a first city level of the eastern region is located at Pattaya city, Chonburi province, a second city level is Rayong Municipality, Rayong province, moreover there are many big and small cities which located all around the region as shown in the Figure 8, urbanization is developing in the region. Rapid industrialization in the eastern region, especially the eastern seaboard area, has brought job and economic benefits, however it has also increased of population and resulted in rapid urbanization. Current rates of population growth and urbanization in the eastern, as result from the urban growth which are mainly of migration, people who move from other areas, mainly rural, to eastern seaboard areas.

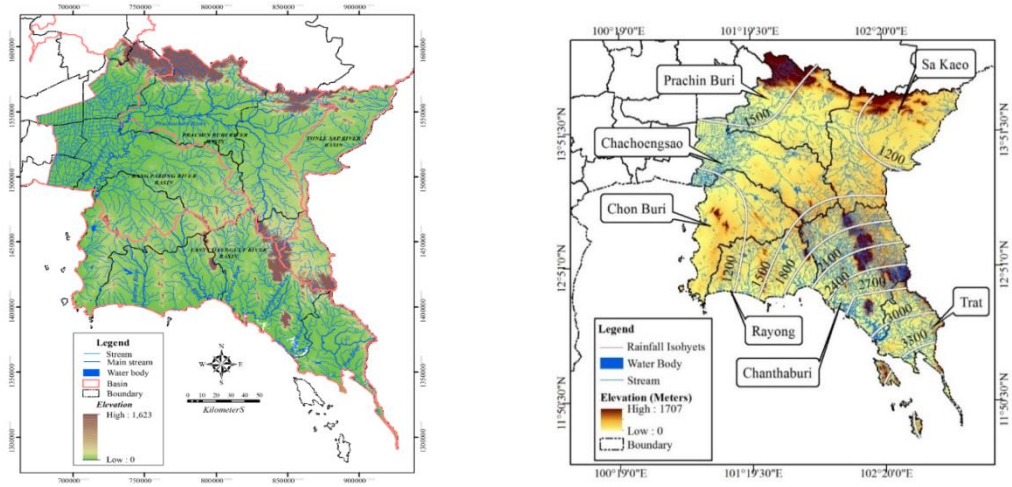
Rapid industrialization development process in achieving, this affluence has not come without high costs. On the other hand, urbanization increases investment requirements because urban populations must be provided with facilities and services such as drinking water, transportation, electricity, and housing. Urban and industrial developments are in direct conflict with agricultural activities, according to industrialization also has a significant impact on local livelihood, apart from the social impact and the degradation of local quality of life of local residents as well as the conflict between the government and local inhabitants is related to development that lacks proper management, one is the water management in the region.

Water Resources: Supply and Demand

Eastern water resources are surface water and ground water. The surface runoff and ground water sources have come from rainfall that runs over the landscape of the river basin in the region. Eastern region consists with 4 river basins in the watersheds, which comprised by 7 short and small rivers, 35 canals/ditches/creeks which serves to people more than 4.6 million people in the region as shown in Figure 6. Eastern topography acts to control the flow of surface water, from upstream which is part of the basin with steep slopes and/or the watershed area on high ground above the spot on the creek that serves rainwater, water flow to the midstream and downstream by the excess water which conveyed from three parts: 1) dehydration of forests/trees, located important forest area in the north, north west, central of the region and small scattered of forest area through entire region; 2) soil absorption of ground water, mostly clay, loamy clay and sandy clay that located covering in Bangprakong river basin some part of Prachinburi, Eastern Coast and Tonle sap river basin; and 3) leaking through the rock beneath the soil outside the basin.

Prachinburi and Bangprakong River Basins, which are an important wetland of the region is main sources of surface water and ground water of the region, Prachinburi river basin area covers 9,672.10 km^2 and

Bangprakong river basin area covers 10,700.71 km^2, where as EasternCoast river basin is surface water sources and few sources of groundwater that are different the terrain such as flat, corrugated and small and short rivers, less streams and lakes or dams, Eastern Coast river basin area covers 13,497.51 km^2. Furthermore, Tonle sap river basin area covers 4,085.93 km^2. Area of Four river basins as shown in Table 3 and Figure 9.



