Management of Urban Spatial Setting to Determine Effect of UHI on Bangkok Metropolis, Thailand

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Abstract

Urbanization and human activities cause higher air temperature in urban areas than its surrounding areas. The high temperature can cause problems to environment, such as high energy consumption on cooling, raised air pollution level and changes in the urban climate. This study uses remote sensing data to observe this urbanization changes land use and create heat island in Bangkok Metropolis, Thailand. The results show that urban, large size, less vegetation and less water resources cause obvious higher than it's surrounding.

Keywords: Urban Heat Island (UHI), GIS

Introduction

1. Issue and problems statement

At present, Global has suffering with high temperature (increase 2-3? C every decade) and urbanization. The global population has increased six times during the last two hundred years; urban population has grown 128 times (Emmanuel. 1997 refer to cf. Schell, et al. 1993). Therefore, global urban population is expected to outnumber the rural population (Oke. 1987). Urbanization phenomenon has happened in the development countries less than the developing countries.

The pattern of city growth were dynamic and rapid (increasing in size), due to urban population increasing and even undistribution pattern of resources to support life. This brought about the concentration of population and changing of the existing land use in the city: green area (agriculture, vegetation, open space), and

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wet land has been transferred to residential, commercial, and industrial areas. The decreasing of open space would reduce the level of humidity in the atmosphere too. The construction in tropical city did not take into account the style, height and orientation of buildings in relation to the direction prevailing wind. Many buildings blocked wind and reflected solar radiation among buildings, wall, and ground. Depending on the respective materials of building, streets. Dark colour, roughness and unshiny materials were able to absorb heat yet unable to reflect radiation as did light colour, smooth and shiny material. And human activities such as travelling and construction, generated dust and smog to block ventilation. This phenomenon called "Heat Island."

Heat Island jacked up the high temperature of city, even higher, which further brought about air and water pollution and changes in human activities. People do not want to expose to outdoor environment; they would prefer to live inside buildings and with air-conditioning. These pattern of living further increased energy consumption (electric, water and petroleum) and deteriorated the health condition of citizen in city.

According, this research aims to study the nature of heat island in Bangkok Metropolis, analyzing the relationship between the pattern land use and the heat island attribute. It aims to elucidate the process, the pattern of and the impact from heat island; phenomena to find an appropriate strategy and approach to control the environment exploiting the heat island pattern.

2. Objectives of study

2.1 To study the process and pattern of heat island under context of Bangkok Metropolis.

2.2 To derived a mean to manipulate the heat island phenomena to reduce temperature,energy consumption and pollution under context of Bangkok Metropolis.

2.3 To find strategy and approach to manage the environment under the context of Bangkok Metropolis.

3. Scope of study

A case study will be applied Bangkok Metropolis by means of urban and surrounding provinces of Bangkok Metropolis are representative a suburban and rural. To determine size of cities by use continuous structure areas without other land use separate especially agriculture, recreation and park, and water resources to be a boundary line.

faceted as multiple reflectors, absorbing heat energy and reflecting it back to other surfaces, urban accepts and store heat. Rural heat is stored mostly in upper layer.

The much greater aerodynamic roughness of built-up areas than in the rural: arrangement of tower blocked placed presented a much rougher surface than the open rural. The effect of slowing down prevailing wind and increasing localized gusts at street corners and around tall buildings and diminishing the cooling power of wind in summer.

The prodigious amount of heat energy pumped into the urban atmosphere from heating and cooling system, factories and vehicles: in summer, air-conditioners cooling interior space pump hot air to the exterior, making the problem of high temperatures worse.

Problems resulting from precipitation: evaporation converts radiated energy into latent heat, acts as a cooling process. Rural, moisture either remains on the surface or immediately below it. Available for evaporation and cooling. Urban, the absence of moisture inhibits evaporation.

Air quality: increased atmospheric carbon dioxide likely will lead to increased air temperatures and exacerbate ozone problems. The conscious modification of the microclimate by human.

3. Heat Island phenomenon

The urban heat island (UHI) effect is a reflection of the micro-climate changes brought about human alternations of the earth's surface in densely populated areas. It is a good indicator of the sensitivity of the climate system to human forcing on a local level. The heat island properties are albedo, heat capacity, heat generation, heating and cooling rates and surface roughness. The addition of human heat and pollutants into the urban atmosphere further contributes to the intensity of the urban heat island effect. The UHI may have a positive or negative impact on human comfort and health, energy conservation and air pollution.