(a) Four River Basins (b) Average Annual Rainfall Precipitation

Fig. 9: Four River Basins and Average Annual Rainfall Precipitation in the Eastern Region

According to monthly and yearly precipitation data during the year 1978 to 2016 collected by the 88 stations measure rainfall, the eastern average annual rainfall precipitation falls on average per year around 1,000-3,400 mm., Chonburi, Chachoengsao and Sakaeo rainfall is lesstest among the provinces in eastern, around 1,000-1,200 mm., where as Prachinburi and Rayong rainfall has amount 1,200-1,800 mm., and Chanthaburi and Trad rainfall is hightest with amount 1,800- 3,400 mm., as shown in Figure 8. Moreover, the rainfall flows into the groundwater each year, about 5 % of the total amount of rain, which is the rainfall flows into the groundwater in the eastern around 3,000 MCM. (ONREP, 2009).

The average surface runoff of the eastern region is 24,029.70 MCM/year or around 11 % of country's runoff, which devide to the eastern region river basin as shown in Table 3, river basin: EasternCoast (53.0%), Prachinburi (20.7%), Bangpakong (16.9%) and Tonle sap (9.0%). On the other hand, the surface runoff data during 1980-2008 by province, Chanthaburi, Trad and Sakaeo has highest surface runoff by approximated 6,743.6 MCM/year, 4,740.1 MCM/year, and 3,489.64 MCM/year, respectively. Then, Prachinburi has approximated 2,592.82 MCM/year, and Chachoengsao has approximated 2,404.58 MCM/year. Where as Rayong

and Chonburi has lowest surface runoff by approximated 2,441.3 MCM/year, and 2,299.72 MCM/year, respectively. The average runoff devide by season, the dry season average is 405.77 MCM and the wet season average is 3,124.41 MCM.

Within the eastern region area, there are requirement a large amount of water to supply all users' demand in the area. Raw water adequacy is the most important issue, water supply in the region is served by various sources such as surfure water, ground water, and precipitation/rainfall. However, the main water sources for serving people and activities in the region is a reservoir which many sizes of reservoir that supply large amount of water to meet the demand of the region. At 2016, the eastern region has developed 51 small reservoirs with capacities 702.84 MCM, and 5 medium and large reservoirs with capacities 1,291 MCM, total of storage capacity of the reservoirs in the region is 1,993.59 MCM.

Water use is driven by changes in population, food consumption, economy (including water pricing), technology, lifestyle and societal views regarding the value of freshwater ecosystems. (Bates, B.C., et al., 2008). Water supply is critical to the region's development for agriculture as crops, orchards, livestock, industry and domestic consumption. The amounts of water demand in the region are increasing highly to meet the need from various users due to the rapid growth of industlization and the increasing urbanization areas and requirements of tourism, agricultural domestic and other sectors. As describe in Table 4, the water supply and demand in the region, there are requirement total of water around 2,527.33 MCM/year which is agriculture sector (1,029.38 MCM/year), industrial sector (789.79 MCM/year), domestic comption (500.13 MCM/year), and ecological balance (307.02 MCM/year). Where as the eastern river basin have total storage capacity 2,335.09 MCM, plus with average runoff 24,029.70 MCM to serve irrigation area 2.6 Million rai. Estimated demand for water all provinces in the eastern per year has apprimated total 20,194.31 MCM which the provinces that has highest estimate amount of water requirement is Trad (~4,740.10 MCM/year) and Sakaeo (~3,845.10 MCM/year), then Chachoengsao (~2,951.75 MCM/year) and Chanthaburi (~2,315.57 MCM/year), while Prachinburi, Chonburi and Rayong has lowest water demand by approximated, (~2,164.63 MCM/year), (~2,118.63 MCM/year) and (~2,058.53 MCM/year), respectively. By estimated demand for water use averaged seven provinces in the dry season and the rainy season are 1,036.02 MCM and 1,279.98 MCM, respectively.

Table 4: Eastern Region Water Provision & Water Demand by River Basins, in 2014

River basin name	Water demand (MCM/year)					Catchment area (km^2)	Storage capacity (MCM)	Irrigation area (*rai*) (6.25 rai = 1 ha)	Average runoff (MCM)
	Domestic consumption	Agriculture	Industry	Ecological balance	Total				
Prachinburi	28.40	468.38	63.09	31.57	591.45	9,672.10	218.02	733,862	4,986.04
Bangpakong	101.71	270.00	357.01	80.63	809.34	10,700.71	646.49	1,353,263	4,058.19
Tonle Sap	11.04	-	5.63	18.11	34.79	13,497.51	149.23	123,720	2,203.53
East-coast	259.98	291.00	364.06	176.71	1,091.75	4,085.93	1,321.35	427,000	12,781.94
Total	500.13	1,029.38	789.79	307.02	2,527.33	37,956.25	2,335.09	2,637,845	24,029.70

Sources: Adapted from Bureau of water management, 2016 and Water Resources Regional Office 6, 2016

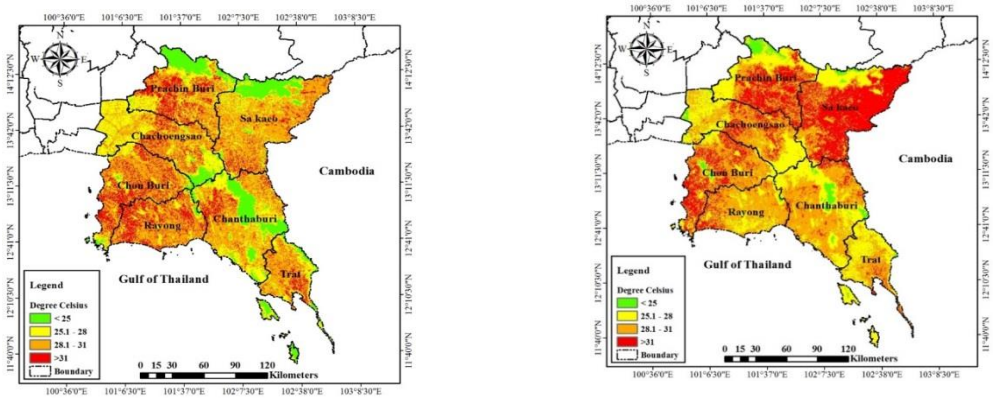
As the main user in the area, water demand for agricultural is high proportion than other sectors, but agricultural demand is stagnant. The proportion agricultural is decreasing proportion, whereas water demand for industrial is growing around 7.04 per year because of manufacturers along the eastern seaboard area, particularly in the petrochemical industry, a huge amount of water is necessary for oil refineries and petrochemical processes. Moreover, demand for domestic use is growing around 3.4 per year. (Janchidfa K., 2007).

According to trend of increasing of water demand, the nation is facing serious water supply constraints to further growth of country due to many impact between water resources and country development schemes, also the climate change and land use change that effects to water in the region. It should be noted that, water quality also has deteriorated significantly, due to sediment loads and discharges of pollutants by all sectors in the region.

Climate Change in Eastern Region of Thailand

Temperatures of Thailand normally range from an average annual high of 38 ℃ (100.4 ℉) to a low of 19 ℃ (66.2 ℉). For the eastern region, seasonal temperatures averages are a mean of minimum to maximum in winter 22.8-32 ℃, summer 24-38 ℃ and rainy 24.4-32.7 ℃, average of temperatures year 1979-2009, as presents in Table 1, indicate that average temperature more than 28 ℃ are located on Chonburi, Rayong, and Prachinburi where are mostly urban and industrial area. Nevertheless, during the dry season, the temperature rises dramatically in the second half of March, spiking to well over 40 ℃ (104 ℉) in some areas by mid-April

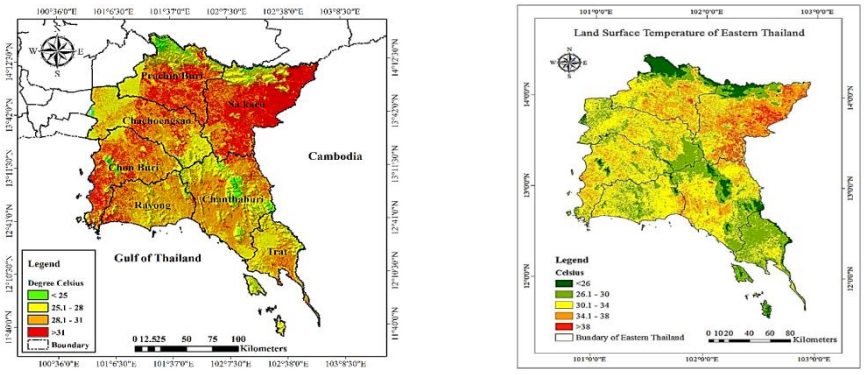
when the sun passes the zenith. The climate change has compared the mean of minimum and maximum temperature from 18-43 ℃ in 2011 and 2016 (see Figure 10), and average LST of the eastern between Febuary in 2011 and 2016 is about 28.51 and 29.27 ℃, respectively. In 2011, the hottest period of the year is during March to May that has the extreme maximum temperatures about 31 ℃. However, the hottest period of the Febuary in 2016 has the extreme maximum temperatures about 38.1 - 43 ℃, located in some areas by mid-April, mostly in some part of urban and industrial area, this exposes the significant change of climate, as shown in Figure 10 (b) there are red color area more than in Figure 10 (a).