The UHI are stronger in the late of afternoon and at night, around 11 p.m. until at least 2 or 3 a.m. when city slowly release the energy stored in its structures. Temperatures are strongly related to land use and land cover. This moderating effect is induced by evapotranspiration from the vegetation around the houses which converts the radiant energy into latent heat, this preventing the release of excessive sensible heat. Surface temperatures are warmer at the top of the canyons than at the bottoms as a result of longer exposure to solar radiation during the day. The UHI has major consequences for people living in urban areas. Incoming solar radiation is absorbed by the roof and walls of the structure, creating a difference in the surface and ambient temperatures. Building residents compensate for this heat by increasing air-conditioning use, increased ambient temperature in urban areas, increase energy consumption. High temperatures also cause increased health risks to city dwellers and related to increased emissions of ozone precursors from automobiles and vegetations.

4. Thermal comfort

Thermal comfort has been defined as "that condition of mind which expresses satisfaction with the thermal environment" The emphasis is on the condition of mind. It will be influenced by individual differences in mood, personality culture and other individual, organizational and social factors. Human thermal comfort is defined by ASHRAE as the state of mind that expresses satisfaction with the surrounding environment (ASHRAE Standard 55). Maintaining thermal comfort for occupants of buildings or other enclosures is one of the important goals of HVAC design engineers. Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. Any heat gain or loss beyond this generates a sensation of discomfort. It has been long recognized that the sensation of feeling hot or cold is not just dependent on air temperature alone. Factors determining thermal comfort include: air temperature, mean radiant temperature, air movement / velocity, relative humidity, insulative clothing and activity levels.

Figures should be kept as simple as possible. Figures should be used where relevant, but do not use them unnecessarily. Make sure that they are referred to from the text and that they are not too complicated or large. A figure caption ("SM2-FigureCaption" style) should be inserted immediately below your figure. If your work relies on the presentation of complex graphics, then the paper can make a point with an extract from a larger graphic. Colour may be lost in the reproduction of the proceedings and cause images to occupy more disk space than monochrome. Do not include screen shots of computer displays. It is better to render the relevant information into a simpler graphic or chart.

5. Limitation of study

5.1 Limited data, Date and time of remote sensing data (LANDSAT 5-TM and SPOT) are not the same period would be difficult to compare data and analysis.

5.2 Limited time and budget should be taken into consideration in completing the study.

Methodology

Methodology applied in the study are based as the reference towards the objective of the study whereby it is aim at researching the process and pattern of heat island under context of Bangkok Metropolis.

1. Collecting of primary microclimate data

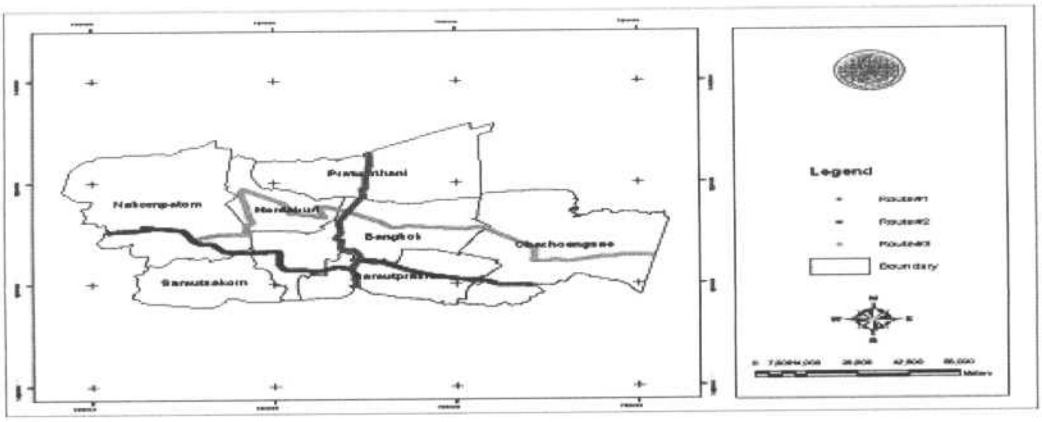
1.1 To install OPUS-200 (Thermograph) at 3 automobiles. To explore temperature after sunset at least 4 hours about 10.00 p.m. is the highest heat because it's diffuse to air temperature.