(a) Land Surface Temperature in 2011 (b) Land Surface Temperature in 2016

Figure 10: Land Surface Temperature (LST) in Febuary in 2011 (a) and 2016 (b)

Land Surface Temperature of the eastern of Thailand has extreme maximum temperatures more than 31 ℃ in 2011, as illustrated in red color in Figure 10 (a), it covers in some part of Prachinburi, Chachosengsao, Chon Buri, Rayong and small part in Sakaeo, Chanthaburi and Trad provinces.



(a) Land Surface Temperature Rang <26 - >31 ℃ (b) Land Surface Temperature Rang <26->38

Figure 11: Land Surface Temperature (a) and (b) in Febuary 2016

LST of eastern in 2016 has extreme maximum temperatures more than 38 ℃, it has covering Sakaeo area and some part of Kabinburi district in Prachinburi province and Laem Chabang sub-district in Chonburi province, furthermore LST is during 34.1-38 ℃, covered the most of Sakaeo and some part of Prachinburi, Chonburi, Chachoengsao, Rayong and Chanthaburi provinces as shown in Figure 11 (b). During summer, LST is more than 31 ℃ in 2016 by covers the most of Sakaeo and some part of Prachinburi, Chonburi, Chachoengsao, Rayong Chanthaburi and Trad provinces as shown in red color in Figure 11 (a)

The Effect of Land Use Change and Climate Change on Water Resource in the Eastern Region of Thailand

Climate factors effected to the precipitation and temperature of the eastern region that is include 1) the wind which influenced by the depression of the South China Sea, this cause a heavy rain in the region; 2) the southwest monsoon blows from the Gulf of Thailand, effected to rain in this region; 3) the northeast monsoon influences to the eastern, but area along with Phanom Dong Rak mountain range, Sakaeo province, weather is not cold; 4) the rest of the mountain range and the Sierra Chanthaburi line to block the direction of the southwest monsoon, effected to rainfall in this area which effected Chantaburi and Trad wettest area in the region; 5) the area that located near coastal area and the upper area away from the sea, resulting in hot temperatures in the upper part of the region which does not get the cool sea breeze like the seaboard area.

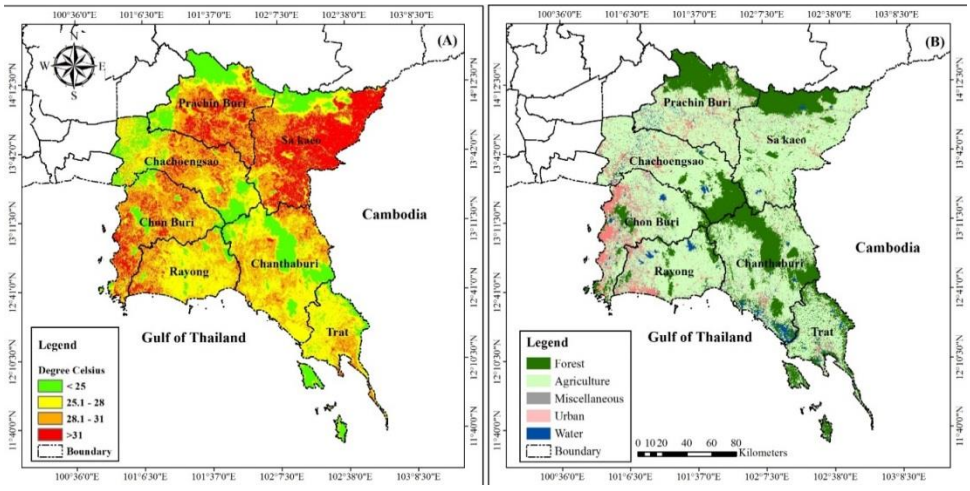
Eastern land use and land cover changes are among the most important factors to be considered with climate change. Land use is a major factor to water resources avalibility. Land use effected to water resources include forestry, agriculture, recreation, urbanization, and industrialization. Many important economic activities, like producing energy for industrial production, raising livestock, and growing food crops, also require water. The amount of water available for these activities may be reduced as higher of temperature, it may lead to competition for water resources. The eastern of Thailand has rapidly socio-economic-industrial development, which drived land use changes, climate change with large impacts on water resources, there are already faced with water shortage conflict among users during year 2005.

Forests are absorbing carbon dioxide, major responsible for helping regulate climate. LST of forest has less than 25 ℃ in national park such as Khao Yai, Thap Lan, Pang Sida, Khao Soi Dao, Khao Khitchakut, Koh Chang. Khitchakut Khao and Koh Chang, also Khao Ang Rue Nai Wildlife Sanctuary. However, the eastern foresty area has been reducing in some area, there are change from forestry area to agriculture and comminity area. Changing of forests effected to infiltration and runoff characteristics, which affect groundwater recharge, sediment and water yield, and

evapotranspiration. Also agriculture area has reducing become to community, city and industrial area. This lead to change water supply and demand.

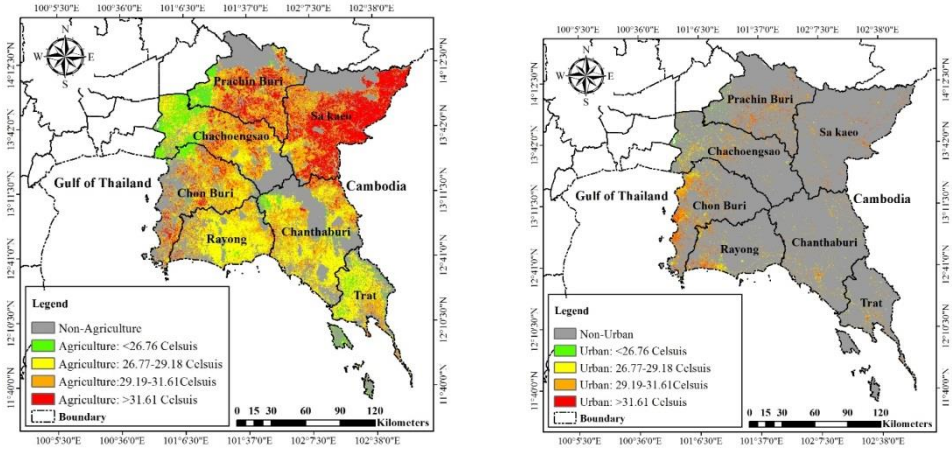
LST is more than 31.61 ℃ covered urban area mostly in the eastern seaboard development area, Chonburi, Rayong and Chachoengsao, also Prachinburi, an industrial estate is located. However, the agriculture also generated heat, LST of agriculture area has more than 25 ℃ covering all region, but some area more than 31.61 ℃ which covered mostly of Sakaeo, some part of Prachinburi, Chonburi and Rayong, also small part of Chanthaburi as shown in Figure 11 (a). The heat from agricultural area is related to the type of plantation in that area, for example, between Sakaeo and Chantaburi, both of them has an agriculture based economic, Sakaeo have total agricultural area of 2,340,093 rai (52% of province), and Chantaburi have total agricultural area of 2,054,326 rai (51.86% of province), both provinces has nearly total amount area of agriculture.

However, one factor that drived these two provinces has very difference of temperature is type of plantation, by most of agriculture in Sakaeo is rice fields and crops i.e cassava, corn, and cane. Whereas, most of agriculture (73%) in Chantaburi is perennial plant, i.e. durian, etc.