1.2 To explore temperature in 2 days. On Sunday is a weekend representative the least accumulating energy in a day. On Wednesday is a middle weekday representative the most accumulating energy in a day.

1.3 Position level of sensor thermograph is 150 centimetres from ground.

1.4 To determine 3 routes cover the study area, Route 1 is represented in north to south. Route 2 is represented in lower east to west. And route 3 is represented in upper east to west. (Figure.1)

Figure 1: Map of collecting routes



2. Collecting of secondary data

2.1 To gathering data from documents.

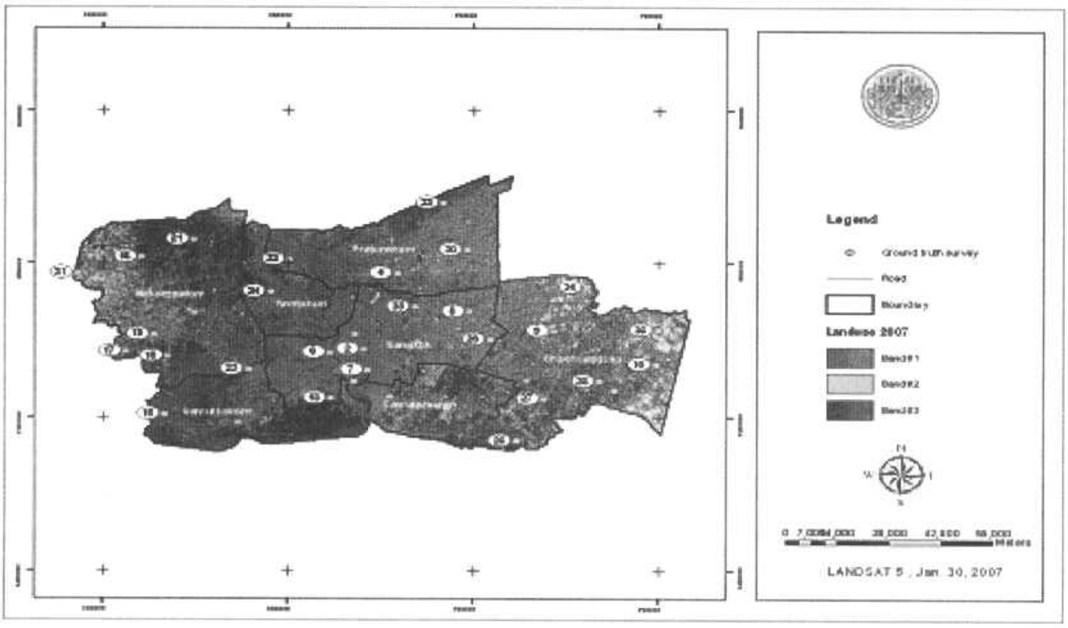
2.2 To interpretative satellite imagery from LANSAT 5-TM and SPOT to characterize land use during 1987, 1997 and 2007. To compare accuracy by ground truth sample. To use binominal probability theory to sampling at least of error percentage of point (36 points) (Figure 2) and sampling imagery points by cluster sampling (Camphell. 1996) and to check overall accuracy of data (LANDSAT 5, Jan. 5, 2007) by confusion matrix (Congalton. 1991) = 86.11%.

3. Analysis data

3.1 To analyst satellite imagery to characterize the heat island effect at the study area with geographic information system (GIS).

3.2 To compare heat island areas by size, pattern and features of cities. To derived a mean to manipulate the heat island phenomena to reduce temperature, energy consumption and pollution.

Figure 2: Map of ground truth survey 36 points



Results and discussion

1. Land use changes during 30 years (1987-2007)

The study area is 9,728.275 sq.kilometers. Land use can divide to 8 types: urban and commercial, residential, industrial, forestry, park and recreation area, agriculture, water resources and open space. (Table 1 and Figure. 3)

Table 1: Land use change in 30 years (1987-2007)