(a) Land Surface Temperature (b) Land Use pattern in Febuary 2016

Figure 12: Land Surface Temperature (a) & Land Use pattern (b) in Febuary 2016

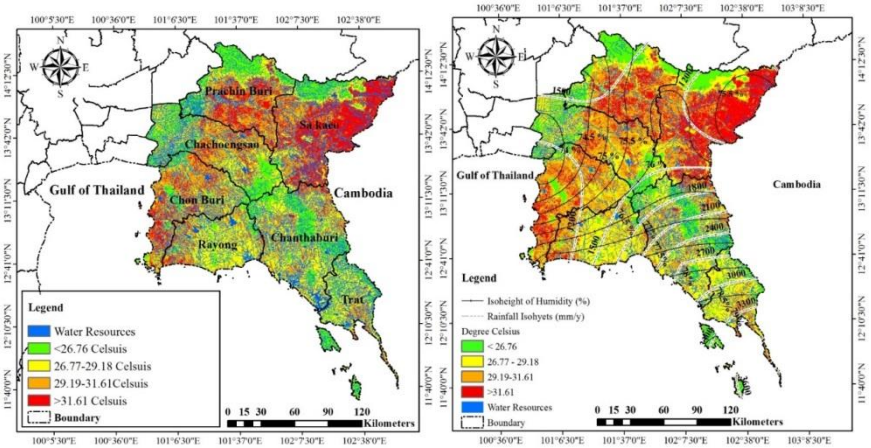


(a) LST cover Agriculture area (b) LST cover Urban area

Figure 13: Land surface temperature by Land use pattern, Agriculture (a) & Urban (b)

Figure 13 presents a relationship between LST with land use pattern, by Figure 13 (a) shows how level of temperature is located in the eastern, and Figure 13 (b) shows how the eastern land use is no doubt that urban area generated heat and effected to temperature of the area. There is relation between levels of heat in Figure 13 (a) and type of land use in Figure 13 (b), the red area in Figure 13 (a) is located in the area that is agriculture and urban area.

As illustrated in Figure 14, there are very small amount of water resources in the region, the eastern physical topography has an influence to the hydrological system such as short river, stream and canal in the eastern basin, moreover there are less of large dam, only medium and small reservoirs to serve water supply to the region.



(a) LST overlay withWater Resources (b) LST overlay withWater Resources & Humidity & Rainfall

Figure 14: Land Surface Temperature overlay with Water Resource (a) and LST overlay withWater Resources and Humidity and Rainfall (b)

The precipitation is less, as some part of Chonburi and Sakaeo provinces have rainfall less than 1,200 mm., and humidity less than 75.5 %, as well as Rayong, Chonburi, Chachoengsao, Prachinburi and Sakaeo have LST more than 31.61 – 56 ℃, especially in summer season. According to land use types: urban, indurial and agriculture area, lead LST higher than other area, affected by industrial development in Rayong, Chonburi, Chachoengsao and Prachinburi, located of industrial estate i.e. Laem Chabang Industrial Estate in Chonburi province, Map Ta Phut Industrial Estate in Rayong province, Gateway Industrial Estate in Chachoengsao province and Kabinburi Industrial Estate in Prachinburi province. On the other hand, LST high in Sakaeo is effected from type of agriculture of the area. So water resource is effected by increasing of LST, reducing of rainfall and humidity, also economic-industrial development disturbance. Increasing of population growth, intensive agriculture and industrial development put the pressure on water resources, this stresses that are likely to be exacerbated by climate change.

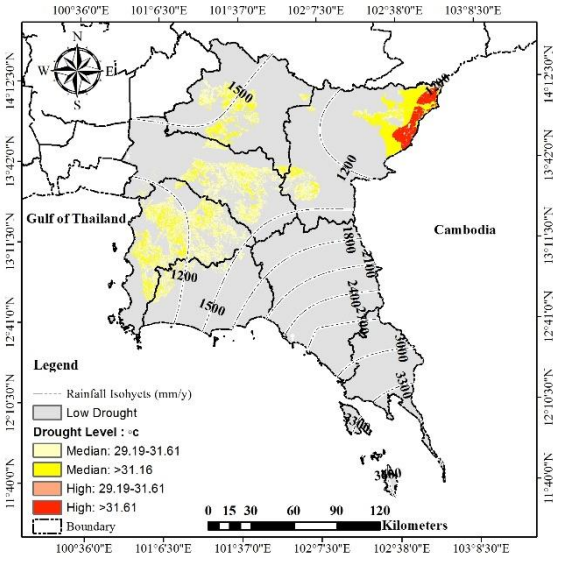


Fig 15: Drought Risk Area by Climate Contexts

There are impacts of climate change on freshwater availability in the future, one reason is that precipitation variability is very likely to increase or to decrease, so more frequent floods and droughts are predicted. Figure 6, 7, 14 and 15 illustrates drought risk area in the region, with the influents of climate contexts, temperature and precipitation, the red color area that shown in the figure presents that possible drought risk area, which located in Sakaeo. Sakaeo Province is facing with environmental drought because this province located in area that influents to a meteorological drought, less of rainfall area, and a hydrological drought, short of river flows and low water

level, as well as there are agricultural drought from low soil moisture and types of crops.

There is also some risk of drought in some area of Prachiburi, Chachoengsao, Chonburi and Rayong, they would face a meteorological drought as level of rainfall is less than 1500 mm./year, and a hydrological drought, with short river flows in the region. Figure 6, 7, and 14 indicates that there is no drought risk in Chantaburi and Trad where rainfall level is higher than other areas of the region (more than 1500 mm./year).

Moreover, there are many factors that drived the eastern region to face the drought, drought has effected from the interaction between human factors and natural conditions. Firstly, natural factor, there are only short rivers in the eastern basin, and also amount of rainfall is lower than other region, moreover, as temperatures increase, evaporation increases, sometimes resulting in droughts. Second, human factors such as changes in land use and land cover, the demand for water, water management and so on. Human contribution to trend of drought, land use pattern is changed, for example agriculture sector change to intensive agriculture; increasing of industrial development and urbanization, these factors lead to increase population and a demand of water. There are increasing risk of droughts in longer summer season, even an increase of annual runoff may not lead to a readily available water resources, if that extra runoff is intensed only during the rainy season, and that runoff is not stored and managed.

The increase in industrials, agricultures, and households water demand due to climate change is likely to be small, however water demand due to land use change plus climate change is likely to be increasing, for instance, urbanization effects more people in the region, heat is increasing due to activities in city and industrial area, people need more water as well as need more electricity demand for the cooling of buildings and their activities, a trend of temperatures has increased, water demand is increasing, where as water supply is deceasing.

The effects of land use change on water resources in Eastern Thailand are overall declined the water quality of Easthern during the observed period (2008 to 2014). Analysis with GIS overlay analysis the average air quality in the year 2551, 2553, 2555 and 2557, the average air quality include sulfur dioxide (SO2), nitrogen dioxide (NO2) gas carbon monoxide. monoxide (CO) gas ozone (O3) particles larger than 10 microns (PM10), and the average water quality of the years 2555 and 2557 consist of dissolved oxygen in the water (DO) oxygen demand, biochemical or BOD. good (BOD) in coliform bacteria (TCB), a collection of coliform bacteria (FCB) analysis overlay average yearly to assess the risk of pollution to air and water. The analysis includes an overlay appears is in the range of 0-100 percent evaluated the risk of polluted air and water. This area has shown that the level and density of the gas SO2, NO2, CO, DO, O3, PM10, DO, BOD, TCB and FCB covering risk as shown in Fig.16

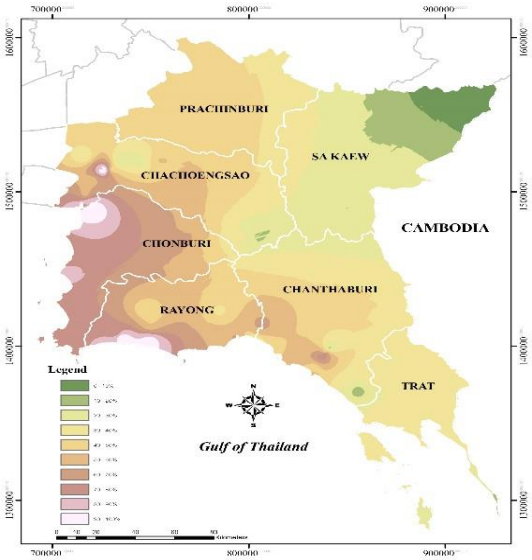


Fig. 16: Risk Air and Water Pollution Area for SO2, NO2, CO, DO, O3, PM10, DO, BOD, TCB and FCB in the Eastern Region in 2008-2014

(1) evaluated the most vulnerable areas in the eastern areas in the 80-100 percent are area spreading Nikhom Phan Thong and Chonburi area and spread to the center of Laem Chabang, Sriracha, Chonburi. And Map Ta Phut and IRPC Rayong District Open Klang, Ban Chang, Rayong province, some areas of the district Bagclga convert long Pho Chachoengsao centers spread into areas other districts

(2) evaluated the risk in eastern ranges. 60-80 per cent spread from areas with very dense distribution to certain areas of Sriracha Ban Nikhom Phan Banglamung Sattahip, Chonburi. Some areas of Ban Muang Rayong.