Urban and commercial, residential and industrial areas are always increase

Type of land use	Land use (km^2)			△ Land use					
	1987	1997	2007	1987 - 1997		1997 - 2007		1987 - 2007	
				km^2	%	km^2	%	km^2	%
Urban and commercial	624.318	725.485	932.417	+101.167	+16.204	+206.932	+28.523	+308.099	+49.350
Residential	737.125	997.430	1,729.798	+260.305	+35.314	+732.368	+73.426	+992.673	+134.668
Industrial	71.908	93.484	194.298	+21.576	+30.005	+100.814	+107.840	+122.389	+170.201
Agriculture	7,933.490	7,665.989	6,553.260	-267.501	-3.372	-1,112.73	-14.515	-1,380.230	-17.398
Park and recreation area	5.188	7.051	12.140	+1.863	+35.921	+5.089	+72.169	+6.952	+134.013
Forestry	163.023	67.102	91.000	-95.921	-58.839	+23.898	+35.614	-72.023	-44.180
Water resources	187.596	136.266	108.556	-51.371	-27.384	-27.669	-20.311	-79.040	-42.133
Open space	5.625	35.507	106.806	+29.882	+531.211	+71.299	+200.802	101.181	+1,798.696

Remark : △ land use calculates by areas different between 1987-2007 in each land uses

+ : increase land use

- : decrease land use

during 30 years (1987-2007); To increase residential areas 134.668%, industrial areas 170.201% and urban and commercial areas 49.35%. First, these land uses were relative with main transportation by cluster along Chao Phraya River. At present, they distributed along road and almost expanded to south of Bangkok Metropolis closely Samutprakarn province and west of Bangkok Metropolis closely Nakornpatom province and Samutsakorn province.

Agriculture, forestry and water resources areas are continued decrease during 30 years because they were became to urban and commercial, industrial and residential areas for responding population's demands. During 30 years, agriculture areas are decreased 17.398%, forestry areas 44.18% and water resources areas 42.133%.

Figure 3 (a): Land use in 1987

Figure 3 (b): Land use in 1997

Figure 3 (c): Land use in 2007

2. Size and features of city effect to pattern of heat island phenomenon

Size and features of city effect to cluster of heat and pattern of heat island that the large city (Bangkok Metropolis, Nonthaburi and Samutprakarn) and middle city (Nakornpatom) were detected urban heat island and similar air temperature (isothermals) but different location of urban heat island and frequency of isothermals. The large city (Bangkok Metropolis, Nonthaburi and Samutprakarn) was detected urban heat island in many locations because it had many bulk of built up (material's surface was concrete and mirror). In opposite, the small city (Chachoengsao) was detected urban heat island less than the large city and middle city (Figure. 4–6)

The large and middle city had nearly temperature, their temperature on weekday (Wednesday) and weekend (Sunday) were differ about 1.5-2 $^{\circ}$c. The small city had different temperature from the large and middle city about 1-3 $^{\circ}$c and its temperature on weekday (Wednesday) was differ about 2-3° c and weekend (Sunday) was differ about 1-1.5°c. Because almost material's surface in the small city was vegetate and water resources (more humidity than concrete and mirror). At the highest of temperature in a day was created at 9.30-11.00 p.m.; on weekday (Wednesday) was detected temperature 29.44 $^{\circ}$c and weekend (Sunday) 28.78 $^{\circ}$c, found at the center of study area located in the large city especially Bangkok Metropolis at Bangna-Trad zone and Vipavadee-Rangsit zone. At the location of green and humidity areas (forestry and park and recreation area) were detected temperature 27.5 °c and the lowest temperature found at agriculture and water resources areas were detected temperature 23 °c.

Thus, the locations of urban heat island has detected in built up of city, almost their features were concrete, asphalt and mirror such as urban and commercial areas, residential areas and industrial areas.

3. Manage the heat island under context urban.

This study found almost urban heat island was created in the lack of vegetate and humidity areas, which compared the size of city found that the large and middle city emitted heat slower than the small city because the small city had less bulk of built up areas and many vegetate and humidity areas. To manage city by heat island phenomenon should be determine urban and surrounding area have buffer of green and humidity areas and more green activities such as park and recreation areas make to be green network's city. And material's surface should be light colour and smoothie pave.

Conclusions

The urban heat island effect is a complex, site and specific phenomenon and can therefore vary in time and place. Many factors can alter the strength of the urban heat island on any day or in any location. Some of these factors include: season, weather conditions, urban characteristics, and anthropometric heat. Heat island develop in areas contain a high percentage of water-resistant surfaces, a low percentage of vegetate and humidity surfaces. Both of the city's size difference and continued development built up areas may increase the heat island conditions.