The risk areas vulnerable to SO2, NO2, CO, DO, O3, PM10, DO, BOD, TCB and FCB, which also includes the percentage of low-risk to high all the relevant authorities need rehabilitation Surveillance prevent. the impact on people and the environment is an area of the river mouth. Phan district and city and Laem Chabang Chonburi province Bang Pakong district and city Chachoengsao Ban Chang district and the city.

The use of land for the benefit of the agricultural sector is the source of most Thai rice. Horticulture and orchard crops perennial importance of countries such as mango, rambutan, durian, mangosteen, pineapple, it cane, palm, rubber areas agriculture is an area that has been changed and reduced, not the area is agricultural land not less than. listed and should increase. 22264.63 to 25,785.37 square kilometers representing 70-75 percent. Forest area includes forest restoration and forest wait condition and Wildlife Area, the area is wild Area Wildlife Khao Ang Rue Nai as the forest covers five provinces and is the elephant lot that should be increased. The amount of space and potential of the forest and increase the food supply of wild

elephants and other wildlife, so all relevant departments should increase the forest area of 7985.14-8595 sq km per cent from 23.23 to 25 percent in order to have the potential capacity to maintain the balance of natural resources and the environment. Preserving the ecosystem of the East.

Conclusion and Recommendation

The situation in the eastern region of Thailand illustrates a relationship among climate, land use and water resource. The case demonstrate that climate change and land use change are effected to exacerbate water system balance, there are factors to determine for water supply and water demand, a significant increase and decrease in runoff over land surface, a significant increase and decrease of land surface temperatures, also industrial and population growths, these factors effected to water availability.

Climate change and land use change are drivers for risk in water resource availability, there are affection to strategy and investement plan of the eastern region due to uncertainty in rainfall and hydrological change conditions in the future. In the future, the number of people living in urban areas trend to increase, this inevitably stress to water resource, not only climate change is a factor that influence future water stress but also land use change pattern which related to population and socio-economic, furthermore advance technology plays more important roles for the water stress in future.

To balance water demand and supply, there are challenges for who involve in water management to simultaneously meet the needs of growing communities, farmers, ranchers, industrial producers, manufacturers and sensitive ecosystems. As situation was happening in 2005 in the eastern region, water conflict on the shortage of water, as well as flood in 2011. Water management is important to deal with changing demands and supplys on water resources, vulnerability of water systems to climate change also depends on reginal and national water management. It need reliability of water management systems to deal with issues both land use change and climate change challenges. There are need supply side and demand side adaptation options, which designed to ensure supply available on the extreme temperature such as drought conditions, mostly of supply side options generally involve increases in storage capacity, to utilize is related with adequate infrastructure to capture and store the extra water as well as fairness of distribution, while demand side options need effectiveness practices in the policy and implementation, because they rely on many sectors.

Rapid industrialization and urbanization of the eastern region, cities increasingly are articulating to the regional economic system which began to experience several types of environmental problem simultaneously:

ecosystem threatened, polluted or destroyed. The green agenda issues increasingly challenge cities, to urban development, the implication to reach the agenda is policies and relationships at the local, provincial, national and international levels. The important issue is that people have access to decision-making and power, an essential element of human development, include 'bottom-up' planning and decision.

Water resource is related to many sectors, these include industries, farmers, individual consumers and water management agencies. Adatation to changing in demand and supply are related to both organization level and individual level, for improving the efficiency and effectiveness management, there are need to intregration between adminstraive agencies, as well as people participation. Also, integrated water resources management (IWRM) should be an instrument to explore adaptation measures to climate change, along with adopted a reliable scenario climate based approach. Some measures and tools to reduce the water demand need more consideration as adaptive approach, such as water awareness advocated to public. Some resilient measures and strategies for flood management or drought management are more robust to deal with uncertainty situation, as well as mitigation measures.

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