Figure 4 (a): The large city on weekend (Sunday)

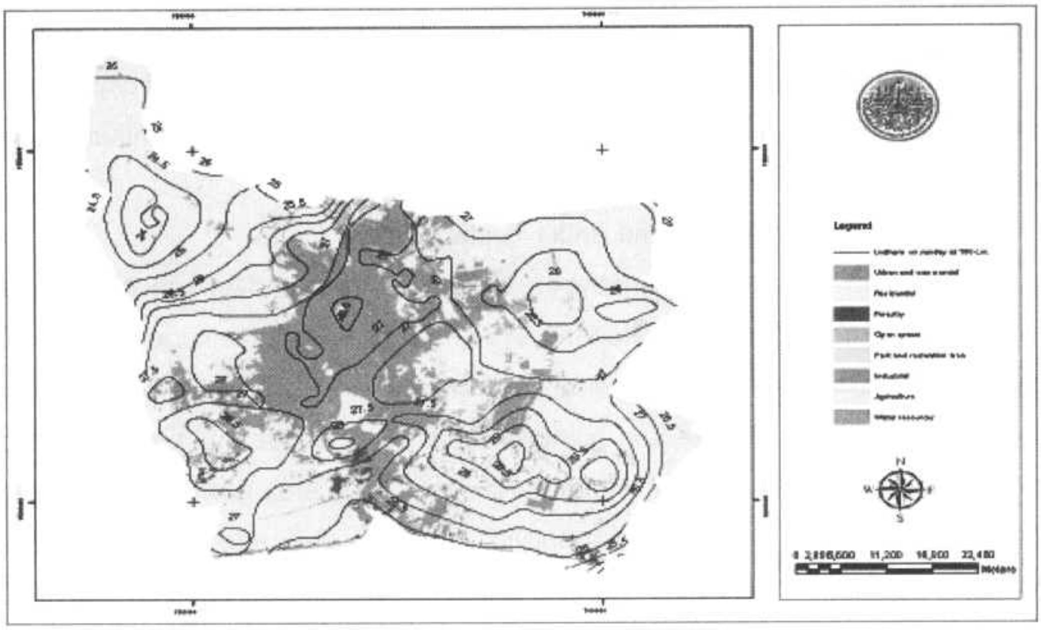


Figure 4 (b): The large city on weekday (Wednesday)

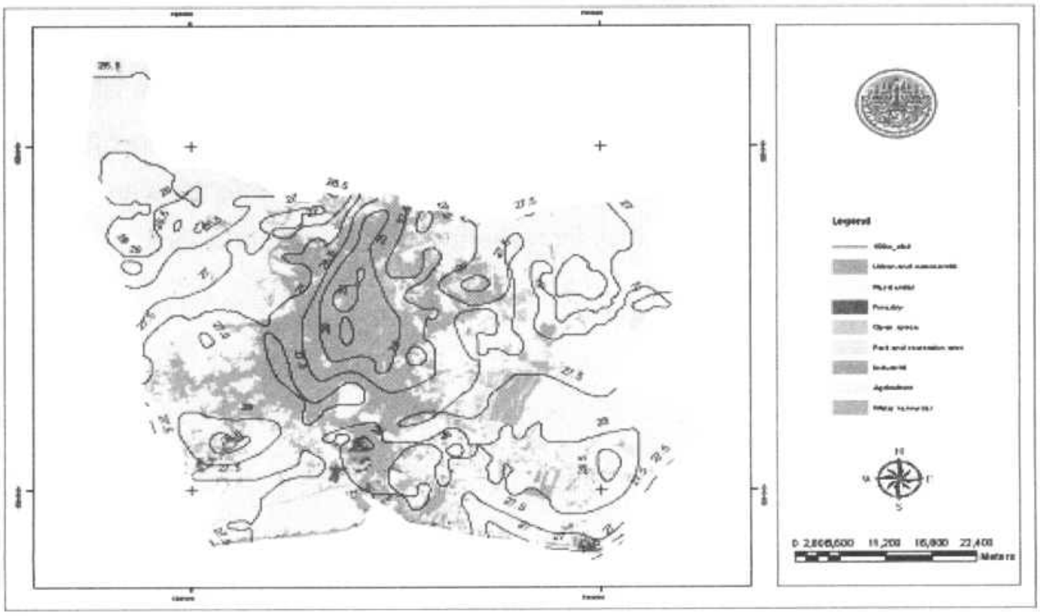


Figure 5 (a): The middle city on weekend (Sunday)

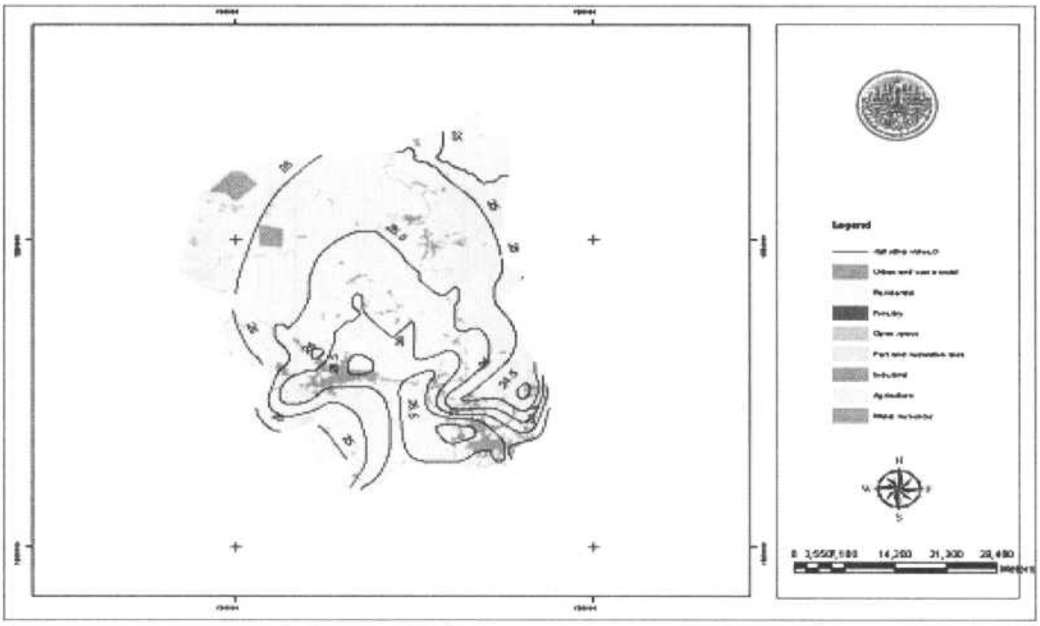


Figure 5 (b): The middle city on weekday (Wednesday)

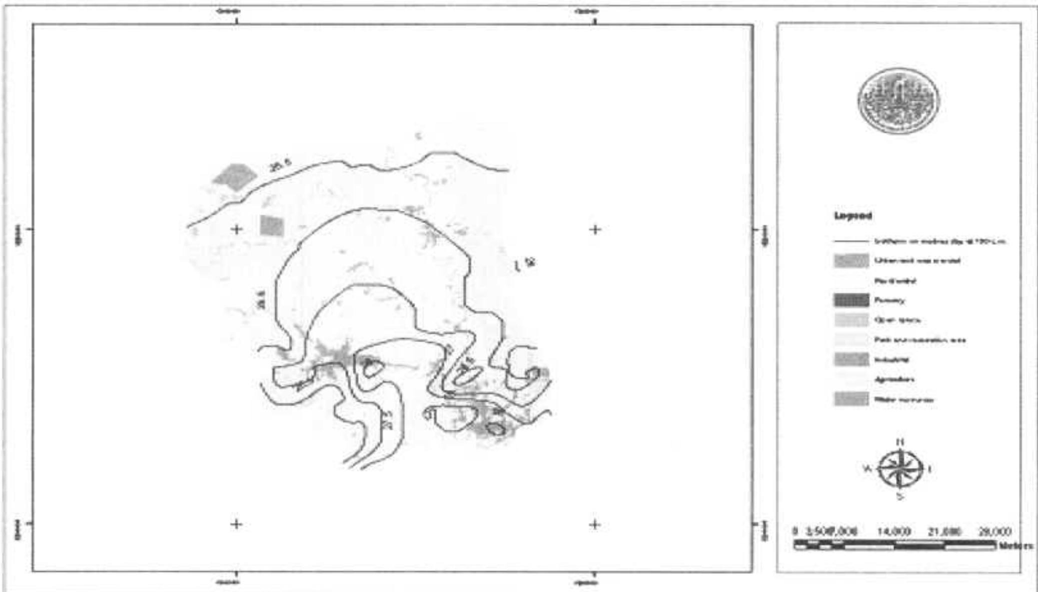


Figure 6 (a): The small city on weekend (Sunday)

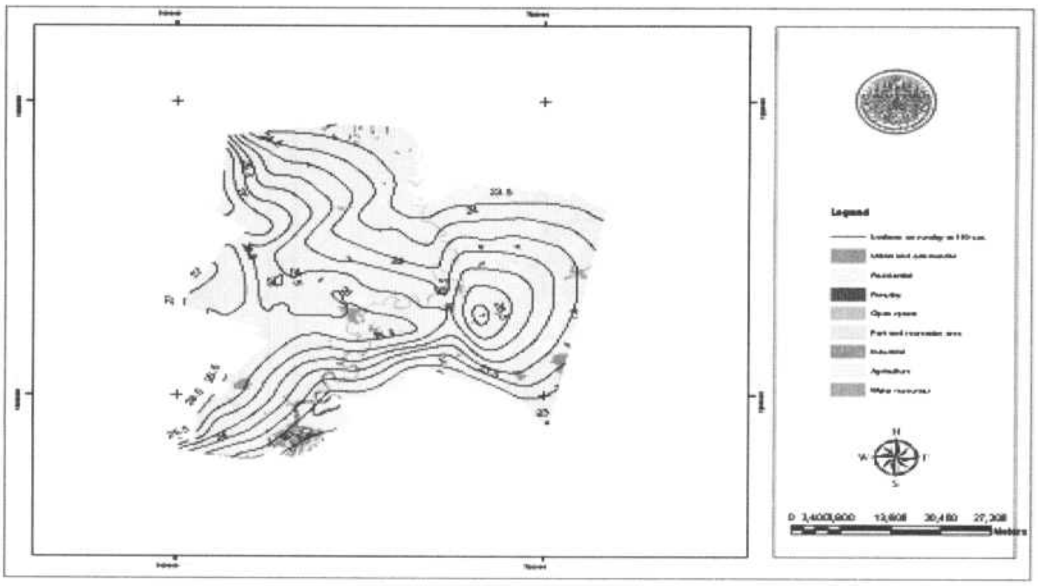
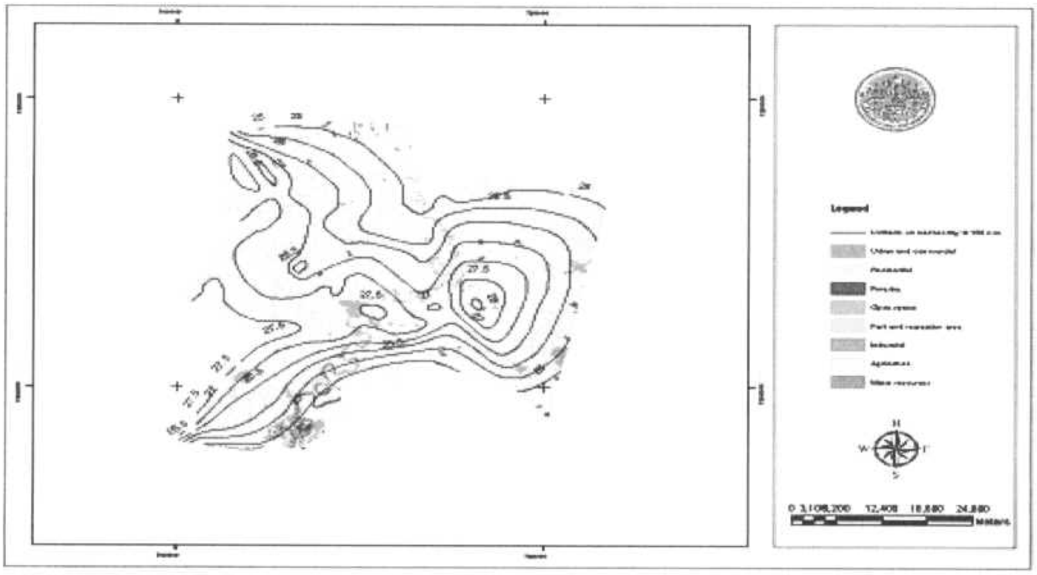


Figure 6 (b): The small city on weekday (Wednesday)



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